GEOGRAPHIC INFORMATION SYSTEM EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

FINAL REPORT

International Association of Fire Fighters
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Washington, D.C. 20006

GRAPEVINE FIRE DEPARTMENT

Grapevine, TX

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Dedication

This report is dedicated to the citizens of Grapevine, TX 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 Grapevine Professional Firefighters, IAFF Local 3113, to provide information and resources to decision makers of Grapevine, Texas regarding the importance of maintaining adequate resources (apparatus, personnel, and stations) to meet incident demand. Using geographic information systems (GIS) mapping software and historical computer-aided dispatch (CAD) data,[1] performance and response capabilities were assessed based on industry standards contained in the National Fire Protection Association (NFPA®) Standard 1500: *Standard on Fire Department Occupational Safety and Health* and NFPA 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*.

The Grapevine Fire Department (GFD) maintains, staffs, and deploys out of five fire stations. The members of the Grapevine Fire Department provide fire suppression, emergency medical services (EMS) first response at the Advanced Life Support (ALS) level, motor vehicle accident response, hazardous materials (HazMat) response, water rescue, wildland fire operation, and specialized technical rescue, coverage to the citizens of, and visitors to, Grapevine, 24 hours per day, seven days per week.

The Grapevine Fire Department engine apparatus do not deploy with four fighters. Thus, first-arriving engine companies must wait until other crews arrive to begin interior firefighting operations. This delays fire suppression operations, which advances fire growth. When not staffed with four firefighters, the Grapevine Fire Department operates apparatus that are not staffed to provide effective, efficient, and safe emergency operations required by NFPA 1710 and the Occupational Safety and Health Administration's (OSHA) rules and regulations. Staffing units below the minimums set by industry standards results in crews being less efficient in completing critical fireground tasks. The smaller the crew size, the more tasks an individual must complete, which contributes to the delay in initiating fire attack, containing fire, and limiting property damage.

This report will provide the department and decision makers with information on how the department's current response capabilities compare to industry standards and how the lack of resources negatively affects GFD's ability to appropriately respond to incidents. This report will also explore how additional resources will improve the department's response coverage and its ability to address demand in the community. It is essential that the Grapevine Fire Department provides fire protection and EMS response and transport in an effective and efficient manner. To do so, the department must be staffed and positioned appropriately to address emergencies in an

[1] Incident data from January 1, 2019, to December 31, 2021.

equitable manner, as they occur. Insufficient resources significantly deteriorate response capabilities and increases the risk to firefighters and citizens of Grapevine.

Key Findings

- The members of the Grapevine Fire Department provide fire suppression, technical rescue, hazardous material mitigation, and ALS EMS first response and transport to the citizens and visitors of Grapevine, 24 hours per day, seven days per week.

- The Grapevine Fire Department typically maintains a daily minimum of 25 firefighters, and one Battalion Chief on duty, each shift, at five stations.

- The Grapevine Fire Department staffs three medic units, for medical response, with two firefighter/paramedics at all times.

- The Grapevine Fire Department staffs most fire suppression apparatus with three firefighters. Truck 1 is typically staffed with four firefighters.[2] Suppression apparatus not staffed with a minimum of four firefighters do not meet minimum company staffing standards outlined NFPA 1500: *Standard on Fire Department Occupational Safety and Health Program* and NFPA 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*.

- NFPA 1710 requires the first-arriving engine company with four firefighters at a structure fire to be on scene within four minutes to 90% of incidents. Currently, these requirements can only be met on 41.2% of roads within the response jurisdiction.

- By implementing the recommended staffing and deployment configuration shown in Table 8, the department would be able to assemble a minimum of four firefighters on 52.5% of roads within four minutes, a 27.4% **increase** in response coverage compared to capabilities under GFD's current staffing.

- NFPA 1710 requires the arrival of 17 firefighters within eight minutes to be the standard for safe, effective, and efficient operations at a typical residential structure fire. Currently, these requirements can only be met on 21.3% of roads within the response jurisdiction.

[2] Staffing of Truck 1 lowers to three firefighters at times. These include instances of on-duty training or when Blocker 1 is deployed to an motor vehicle accident. Blocker 1 is staffed by one firefighter assigned to Truck 1.

- NFPA 1710 requires a minimum of 28 firefighters,[3] including one incident commander with an aide, arriving on the scene of a medium-hazard[4] structure fire within eight minutes of travel. Currently, the department's daily staffing levels cannot provide for the arrival of 28 firefighters on any of the roads within the response area within eight minutes.

- According to Grapevine Fire Department emergency call volume data, total incidents increased 7.0% from 2019 through 2021.

- NFPA 1710 states that the first unit shall be on scene within four minutes (240 seconds) of travel to 90% of incidents. From 2019 through 2021, the 90th percentile travel time to all incidents for the first unit on was over seven minutes (420 seconds) for each year. Rapid response is 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.

- Department travel times that are consistently higher than four minutes suggest that the department may need additional resources. Not only are the department travel times more than four minutes, but each station had 90th percentile travel times of over six minutes. Growth in demand on the department will further increase travel times and risk to the citizens of Grapevine.

- Additional resources will significantly improve response to areas with high demand outside the department's current four-minute and eight-minute capabilities including neighborhoods with increased demand, risk and population.

- This report determined that most area roads are not currently serviced within safe and effective time frames. As such, there is an increased risk of death or injury to firefighters and citizens, as well as increased risk for considerable property loss of housing units and businesses throughout the city.

[3] NFPA 1710 §5.2.4.3.1 requires "the establishment of an initial medical care component consisting of least two members capable of providing immediate on scene emergency medical support and transport that provides rapid access to civilians or members potentially needing medical treatment." If this service is provided by the fire department, the requirement for a medium-hazard structure fire would be 28 firefighters arriving within eight minutes.

[4] NFPA 1710. §5.2.4.2.1 describes "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." NFPA 1710. §5.2.4.3.1 describes "in a typical 1,200 ft^2 (111 m^2) apartment within a three-story garden-style apartment building." Medium-hazard occupancies descriptions include apartments, offices, mercantile, and industrial occupancies not normally requiring extensive rescue or firefighting forces.

- Mapping analysis shows that increasing apparatus and staffing levels would increase existing initial full alarm response capabilities to low-hazard incidents, including typical residential structures, and improve response capabilities for simultaneous incidents.

Recommendations

The recommendations listed are based on the desire to meet the performance objectives in NFPA 1710 and the findings of the GIS evaluation of the current staffing and deployment practices of the Grapevine Fire Department.

Short-Term Recommendations

- GFD should increase firefighter personnel totals to ensure all fire apparatus are always staffed with a minimum of four firefighters. Staffing fire suppression apparatus with four firefighters would meet the minimum staffing objectives in NFPA 1710 and enhance safety and operational effectiveness and efficiency.

- GFD should add a medic unit at Station 4, staffed with two firefighter/paramedics at all times. Increasing the number of medic companies to ensure there are adequate units staffed and available to respond to incidents as they occur throughout Grapevine's response area. The addition will also reduce the department's reliance on medic units staffed further away consistently deployed to incidents occurring closer to Station 4.

- Staffing fire apparatus with four firefighters will significantly improve response to areas with high demand outside the department's emergency "2 In/2 Out" capabilities including neighborhoods near Station 4.

- GFD should increase staffing to ensure its personnel response to a low-hazard structure fire consists of a minimum of 16 firefighters and one command officer to total 17 personnel. Additional staffing personnel will not only increase full alarm assignment coverage but also decrease the overall workload of firefighters by placing more personnel at the scene sooner.

- The GFD should maintain acceptable levels of both the distribution and concentration of resources. An adequate distribution of resources will allow for quick responses to different areas of the municipality while the concentration element will assist in the assembly of an initial effective response force consisting of both personnel and apparatus within a specified time frame to initial alarm assignments.

Long-Term Recommendations

- GFD should add a new fire station near the intersection of *William D Tate Avenue and W Nash Stree*t. The station should deploy an engine staffed with a minimum of four fighters. Deploying from this station would ensure there is adequate personnel responding to incidents throughout Grapevine Fire Department's response area. Doing so will

significantly improve response to areas with increased demand outside the department's initial four-minute capabilities in more parts of Grapevine.

- The department should be involved with Grapevine decision makers concerning growth and development to address areas not currently covered with effective response forces including those areas of increasing demand. A comprehensive growth plan will help the department decide where to place future fire stations, apparatus, and staff. Stations should be built over time to address current and future demand, and additional full-time units staffed within industry standards should be added as needed.

- GFD should increase staffing to ensure response to a medium-hazard structure fire consists of a minimum of 24 firefighters, one command officer, and one officer aide to total 26 personnel, and to a high-hazard structure fire consist of a minimum of 32 firefighters, six officers, and one command officer to total 39 personnel to meet the objectives outlined in NFPA 1710. Currently, the department does not have sufficient staffing for medium (garden-style apartments) or high-hazard alarms, which include high-rises but may be applied to large area buildings like manufacturing centers, warehouses, school and more.

Executive Summary Conclusion

The provision of fire protection and EMS response are essential services that government must provide. However, 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. A fire department should be designed to adequately respond to several 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. Staffing and deployment decisions should be made based on the historical location of calls, travel times to specific target hazards, compliance with departmental Standard Operating Procedures (SOPs), existing industry standards (e.g., 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.

The Grapevine Fire Department's staffing levels do not meet objectives found in the industry standards and have significantly limited the department's emergency response capabilities. Fire suppression resources are inadequately deployed for the arrival of a first response company of four firefighters within four minutes and/or the arrival of an effective response force to 90% of incidents. Insufficient resource allocation will increase risk to the firefighters, citizens, and visitors of Grapevine. Additional staffing will improve the ability to provide for the arrival of the initial unit within four minutes and an effective response force within eight minutes for low-

hazard structure types. Furthermore, additional staffing and resources will improve the ability to respond to medical or fire emergencies in the event of concurrent or simultaneous incidents.

The findings in this report will provide decision makers with information on how the department's current response capabilities compare to industry standards and how the lack of resources negatively affects GFD's ability to appropriately respond to incidents within their response boundary.

Background

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Grapevine Professional Firefighters, IAFF Local 3113, to create a data-driven document for the decision makers of Grapevine and fire department administrators to assist with informed decisions regarding emergency response. Local 3113 has observed the effect of deficiencies of resources on fire department response capabilities and has communicated the need for more resources to city officials. Local 3113 continues to communicate the need for more personnel to meet NFPA staffing objectives. Insufficient staffing levels yield inadequate response coverage, especially in areas experiencing high demand and increased population density. This report assists with improving emergency services response for all citizens while exploring the impact of additional resources to address demand and risks present in the community.

The Grapevine Fire Department (GFD) provides fire suppression, specialized technical rescue, aircraft rescue and firefighting, hazardous material response (HazMat), and emergency medical services (EMS) first response and medical transport at the Advanced Life Support (ALS) level. In addition to emergency response, the department performs other services such as hazard reduction services, fire prevention, and safety programs, which include fire-safety inspections and a wide range of public education. GFD also provides mutual aid response to the surrounding jurisdictions. Mutual aid allows for dispatch centers to communicate with each other to request nearby resources be dispatched to an incident outside their home jurisdiction. GFD responds to all emergencies, deploying units based on the type and location of the incident.

Historical call volume data provided by IAFF Local 3113 as computer-aided dispatch (CAD) data shows call location and time stamp data for all incidents to which the department responded between 2019 and 2021. The call data were used to assess the department's performance. This analysis examined the CAD data to evaluate the department's historical response capabilities and determine the possible need for additional resources. Geographic Information Systems (GIS) analysis was performed to evaluate how different staffing and deployment configurations change the department's response capabilities. This computer-based analytical study examines predicted travel times and geographic coverage areas for emergency response units deployed from fire station locations in the Grapevine Fire Department's response jurisdiction under existing and recommended scenarios. Using historical traffic patterns,[5] analysis was performed to examine the department's ability to meet industry standard response requirements such as four-minute initial unit arrival, the establishment of a minimum of four personnel on scene within four minutes, the arrival of 17 and 26 firefighters within eight minutes for an initial full alarm to low- and medium- hazard structure fires, and 39 firefighters within 10 minutes 10 seconds to high-hazard structure fires.

[5] Historical traffic data contained in ESRI's StreetMap Premium, version 21.3.

Grapevine Fire Department Risk Assessment

The Grapevine Fire Department serves the City of Grapevine, an 35.7 square mile area of Tarrant County, Texas, which also includes portions of Grapevine Lake. A risk analysis was performed on the City of Grapevine to assess the need for emergency services. According to the 2020 U.S. Census, the city had a population of 50,631.[6] The 2020 census estimates also revealed that 21.1% of the population was in a vulnerable category due to age. This category consists of persons under the age of five (5.0%) and persons 65 years of age and older (12.1%) but does not include the special needs population[7]. These populations typically place an increased demand on public safety resources because they are at a higher risk of fire-related injury and death as a result of their inability, or reduced ability, to evacuate in an emergency. These groups may also be unable to care for themselves or have multiple health issues. Additionally, 5.5% of the population was living at or below the poverty level.[8] These are people who generally lack the means to properly maintain residences, which can lead to an increased risk for fire.

In addition, 8.2% of the population had a disability[9] and 11.0% of the population was uninsured.[10] People living with disabilities are more likely to experience medical complications and require specialized patient care placing increased stress on responders. Those without health insurance are more likely to not receive preventive services and screenings, have poorer health outcomes due to delayed diagnoses, and may not be able to receive care to manage chronic diseases.[11] Lack of access to regular medical care leads to a higher risk for medical complications resulting in an increase in EMS demand. Typically, people living within these demographic characteristics are at an increased risk for medical complications.

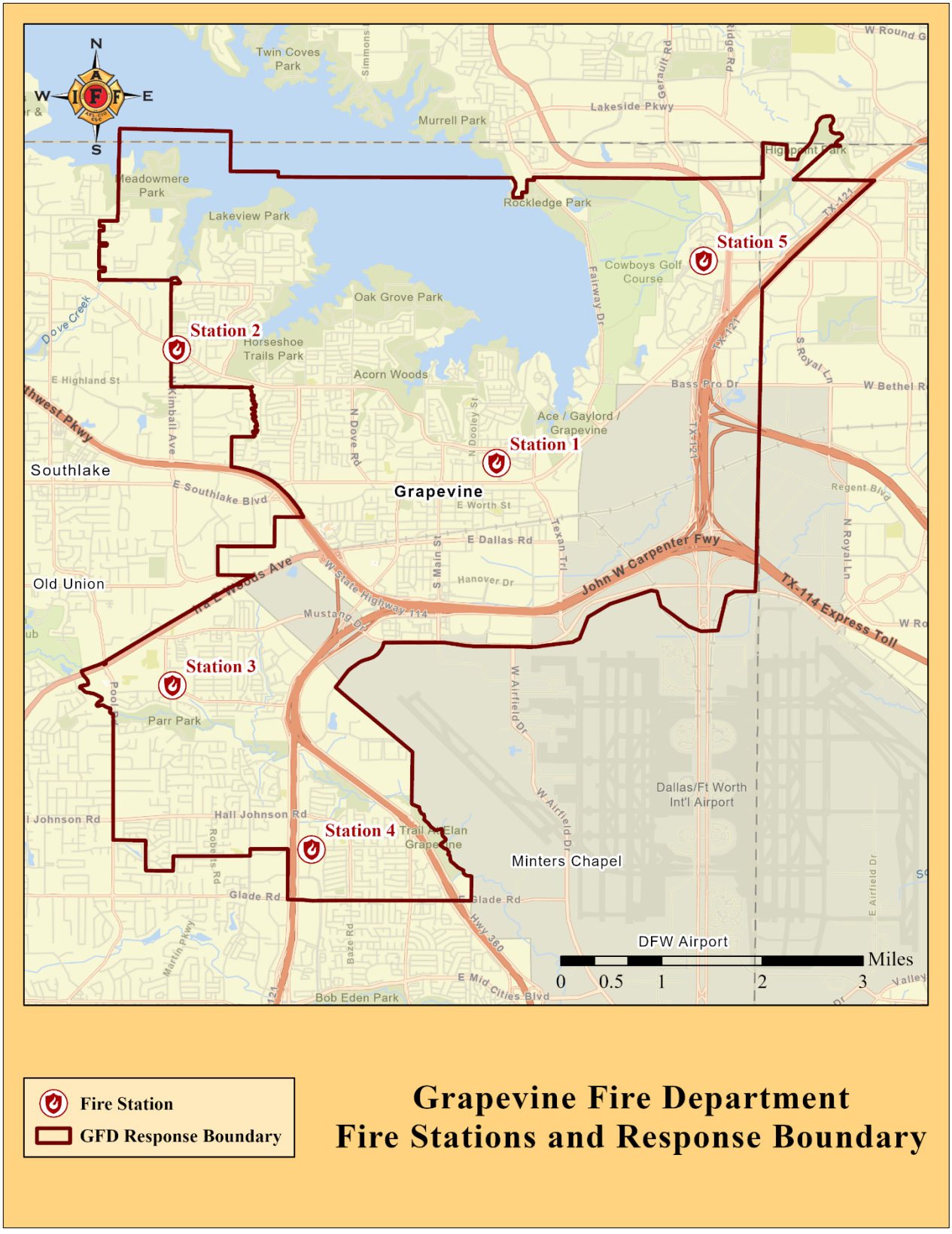
There were 22,236 housing units estimated in 2020.[12] Housing units consist of single or semi-detached houses (69.3%), multifamily housing structures containing between two and 10 apartment units (11.8%), multifamily housing structures containing 10 or more apartment units

[6] U.S. Census Bureau, 2020 Decennial Census - Population of Grapevine, TX visited November 29, 2022.
[7] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX - Demographic and Housing Estimates visited November 29, 2022.
[8] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX - Poverty Status in the Past 12 Months visited November 29, 2022.
[9] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX - Disability Characteristics visited November 29, 2022.
[10] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX - Selected Characteristics of Health Insurance Coverage visited November 29, 2022.
[11] https://www.ncbi.nlm.nih.gov/books/NBK220636/
[12] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX - Occupancy Status visited November 29, 2022.

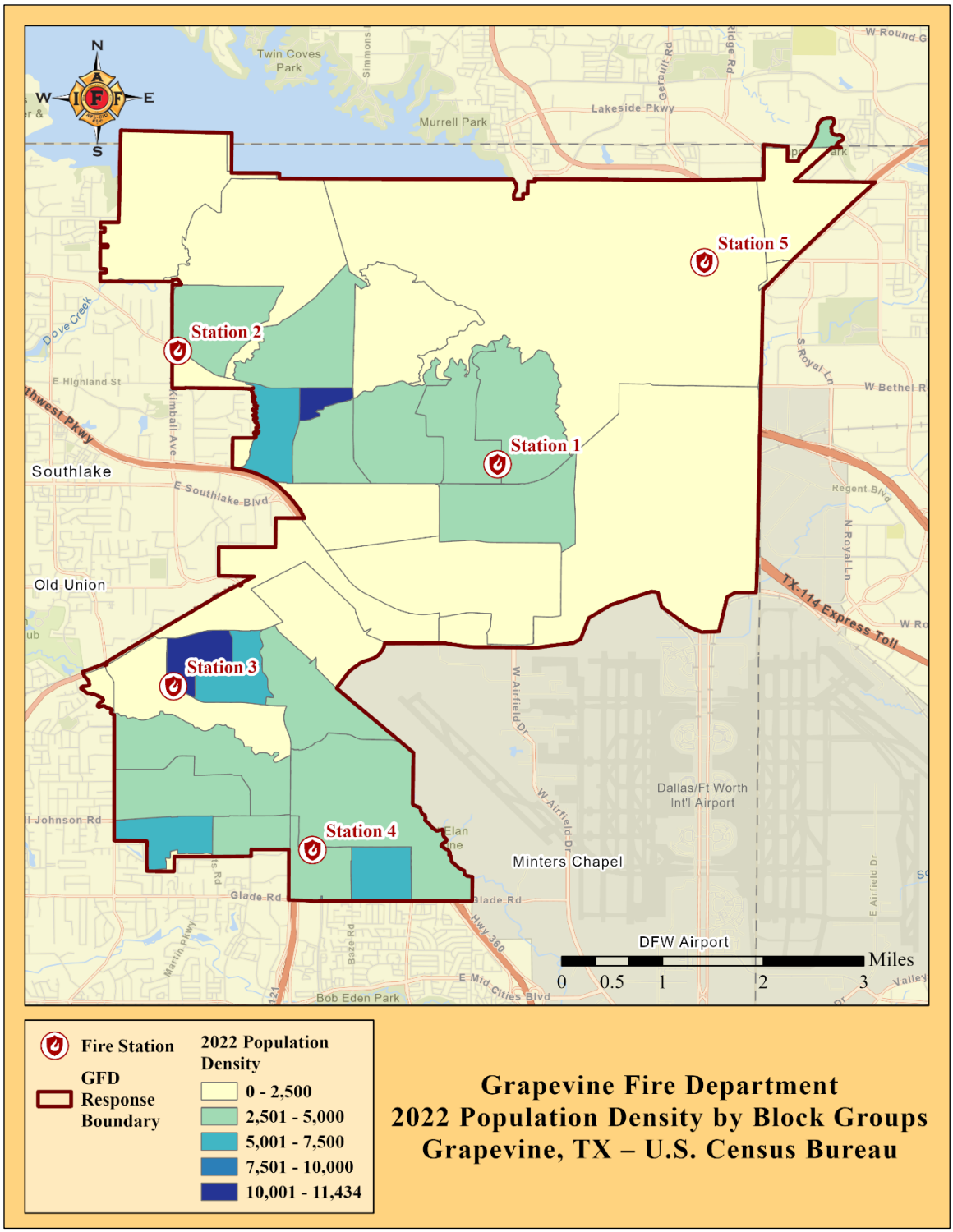
(13.7%), and other dwellings including mobile homes (5.2%).[13] Of these structures, 38.5% were constructed between 1940 and 1980, and 11.4% were built in 1939 or earlier. Typically, when there are high numbers of older buildings constructed before current fire codes were developed, there is an increased demand on emergency services. Census estimates also indicated vacant housing units made up 5.8% of total housing. Based on a January 2018 NFPA study, over 50% of all structure fires in vacant buildings are intentionally set. Structure fires in vacant structures are approximately three times more likely to spread beyond the structure of origin compared to structure fires in occupied properties. Firefighters have an increased risk for injury in vacant building fires due to poorly maintained properties, unsafe heating sources, and the lack of working fire alarms and sprinklers.

The following map shows the location of GFD's fire stations and response boundary.

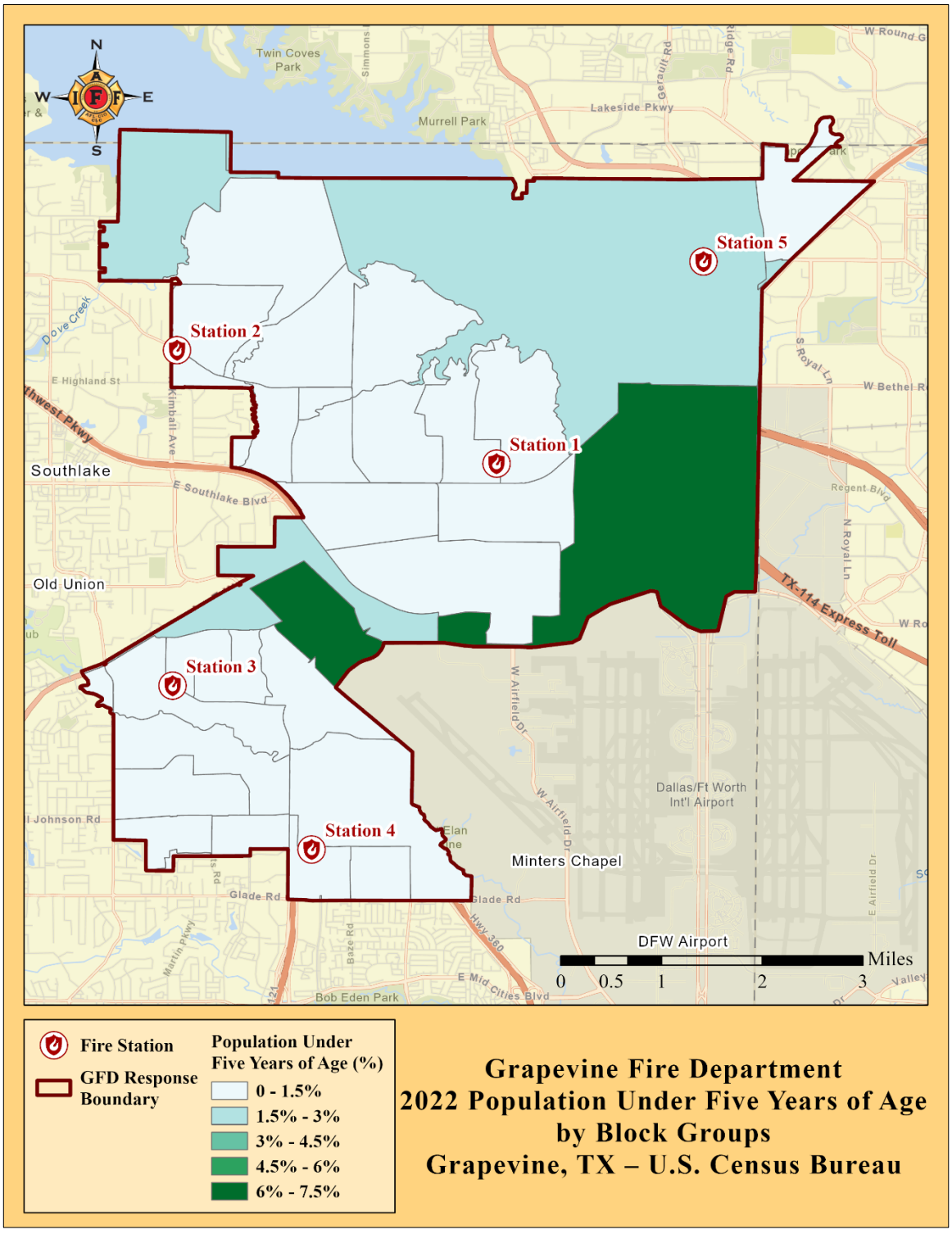
[13] U.S. Census American Community Survey – 2020: ACS 5-Year Estimates Data Profiles of Grapevine, TX – Physical Housing Characteristics for Occupied Housing Units visited November 29, 2022.



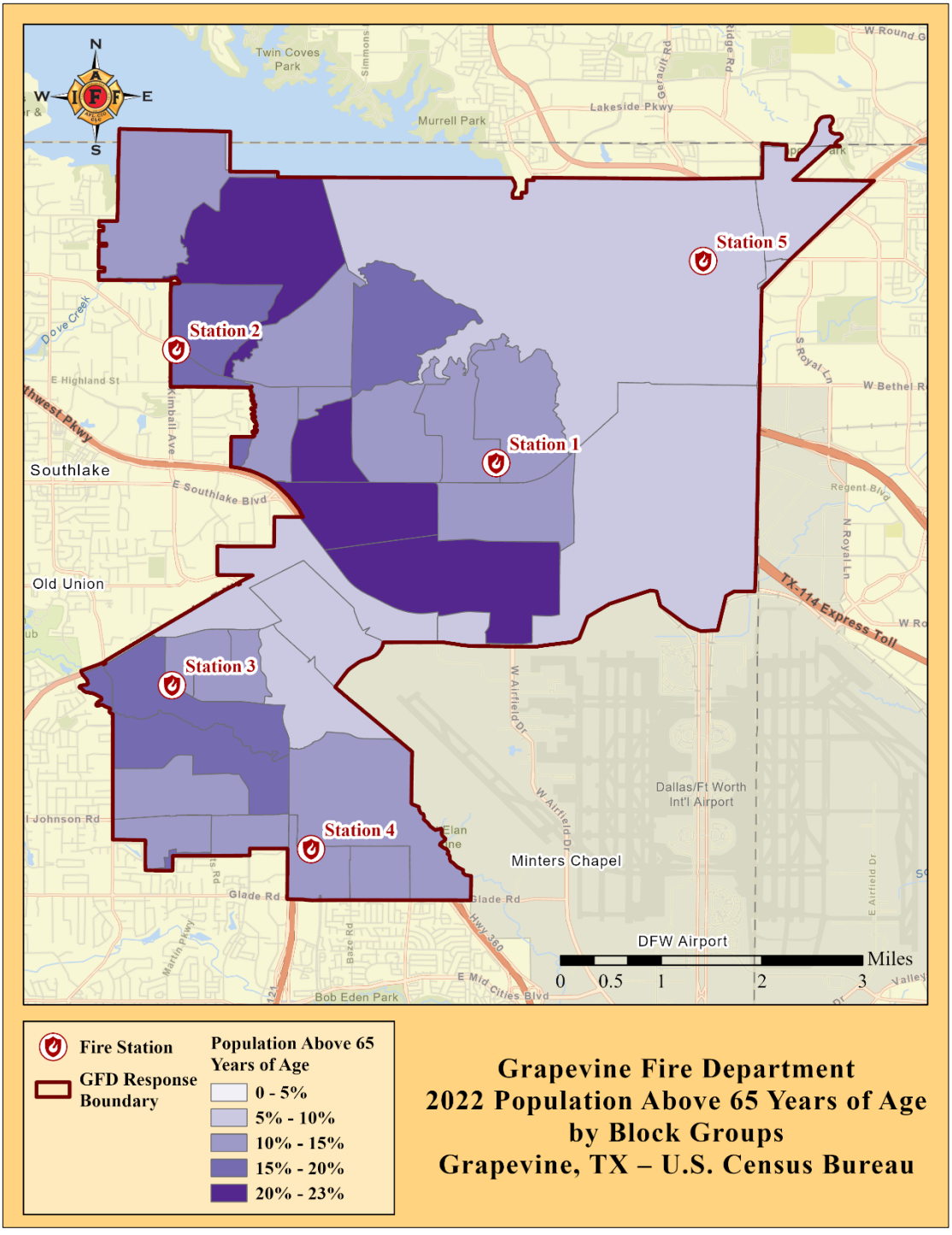
Map 1: Grapevine Fire Department Response Area and Fire Stations. Map 1 depicts the Grapevine Fire Department's response area boundary and fire station locations.



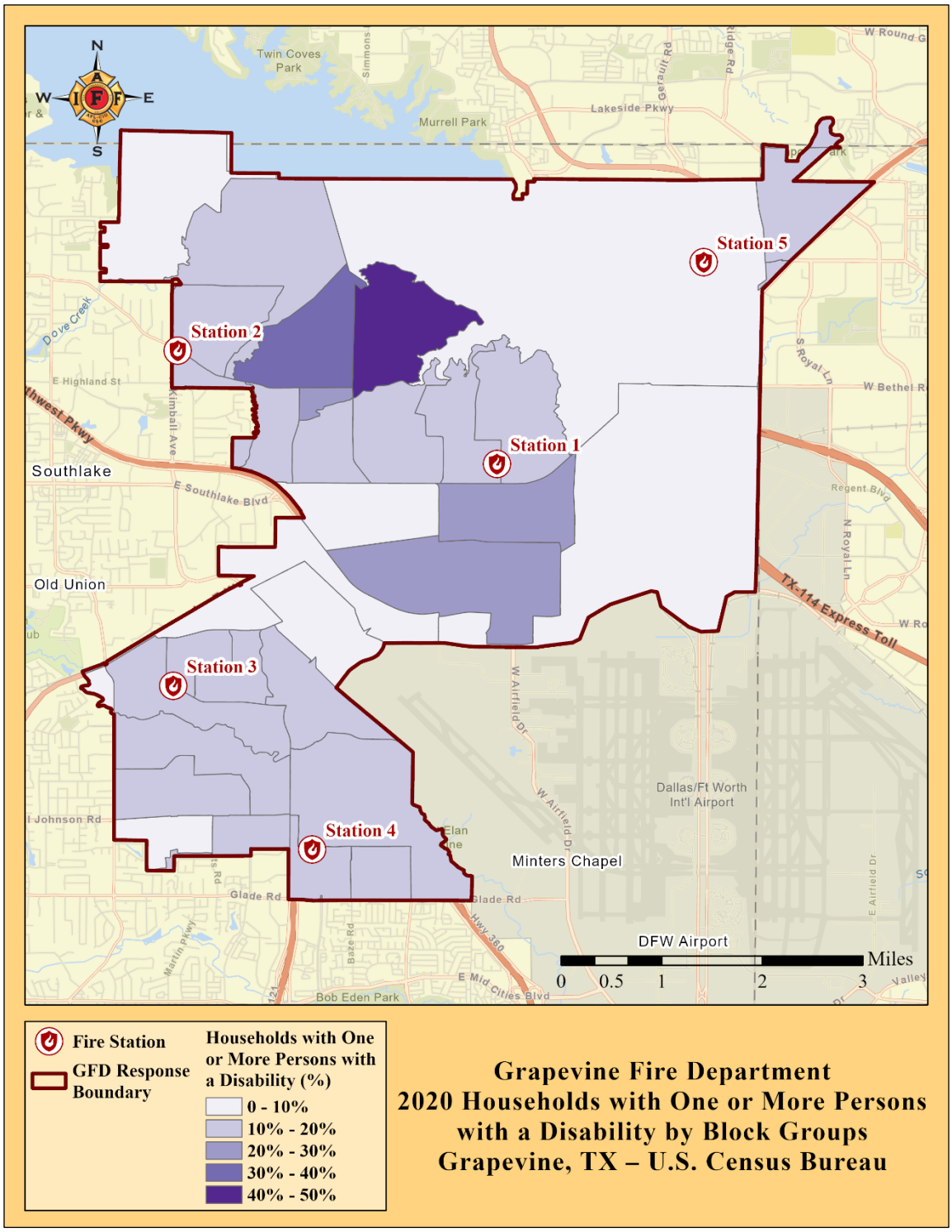
Map 2: 2021 Population Density by Block Groups, Grapevine, TX. – U.S. Census Bureau: Map 2 shows 2022 population density by block group from the U.S. Census Bureau for Grapevine, Texas. Areas with higher population densities tend to place a greater incident demand on emergency services. Areas with high density population, more than 3,000 people per square mile, require additional resources. Neighborhoods near west, south and downtown Grapevine are dense urban areas with increased population and should have additional firefighters to meet NFPA minimum staffing requirements at all times.



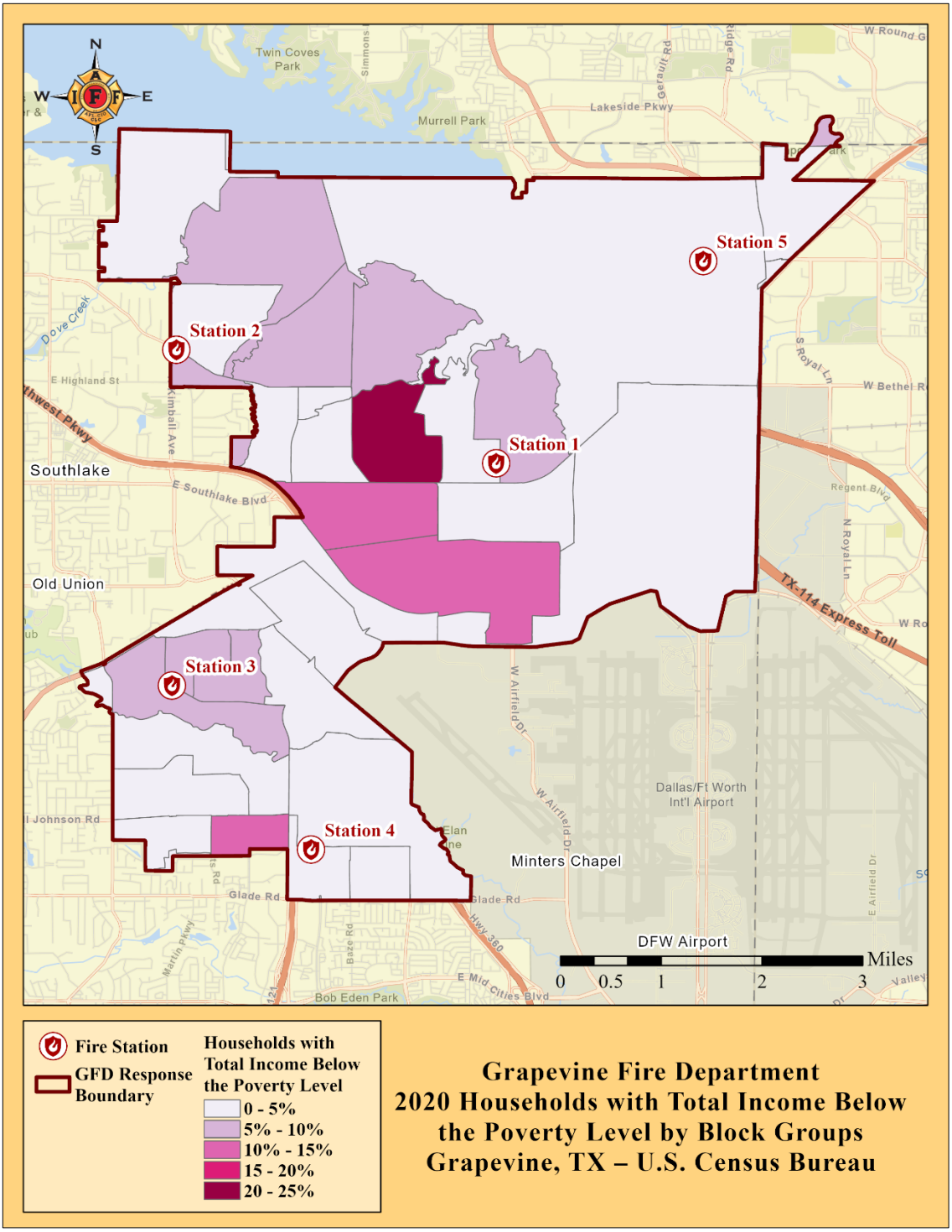
Map 3: 2022 Population Under Five Years of Age – U.S. Census Bureau: Map 3 reflects the percentage of the total 2022 population under five years of age by U.S. Census block groups estimated for Grapevine, TX. This map identifies areas with increased vulnerability most likely needing additional resources for emergencies. According to a September 2019 U.S. Fire Administration statistical analysis, children under the age of five accounted for 41% of fire-related childhood deaths.



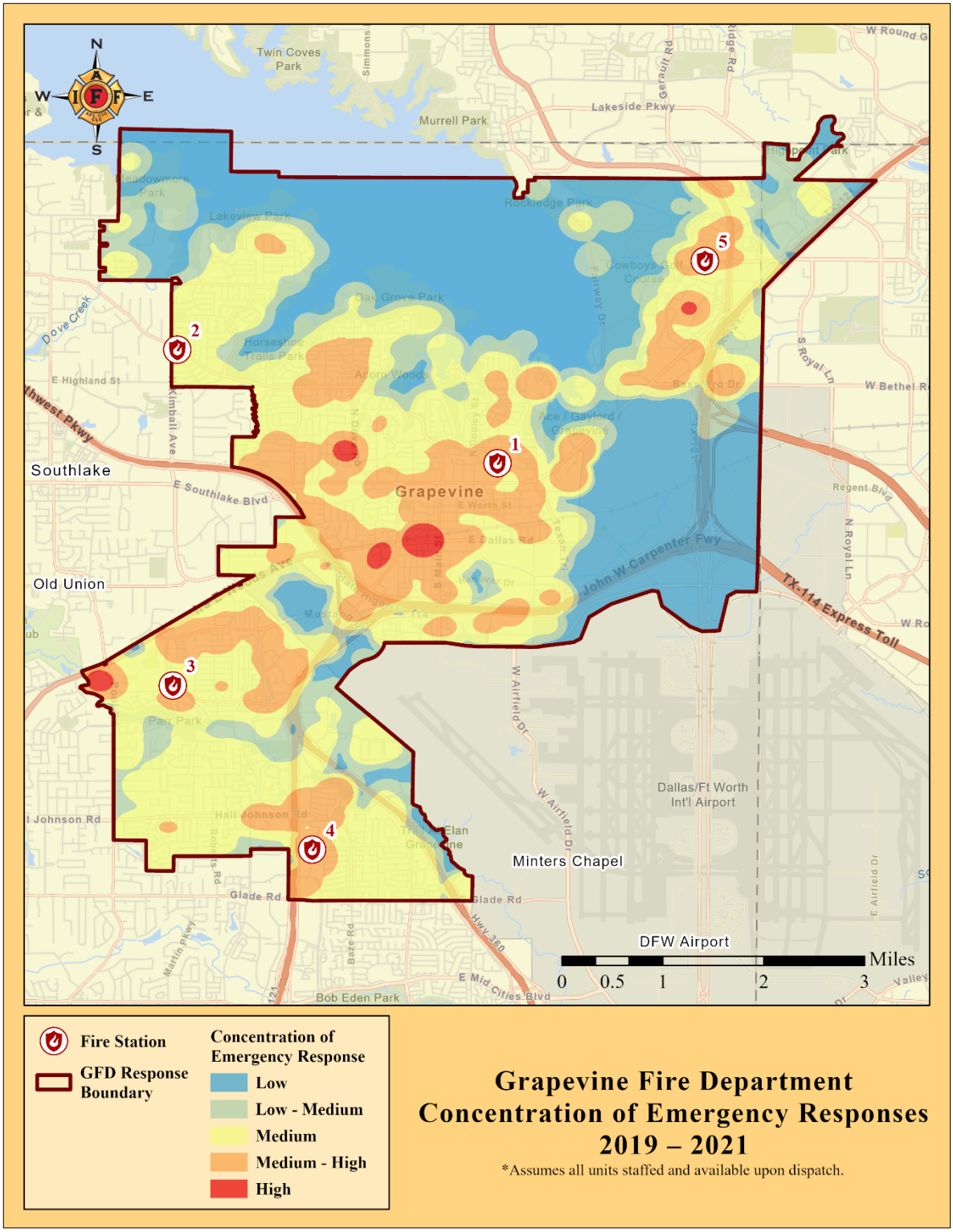
Map 4: 2022 Population Above 65 Years of Age –U.S. Census Bureau: Map 4 reflects the percentage of the total 2022 population aged 65 years and older by U.S. Census block groups estimated for Grapevine, TX. This map identifies areas with increased vulnerability most likely needing additional resources for emergencies. Typically, people aged 65 and older are at a higher risk for injury or death because of their inability or reduced ability to evacuate in an emergency. According to a September 2019 U.S. Fire Administration statistical analysis, people over the age of 65 accounted for 40% of all fire fatalities. This age group also tends to place an increased demand on emergency medical resources.



Map 5: 2020 Population - Households with One or More Persons with a Disability – U.S. Census Bureau: Map 5 reflects the percentage of the total households with at least one person with a disability by 2020 U.S. Census block groups estimated for Grapevine, TX. This map identifies areas with increased vulnerability most likely needing additional resources for emergencies. Typically, people with a disability are at a higher risk for injury or death because of their inability or reduced ability to evacuate in an emergency. Persons with a disability are also more likely to experience medical emergencies requiring EMS response.



Map 6: 2020 Households with Total Income Below the Poverty Level – Source: U.S. Census Bureau: Map 6 reflects the percentage of the total households living below the poverty lines, according to 2020 U.S. Census block groups estimated for Grapevine, TX. This map assists in identifying area with increased vulnerability most likely needing additional resources to fire emergencies. Typically, persons that live at or below the poverty line lack access to health care and have an increased risk for medical emergencies. Additionally, these households have an increased possibility of fire due to overcrowding, unsafe living conditions and lack of fire alarms resulting in increased injury or death from fire-related event.



Map 7: Concentration of Emergency Responses 2019 - 2021. Map 7 models the concentration of emergency responses from 2019 through 2021 in the Grapevine Fire Department's response area. Response concentrations are mapped using geographic statistical analysis to analyze CAD location-based incident data. The analysis reveals that areas with the highest concentration of emergency responses occurred throughout Grapevine

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,[14] 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 eight 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.

The following section will explain 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.[15]

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

[15] NFPA 1710, 2020 ed. Pg. 1710-20 A.4.1.2.5.1

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 correlates 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 fireground 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/UCGFDoperations.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.

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

[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.

firefighters with advancing the hoseline into the building and to the location of the fire. Before 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 complete all tasks associated with fire suppression, search and rescue, and other critical fireground activities. As dispatched units arrive with sufficient numbers of firefighters, the overall time on the scene of the 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	0:15:44	
3-Person Close Stagger	0:20:30	23% 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.

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 seven 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 five to six 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 one-minute time difference in the arrival of each responding company. Far stagger was defined as a two-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.

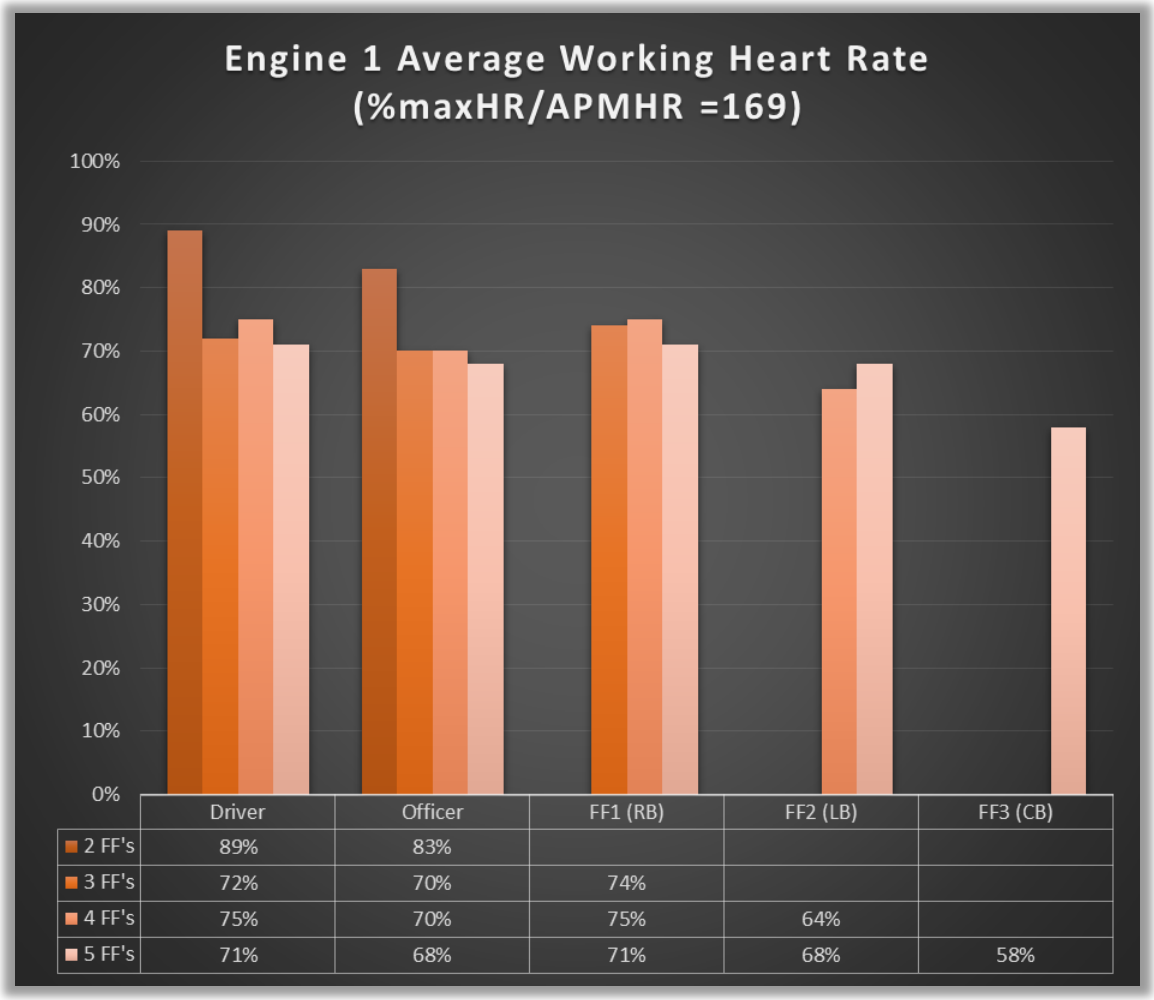
- Average heart rates were higher for members of small crews.
- These higher heart rates were maintained for longer durations.[21]

[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.
[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.

In 2018 alone, 44% 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 tasks 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 two to five 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.

[22] Fahy, R.F., Molis, J.L. (June 2019) Firefighter Fatalities in the United States-2018. 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



	Driver	Officer	FF1 (RB)	FF2 (LB)	FF3 (CB)
2 FF's	89%	83%			
3 FF's	72%	70%	74%		
4 FF's	75%	70%	75%	64%	
5 FF's	71%	68%	71%	68%	58%

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 two firefighters were working. When staffing was at two 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 two 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

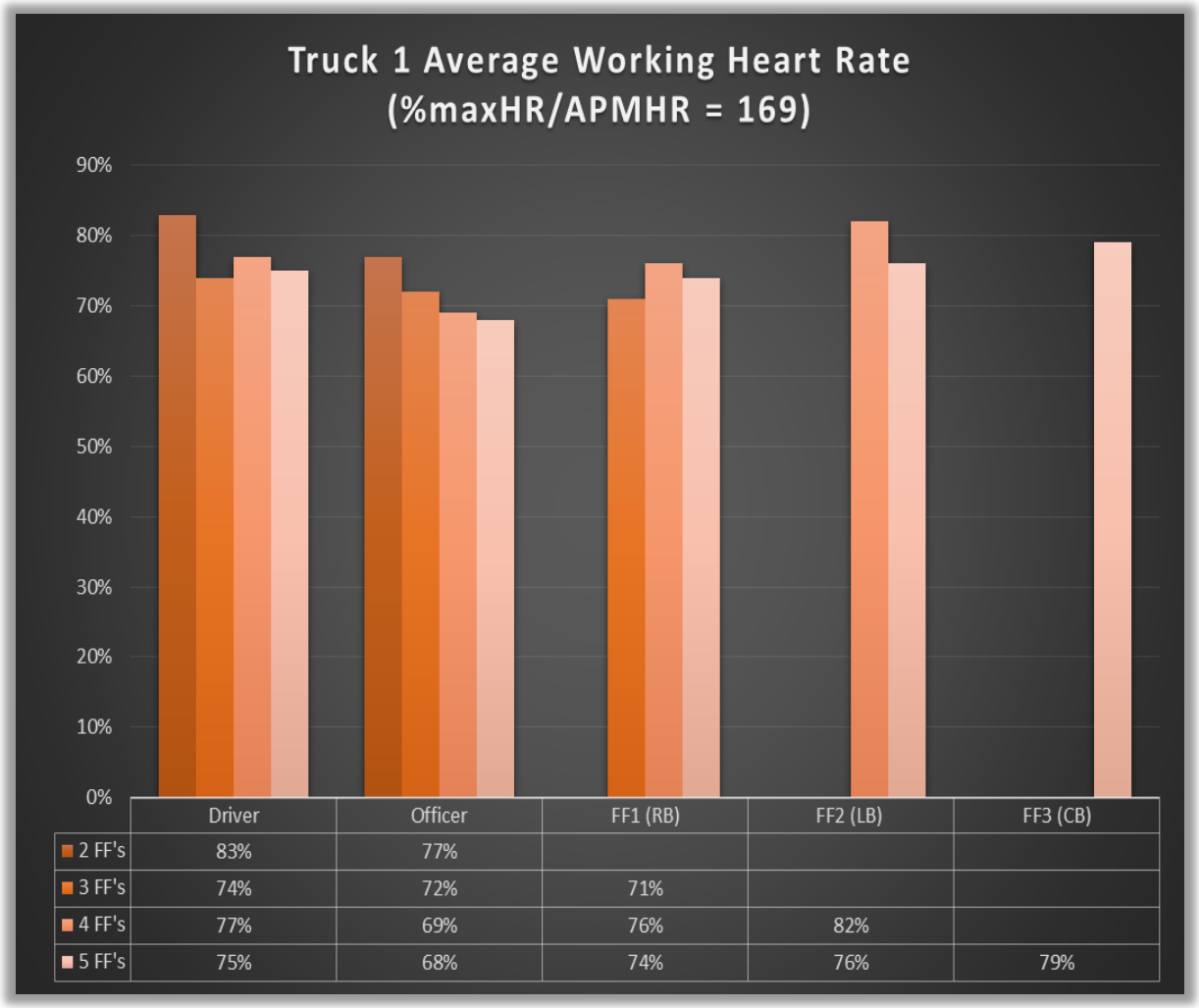


Chart 2: Average Peak Heart Rate of First Truck (T1) with Different Crew Sizes by Riding Position.[26] In Chart 2, heart rates are expressed as a percent of maximal age-predicted maximal HR. The average heart rates for firefighters on the first truck company were above 80% of age-predicted maximum values when only two 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 two 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, p. 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 five- to seven-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 showed 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	8.7	$200
Confined to object of origin	0.4	11.1	$1,200
Confined to room of origin, including confined fires by incident type[29]	1.8	23.8	$4,000
Beyond the room, but confined to floor of origin	16.2	76.3	$35,000
Beyond floor of origin	24.6	55.0	$65,900

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 five- to seven- minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

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 (OSHA) 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 (IDLH) also covers the number of persons who must be on the scene before firefighting personnel may initiate an interior attack on a structural fire. An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH 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

[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 (2020), Table A.5.2.2.2.1 Fire Extension in Residential Structures, 2012-2016.

[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 firefighters 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)

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]

However, the number of personnel required per fire suppression apparatus increases with risk and demand. NFPA 1710, 2020 edition states that engine and ladder companies that are assigned to first-due districts that have a high number of incidents, geographic restrictions[35], geographic isolation[36], or areas considered to be urban[37] with regards to population density, all as identified by the authority-having jurisdiction (AHJ), should be staffed with a minimum of five firefighters. First-due districts that have tactical hazards, high-hazard occupancies, or densely populated urban areas[38], as identified by the AHJ, shall have companies that are staffed with six firefighters.[39]

[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] Geographic Restriction is a defined condition, measure, or infrastructure design that limits response and/or results in predictable response delays to certain portions of the jurisdiction.
[36] Geographic Isolation is a first-due response zone or jurisdiction with staffed resources where over 80% of the response area is outside of 10-minute travel time from the next closest staffed suppression apparatus.
[37] An urban area is an incorporated or unincorporated area with a population over 30,000 people and /or a population density over 1,000 people per square mile but less than 2,999 people per square mile.
[38] A dense urban area is an incorporated or unincorporated area with a population density of over 200,000 people and/or a population density of over 3,000 people per square mile.
[39] 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.

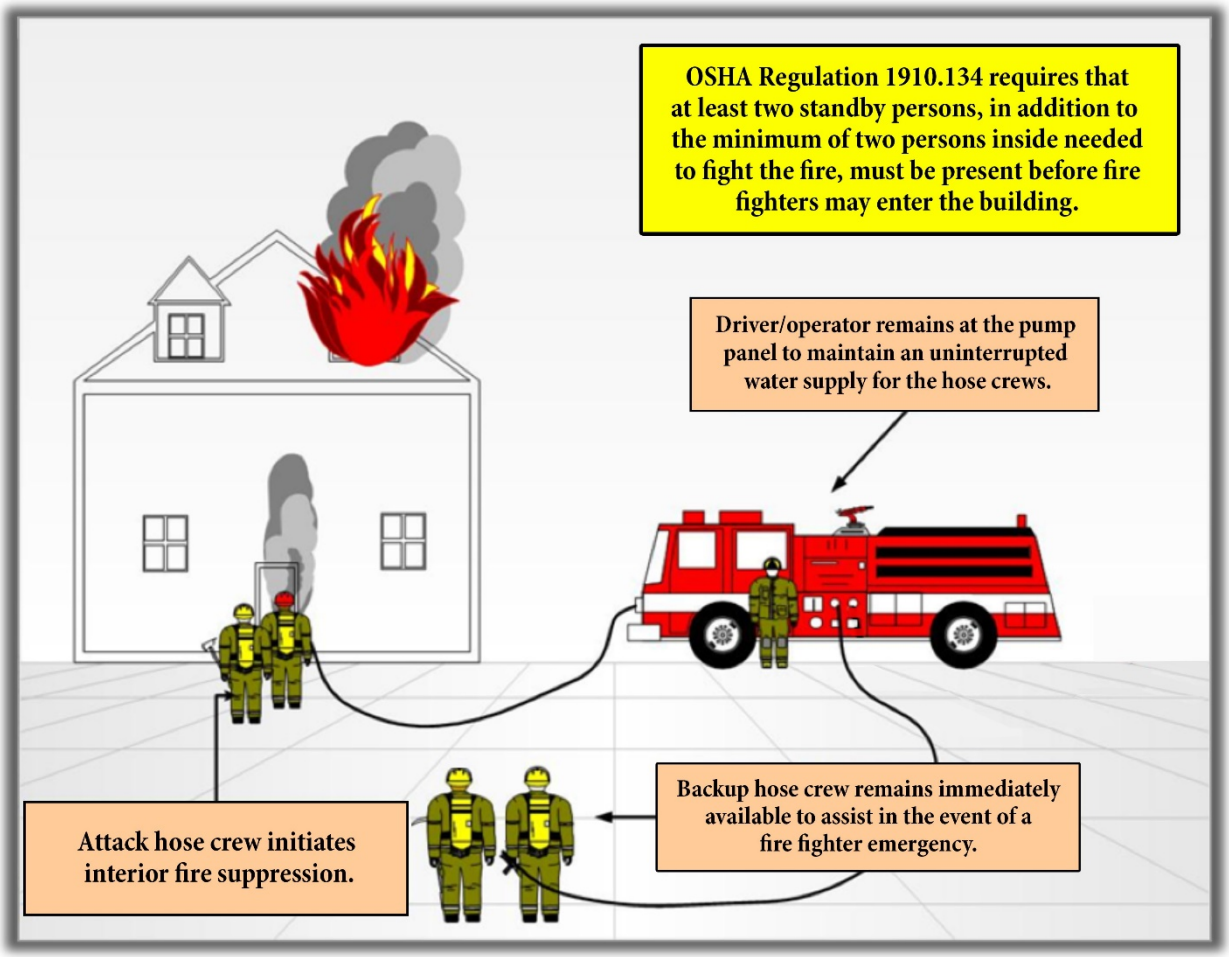


Figure 1: The OSHA "2 In/2 Out" Regulation. The above figure depicts the number of firefighters required to meet OSHA regulation 1910.134, which demands one firefighter outside for every firefighter inside. The firefighters outside can support a secondary attack line and facilitate the rescue of trapped or disabled firefighters should the need arise. In this scenario the driver/operator of the apparatus is not counted toward the total number of firefighters.

Several examples of incidents exist 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.

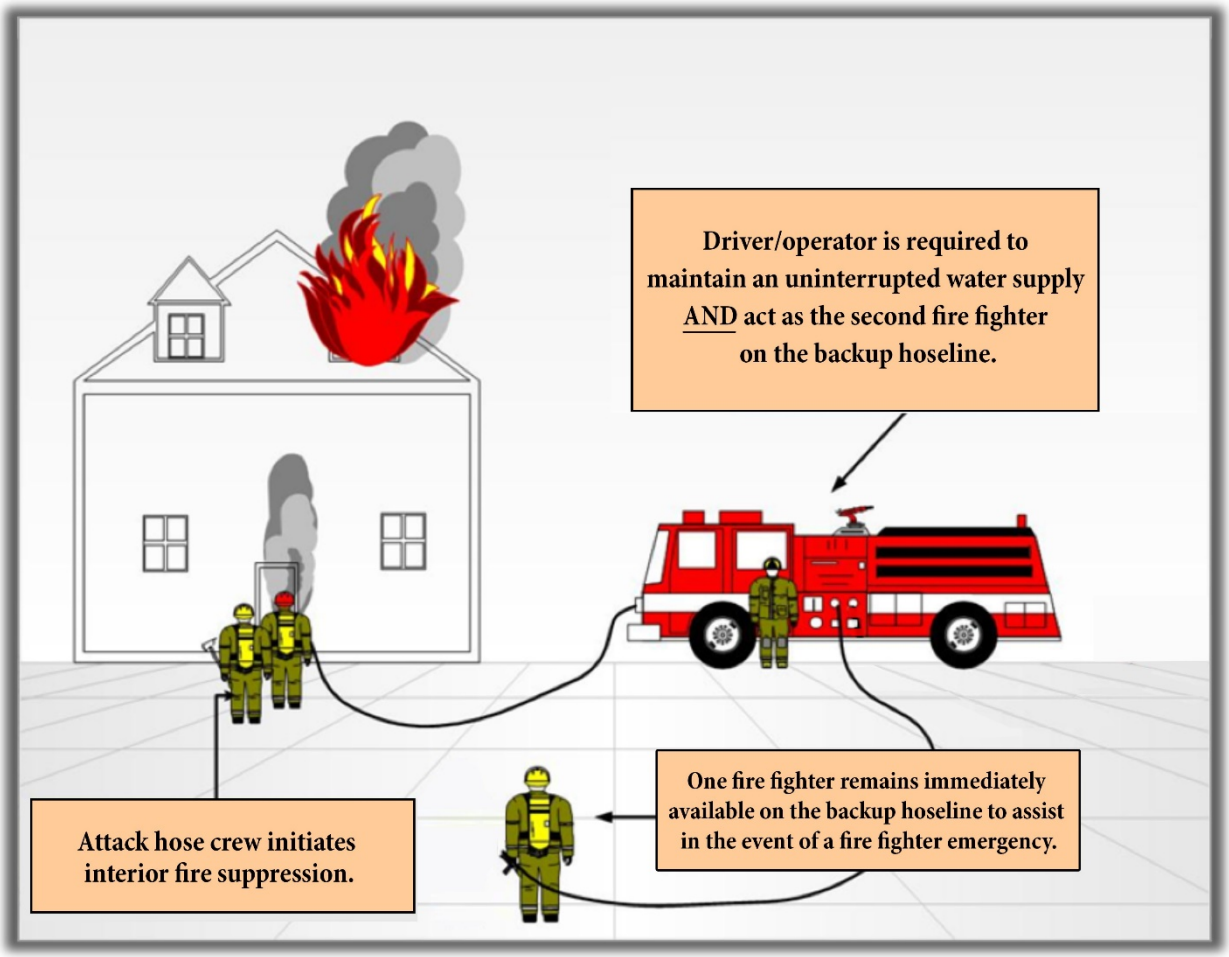


Figure 2: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of four personnel and operates under emergency conditions. In this case the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter 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 can 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 four

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

Initial Full Alarm Assignment Capability, as outlined in NFPA Standard 1710, recommends that the "fire department shall have the capability to deploy an initial full alarm assignment within a 480-second travel time to 90% 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)	4 Firefighters
Required Minimum Personnel for Full Alarm	**16 Firefighters & 1 Incident 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 17 fire suppression personnel.

In addition, NFPA 1710, §5.2.4.6.2 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.

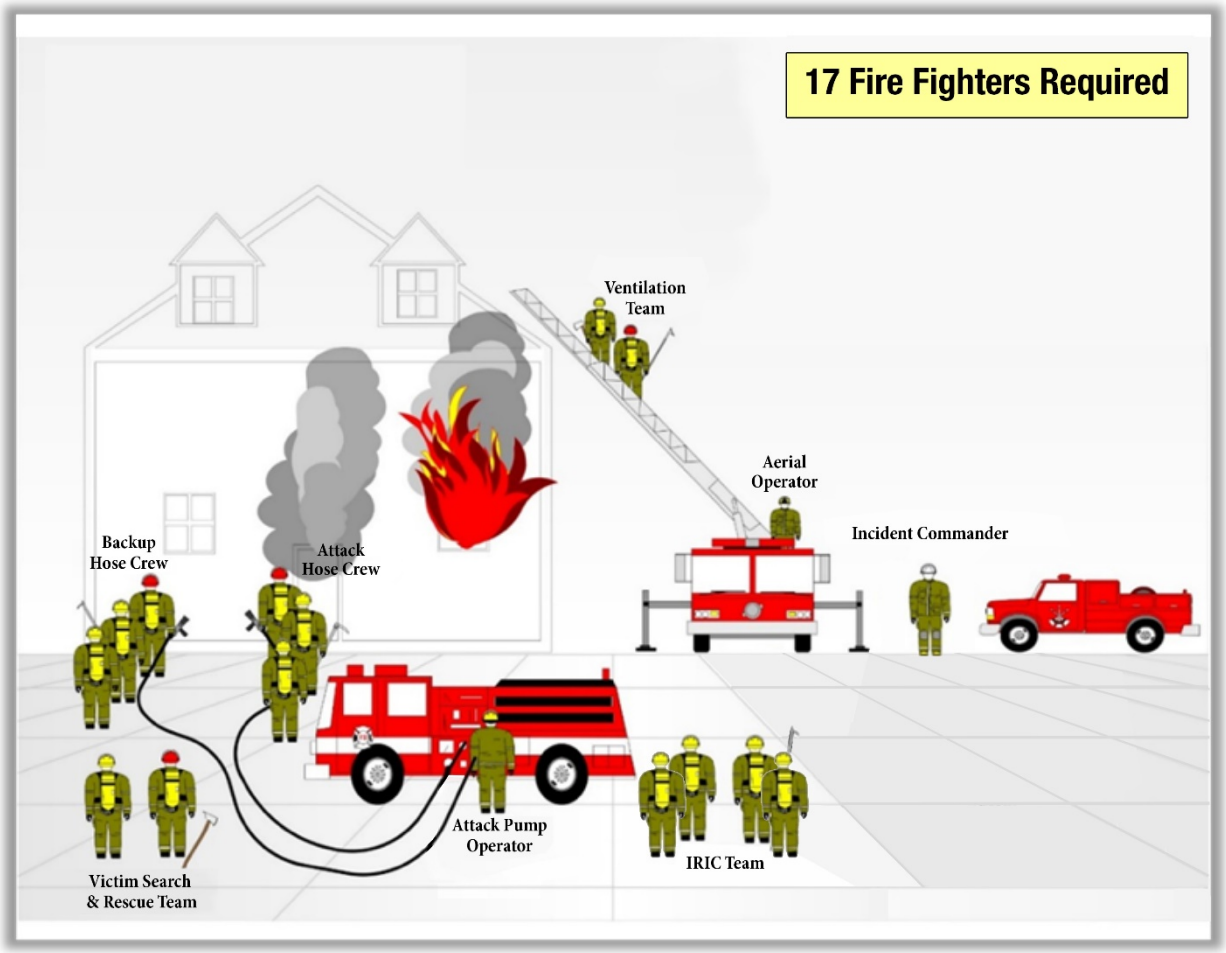


Figure 3: Initial Full Alarm Assignment Deployed Within Eight Minutes, 17 Firefighters Required. The above figure depicts the full alarm assignment required by NFPA 1710 as discussed in Table 4.

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.

Medium-Hazard Operations

Many structures are larger than low-hazard buildings but also do not qualify as high-hazard or high-rise style buildings according to NFPA 1710. Although the NFPA 1710 standard only explicitly identifies two specific structure types as medium-hazard, open-air strip shopping centers and garden-style apartment buildings,[40] anything larger than the 2,000 ft^2 single-family home with no basement or exposures would need a larger effective response force to operate safely and efficiently.

Additionally, there has been a recent building boom of mid-rise podium (also known as pedestal) construction.[41] These buildings are often occupied with commercial property at the ground level, multi-story apartments or condominiums above, and a parking garage below grade. This type of structure poses a greater risk to both the occupants and the firefighters. The wood frame construction is often made of lightweight material, thus making the structure prone to catastrophic collapse once a fire advances beyond the room or contents of origin and begins to attack the wood frame structural components. As can be seen in the following image, these buildings are typically designed to house retail businesses on the ground floor and maximize living space as apartments or condominiums five stories above. They are often just one or two stories shorter than the 75-foot benchmark for a high-hazard building, and due to the construction materials, can be particularly hazardous.

These types of structures, along with other residential garden-style apartment buildings and open-air strip shopping centers, all require an effective response force of at least 26 firefighters (28 firefighters if providing EMS transport) to assemble within eight minutes. Without adequate staffing, responses to these medium-hazard structures are dangerous, and the risks posed to the residents, business occupants and visitors, and firefighters at the fireground are extensive.

[40] NFPA 1710 Standard, §5.2.4.2 and §5.2.4.3

[41] Podium construction is a type of building characterized by horizontal divisions between upper tower and lower tower, resulting in the podium being constructed with steel or concrete and the upper portion being constructed with four to five stories of wood frame.

Figure 4: Podium Construction. This image is an example of a podium construction building under construction. The first story is concrete and the five stories above are wood frame; typically, light weight wood I-beams are used as the floor and roof supports.

Assignment	***Required Personnel***
Incident Command	1 Incident Commander 1 Incident Command Aide
Two Uninterrupted Water Supplies	2 Fire Engine Operators
Water Flow from Three Handlines on the Involved Floor	6 Firefighters (2 for each line)
One Support Member for Each Attack Line	3 Firefighters (1 for each line)
Two Victim Search and Rescue Teams	4 Firefighters (2 per team)
Aerial Device Operator	1 Firefighter
Two Teams to Raise Ground Ladders and Perform Ventilation	4 Firefighters (2 per team)
Full and Sustained Rapid Intervention Crew (IRIC)	4 Firefighters
2 EMS ALS Transport Units	2 Firefighters
Required Minimum Personnel for Full Alarm	**28 Firefighters** **or** **26 Firefighters (If FD does not provide EMS Transport)**

Table 5: NFPA 1710, §5.2.4.2.1. and 5.2.4.3.1. This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 28 fire suppression personnel on scene or 26 fire suppression personnel on scene if the department does not provide EMS transport.

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.3.3.36 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 risks to firefighters and occupants increase in proportion to the height of the building and the height of the fire above grade level.[42] 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 2007 and 2011, there were an estimated 15,400 reported high-rise structure fires per year that resulted in associated losses of 46 civilian deaths, 520 civilian injuries, and $219 million in direct property damage. Office buildings, hotels, apartment buildings, and health care facilities accounted for nearly half of these high-rise fires.[43]

[42] Klaene, B. and Sanders, R. (2007). Structural Firefighting: Strategies and Tactics- High-Rise. Jones and Bartlett 2007.
[43] Hall, J.R. (2013), High-Rise Building Fires. NFPA.

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 risks 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[44] 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 regarding 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 most 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.

Like 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 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.

[44] Structural Firefighting Strategy and Tactics 2nd Edition. Klaene B., Sanders R. NFPA 2008

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 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. It should be noted that in regard to high-rise fire suppression, crews larger than four performed searches faster than crews of four, thus minimizing a person who is trapped exposure to fire and toxic gases.

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

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.

Support

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, fireground 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[45] 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

[45] 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.

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 structure:

- In first-due response areas with a high number of incidents, geographical restrictions, geographical isolation, or urban areas, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[46]

- In first-due response areas 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.[47]

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 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 several 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 6, on the next page, displays the minimum number of firefighters required to arrive in the first full alarm assignment to a high-rise fire.

[46] NFPA 1710. §5.2.3.1.2 and §5.2.3.2.2
[47] NFPA 1710. §5.2.3.1.2.1 and §5.2.3.2.2.1.

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	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters** **1 Incident Commander** **6 Officers**

Table 6: 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, one incident commander, and six officers.

Fire Department EMS Operations

In recent years, the provision of EMS has progressed from an amenity to a citizen-required service. More than 90% of career and combination (career/volunteer) 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.[48] 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.[49] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with dual-role firefighter/emergency medical 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 toward 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 arriving on scene within four minutes. In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

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

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, and survivable cardiac arrest. Many times, patients experiencing symptoms associated with these events may not recognize the onset indicators and immediately call for assistance.[50] [51] [52] [53] 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 three hours.[54]

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 three to four hours and 30 minutes[55] 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"[56] 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 one hour and 36 minutes.[57]

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

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

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

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

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

[54] 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.

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

[56] "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.

[57] 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

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 time. Following completion of critical tasks, the crew can then facilitate a safe removal of the patient to the transport vehicle and minimize the risk of injury to patient and provider.[58]

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.[59] 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.[60] [61] 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.[62] 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

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[58] Moore-Merrell, L. et al. (2010) Report on Residential EMS Field Experiments, Fire Fighter Safety and Deployment Study; Washington, DC, September 2010.
[59] Highlights of the 2010 American Heart Association Guidelines for CPR and ECC
[60] Determinants of Blood Flow during Cardiac Resuscitation in Dogs. Halperin, HR et al. *Circulation* 1986;73:539-550
[61] 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
[62] 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

responding fire apparatus. However, these deployment options are determined by state directive 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, it is imperative to understand the intricacies of distribution and concentration.

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.[63] In this case, distribution is measured by the percentage of roads that are covered from each fire station within four-[64], six-[65], eight-minute[66] and 10-minutes and 10-seconds[67] travel times to adhere to NFPA 1710, 2020 edition.

Distribution study requires geographical analysis of first-due resources. Distribution measures may include:[68]

- 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

[63] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[64] Four minutes of travel time is the allowable maximum travel time for the first-arriving apparatus at the scene of a fire, first responding unit to an EMS incident, and BLS-equipped ambulance if there is not a first responding unit already on the scene.
[65] Six minutes of travel time is the maximum amount of travel time permitted for the second arriving apparatus. Although not explicitly stated, it is recommended that this apparatus be the ladder truck or a company that will be assigned to ladder duties.
[66] Eight minutes of travel time is the maximum amount of travel time permitted for a low-hazard alarm assignment and the arrival of an ALS-equipped unit, assuming a minimum BLS-equipped unit is already on the scene within four minutes of travel time.
[67] 10 minutes and 10 seconds of travel time is the maximum amount of travel time permitted for a high-hazard alarm assignment.
[68] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

- Catchment areas (four-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources

- Areas outside of actual performance
    1. Population not served
    2. Area not served (square miles)
    3. Road miles not served (miles)
    4. Dwelling unit square footage not served

- First-due unit arrival times (Engine, Truck, ALS unit, etc.)

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the element of travel time and the response goal. Travel time should be periodically sampled and analyzed to determine whether the fire department is achieving a reasonable response performance to handle emergencies.[69]

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 three to five years will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period will allow for trend analysis as well.[70]

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 a jurisdiction 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 stations near high risk areas to provide shorter 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.

[69] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[70] Ibid.

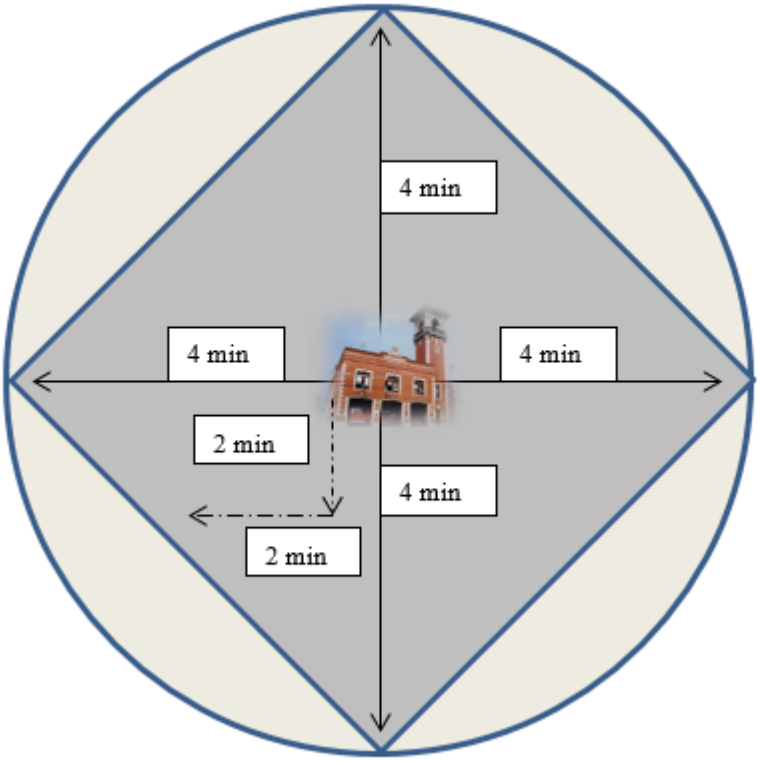


Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[71] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

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 four-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue.[72] 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.[73] Specialty units tend to be trucks, medic 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

[71] Derived from Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[72] Commission on Fire Accreditation International, 5th Edition. 2008. Page 55
[73] Commission on Fire Accreditation International, 5th Edition. 2008. Page 62

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 jurisdiction.

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.[74]

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

Mapping Analysis of the Grapevine Fire Department

In creating this document, it was important to ascertain where stations are located and if they are located to provide fair and equitable coverage to the citizens. To make this assessment, the IAFF created maps of the department's response area and plotted the fire stations. Computer modeling was then used to determine the distance apparatus could travel in four, and six, eight minutes.

Travel times were modeled using ESRI ArcGIS Pro version 3.0. Fire stations were identified on GIS maps as starting points with vehicles traveling at road speeds based on historic traffic conditions.[75]

When generating the maps, several 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 using the Wednesday at 5:00 pm.[76] 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.

[75] This dataset is derived from an average of the last two years of traffic data. Traffic volume decreased in 2020 compared to previous years due to the COVID-19 pandemic. Thus, when restrictions lift and traffic increases, the coverages shown in the following maps may be reduced.
[76] Historical traffic data contained in ESRI's StreetMap Premium, Version 22.3.

- 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.[77]

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.

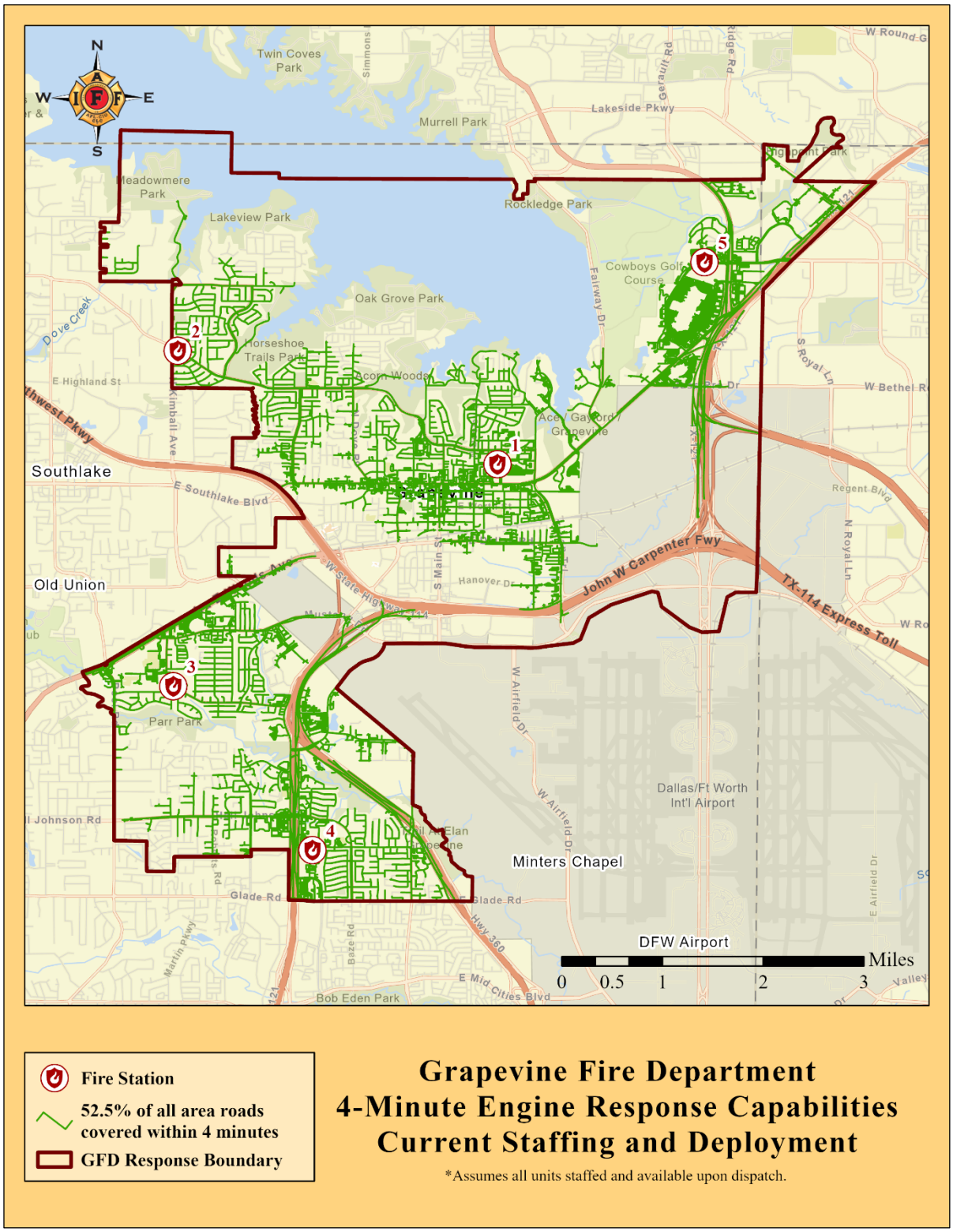
[77] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Minnesota Transportation Institute, Minnesota A&M University: September 2003).

Current Staffing and Deployment

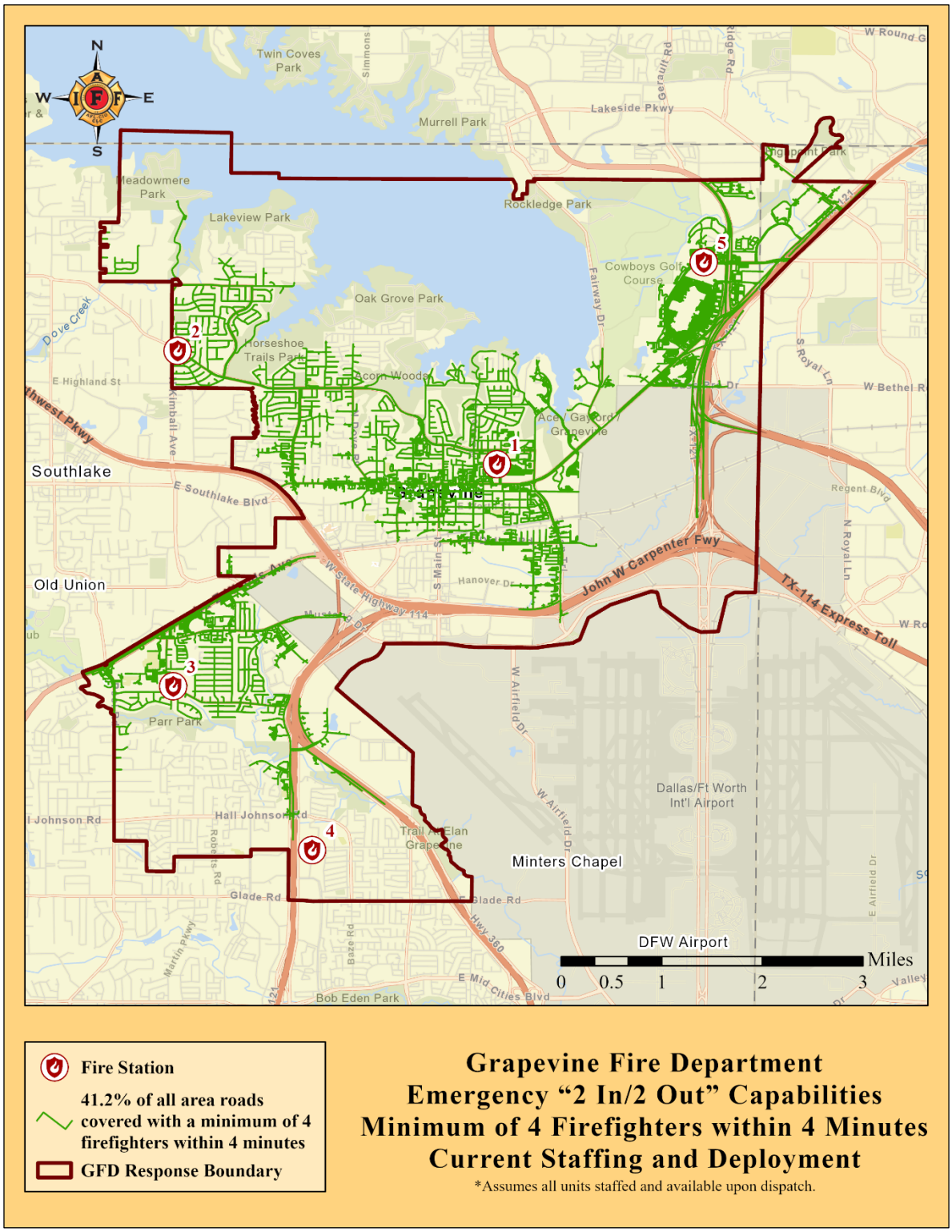
For this portion of the study, response capabilities were examined based on Grapevine Fire Department's current staffing and deployment. The following table specifies the locations of the fire stations and the units and staff deploying from the station.

Station #	Address	City	Apparatus	Staffing
1	701 Turner Rd	Grapevine	Truck 1 Engine 1 Dive 1 Battalion 1	**1 Captain, 3 Firefighters** **1 Captain, 2 Firefighters** Specialized Dive Response with Truck 1 personnel **1 Battalion Chief**
2	3091 Dove Rd	Grapevine	Engine 2 Medic 2 Marine 1 Marine 2 Marine 3	**1 Captain, 2 Firefighters** **2 Firefighter/Paramedics** Specialized Marine Response with Engine 2 personnel
3	3100 Timberline Dr	Grapevine	Engine 3 Medic 3	**1 Captain, 2 Firefighters** **2 Firefighter/Paramedics**
4	4500 Merlot Ave	Grapevine	Engine 4 Rescue 56	**1 Captain, 2 Firefighters** Specialized Rescue Response with Engine 4 personnel
5	2801 N. Grapevine Mills Blvd	Grapevine	Quint 5 Medic 5 Brush 5	**1 Captain, 2 Firefighters** **2 Firefighter/Paramedics** Specialized Wildland Response with Quint 5 personnel

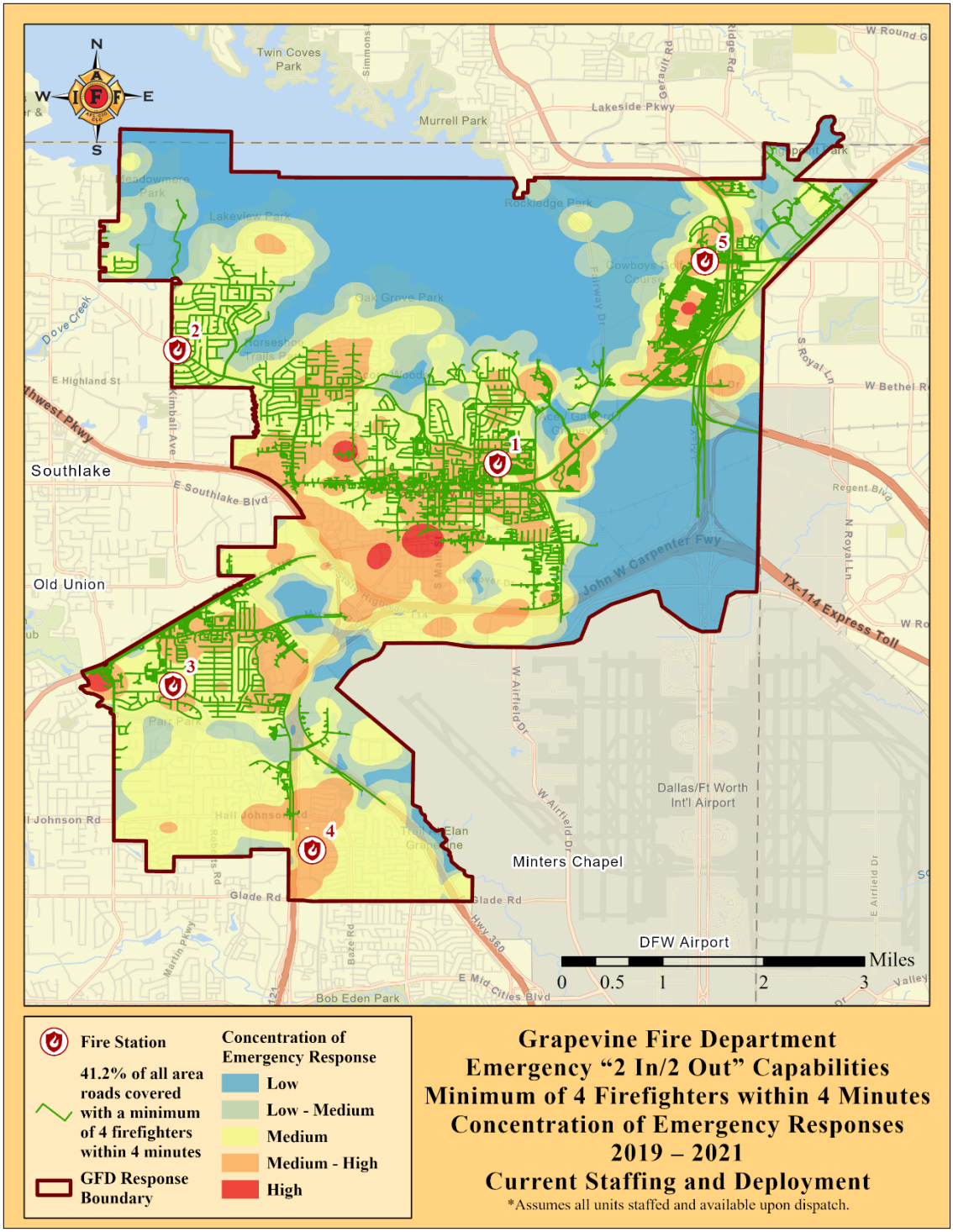
Table 7: Current Fire Station Locations and Staffing. This table displays where apparatus are housed and the current staffing levels for each unit.



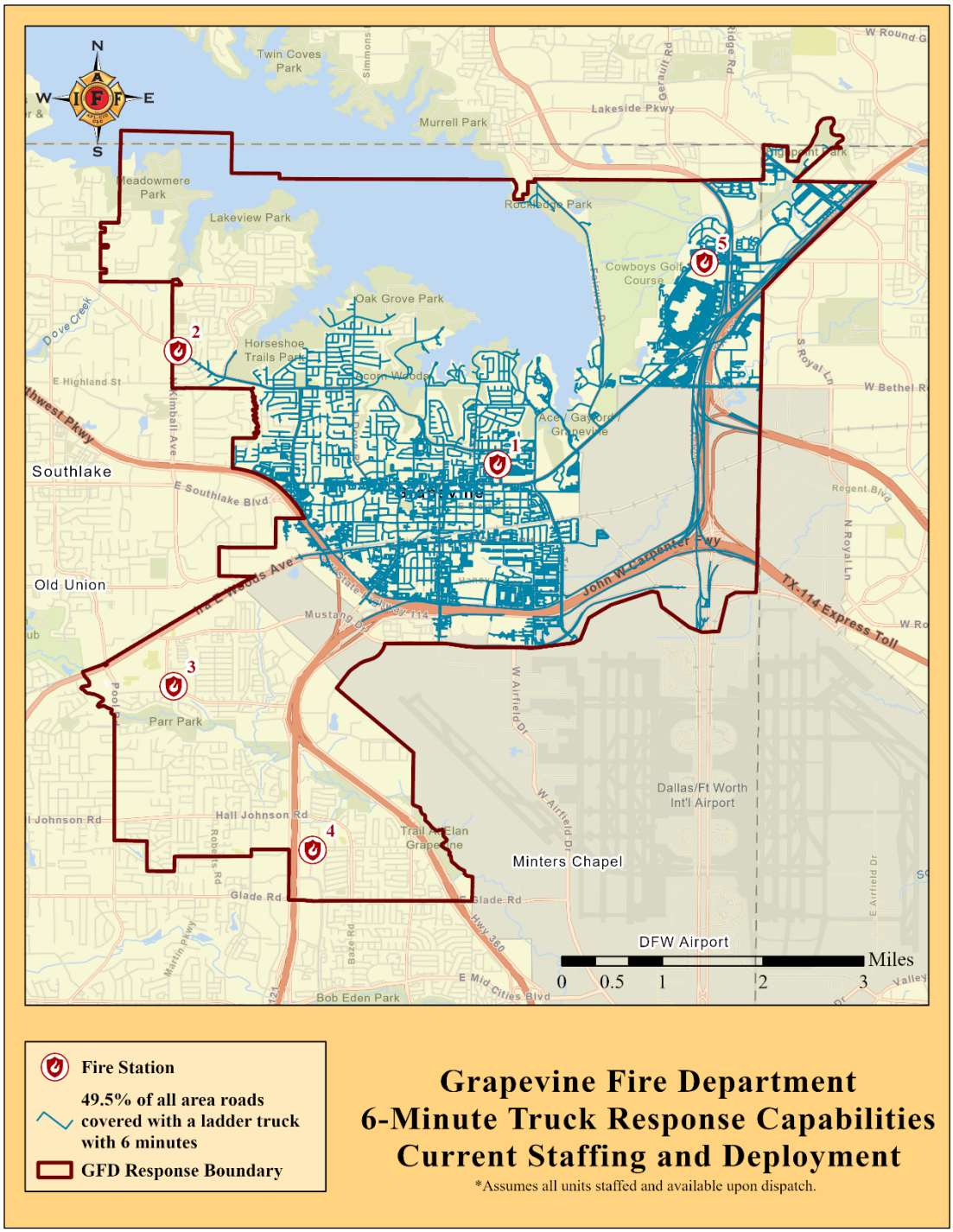
Map 8: 4-Minute Engine Response Capabilities, Current Staffing and Deployment. Map 8 identifies those roads where an engine company is capable of arriving on scene within four minutes of travel. NFPA 1710 requires the arrival of an engine company within four minutes of travel time. Currently, the Grapevine Fire Department is able to respond to 52.5% of roads within four minutes with an engine company.



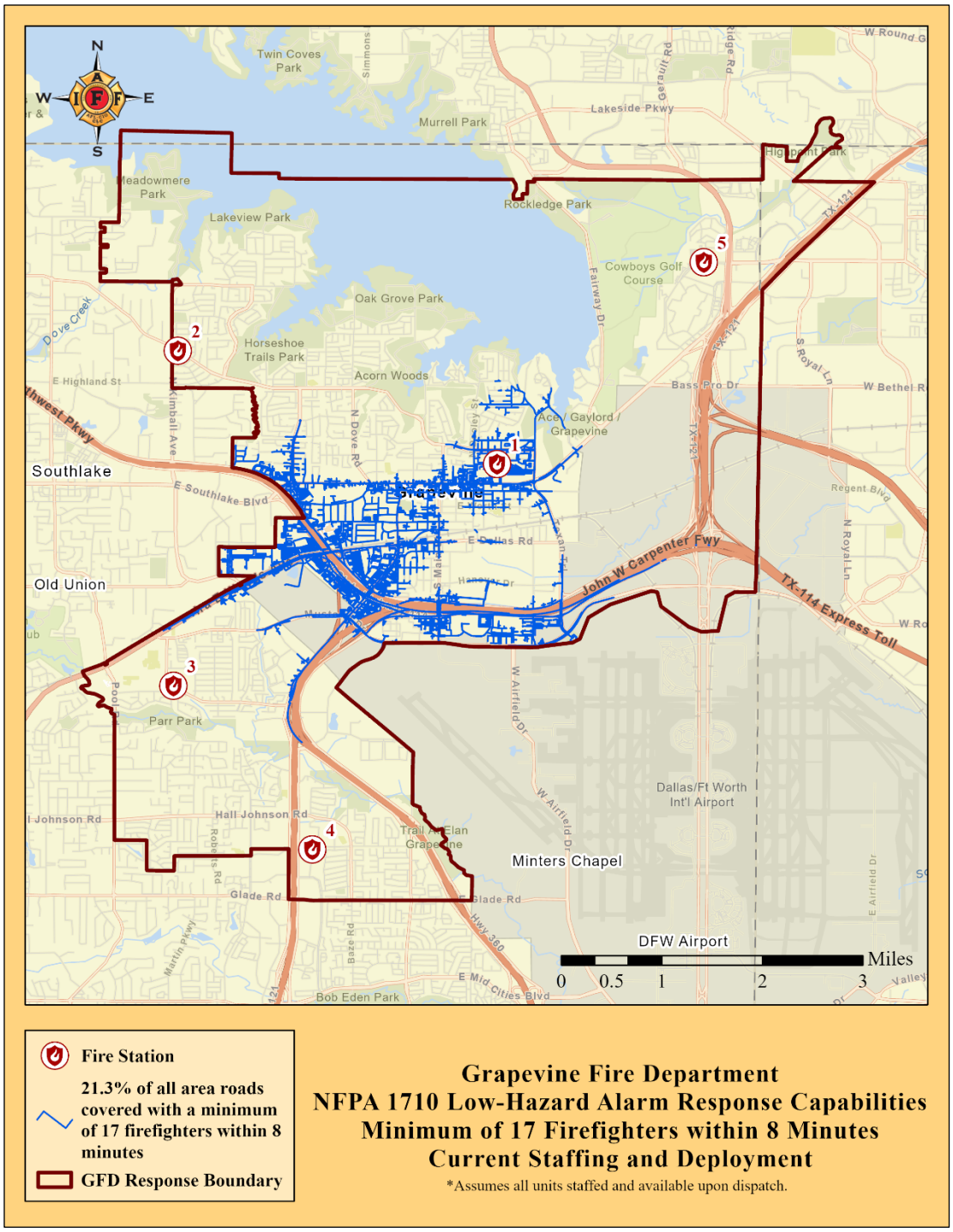
Map 9: Emergency "2 In/2 Out" Capabilities, Minimum of 4 Firefighters within 4 Minutes, Current Staffing and Deployment. Map 9 identifies those roads where a minimum of four firefighters can assemble on scene within four minutes of travel assuming all units are available and in station. Currently, the Grapevine Fire Department is capable of assembling at least four firefighters on 41.2% of roads within the response area within four minutes.



Map 10: Emergency "2 In/2 Out" Capabilities, Minimum of 4 Firefighters within 4 Minutes, Concentration of Emergency Responses, 2019 – 2021, Current Staffing and Deployment. Map 10 depicts the concentration of emergency incidents from 2019 through 2021 overlaid with the current "2 In/2 Out" response capabilities. Grapevine Fire Department can respond with a minimum of four firefighters within four minutes to 41.2% of area roads. There are areas outside of the four-minute response coverage with medium to high density response concentrations, including areas in south and central Grapevine. Those areas without coverage highlight the need to always staff fire apparatus in those places.



Map 11: 6-Minute Truck Response Capabilities, Current Staffing and Deployment. Map 11 identifies those roads where a truck company is capable of arriving on scene within six minutes of travel. NFPA 1710 requires the arrival of a second company within six minutes of travel time, but it does not specifically state a truck company. However, using the NIST Report on Residential Fireground Field Experiments as a model for response, the truck (ladder) company should not only arrive in close proximity to the first engine company but should also be the second company to arrive. Currently, the Grapevine Fire Department is able to respond to 49.5% of roads within six minutes with a truck company. Although Quint 5 perform ladder duties, this apparatus primarily perform engine responsibilities when first on scene, reducing truck response capabilities.



Map 12: NFPA 1710 Low-Hazard Alarm Response Capabilities, Minimum of 17 Firefighters within 8 Minutes, Current Staffing and Deployment. Map 12l identifies those roads where a minimum of 17 firefighters are able to assemble on scene within eight minutes of travel. Currently, the GFD is capable of assembling a minimum of 17 firefighters on 21.3% of roads within the response area within eight minutes. NFPA 1710 requires the arrival of 17 firefighters at a low-hazard structure fire[78] within eight minutes to 90% of incidents.[79]

[78] Low-hazard structures are typically two-story single-family dwellings without a basement and with no exposures.
[79] NFPA 1710 §5.2.4.1

Workload Analysis of the Grapevine Fire Department

To evaluate the department's workload, incident and response data were examined. Local 3113 provided CAD data for responses performed by the GFD from January 1, 2019 through December 31, 2021. The CAD data include, but are not limited to, details such as incident identifier number, type of incident, location of incident, responding apparatus, dispatch time, enroute time, arrival time, and the time when the apparatus and personnel have cleared the scene. The CAD data were analyzed to evaluate the department's workload metrics including the total number of incidents and unit responses, identify where incidents occurred in the past, and the 90th percentile travel time of the first unit on scene.

Using these findings, the department will be able to assess how workload, call volume, and deficiencies in staffing and apparatus utilization have affected their response capabilities. It will provide decision makers with the necessary information to better allocate resources to ensure GFD provides effective and efficient emergency response.

Data Notations

To accurately examine the department's workload and past performance the following should be noted:

- Analysis is based on the typical staffing configuration, Table 7 (pg. 53) from January 1, 2019 through December 31, 2021.

- Records with errors in reporting enroute time, arrival time, and/or incidents that were canceled before the first unit arrived on scene were excluded when evaluating travel times.[80]

The following set of definitions were used in the data analysis.

Incident: refers to an emergency to which individual or multiple department resources are dispatched to intervene and mitigate.

Response: refers to an individual unit, or units, being dispatched and traveling to the scene of an incident.

Dispatch Time: refers to the time when an assigned unit has been alerted to respond to an incident.

[80] 17.4% of responses were excluded due to errors in reporting times or the calls were canceled before resources arrived on scene.

Turnout Time: refers to the time interval between dispatch time to en route time of a unit.[81]

En Route Time: refers to the time when assigned units and personnel leave the current location travel to the incident location.

On-Scene Arrival Time: refers to the time when 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.[82]

Available Time: refers to the time when units and personnel complete all tasks at an incident and become available.

Response Time: refers to the interval of time between dispatch time and the on-scene arrival time of a unit.

Incident Duration: refers to the interval of time between dispatch time and the available time of a unit.

90th Percentile: In statistics, percentile is defined as the value below which a given percentage of observations fall. For example, the 90th percentile of the travel time is the value below which 90% of the travel times fall.

Call Volume Analysis

An important metric to consider is the number of incidents compared to the number of apparatus responses. Each incident can require more than one apparatus to respond. Responses are labor intensive and frequently require personnel from multiple apparatus to complete critical tasks simultaneously. Examining the number of responses performed by each apparatus will assist in determining the workload of each unit.

From 2019 to 2021, GFD's units responded to 18,912 incidents and performed 40,527 responses. Typically, incidents require more than one apparatus to respond. From 2019 to 2021, total incidents increased 7.0%; this number is expected to increase with increased building development and population growth. Additional resources should be positioned at fire stations that have a high frequency of responses to incidents to ensure equitable, timely, safe, and effective responses**.**

[81] NFPA 1710 §3.3.64.8 (2020)
[82] NFPA 1710 §3.3.64.7 (2020)

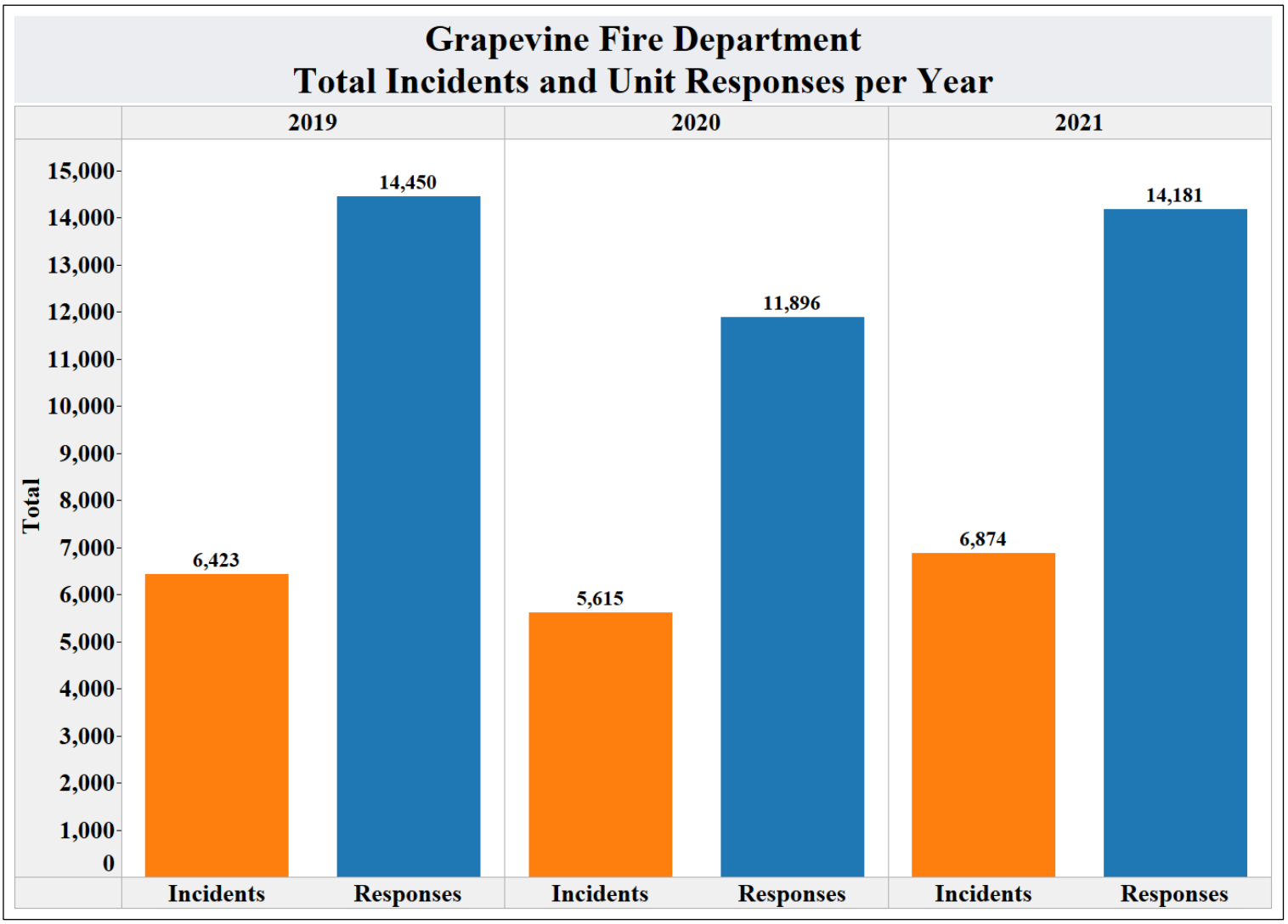


Chart 3: Total Incidents and Unit Responses per Year. This chart shows the number of incidents and unit responses made by the Grapevine Fire Department each year. The department's incident total has grown, with a 7% increase of incidents from 2019 to 2021. Increases in incident totals in conjunction with projected building demand increase demonstrates the need for an increase in fire department resources.

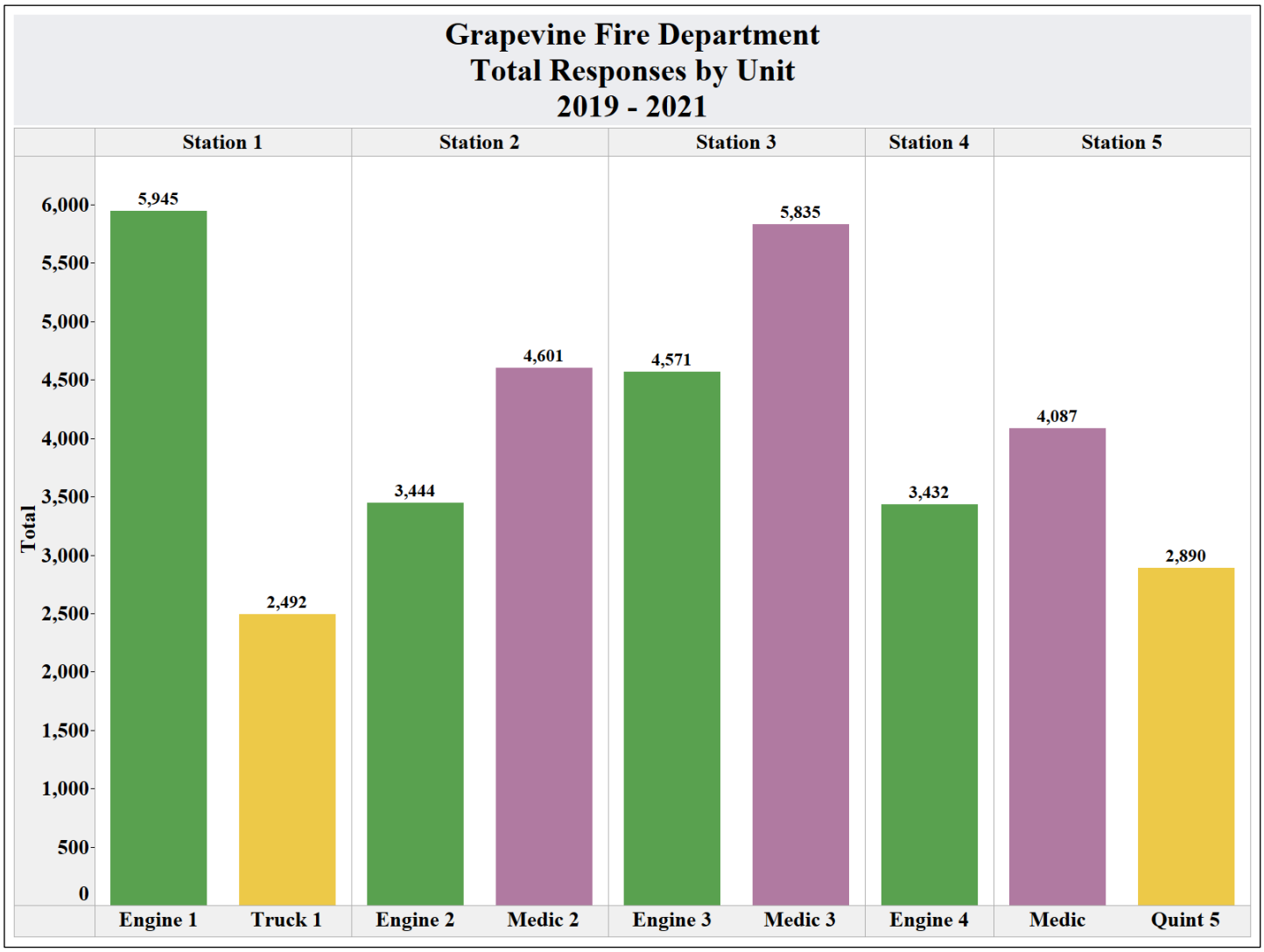


Chart 4: Total Responses per Unit: 2019 – 2021. Chart 4 depicts the number of responses by staffed fire apparatus and medic units from 2019 through 2021. Engine 1 at Station 1 made the most responses for the Grapevine Fire Department from 2019 through 2021. Apparatus from Station 4 are not staffed with four firefighters and when responding to fire incidents must wait for seconds arriving unit before starting interior structure fire operations. An additional medic unit at Station 4 would reduce the reliance on Medic 3 at Station 4, to respond to incidents in Station 4's district. Medic 3 responded to the most incidents from 2019 through 2021.

Travel Time Analysis

The travel time analysis examined the en route and arrival on scene times included in the CAD data to calculate the travel times for apparatus responding to incidents. NFPA 1710 requires a travel time of four minutes (240 seconds) or less for the first-arriving engine company at the scene of fire incidents and for the first-arriving EMS company with basic life support (BLS) capability or higher at the scene of EMS incidents for at least 90% of the incidents. Travel times that are consistently higher than these benchmarks pose a risk to the community and suggest that the department needs additional resources. The department did not meet NFPA 1710 travel time objectives for EMS and fire incidents. Between 2019 and 2021, GFD exceeded the NFPA objective each year with travel times of the first responding unit from each station.

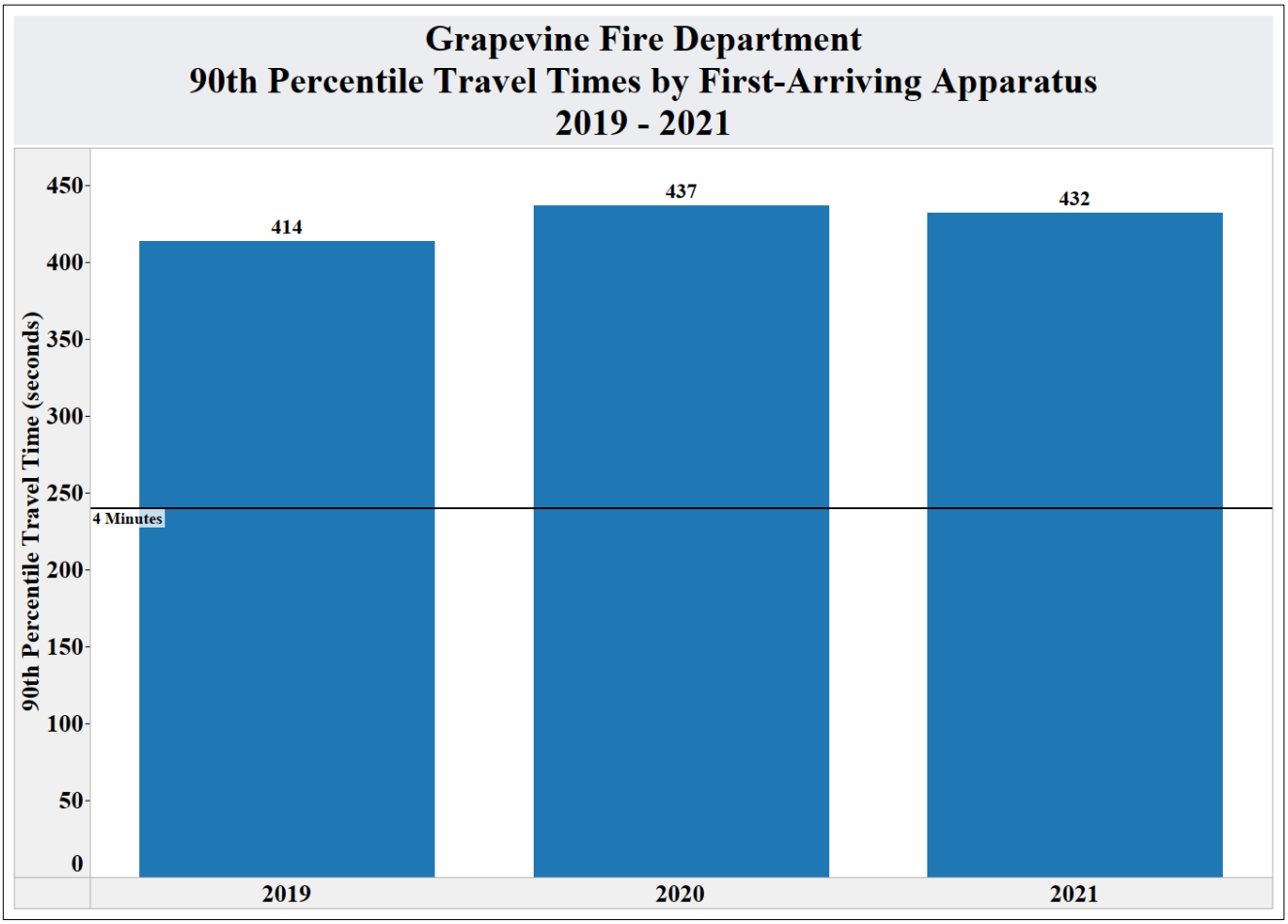


Chart 5: 90th Percentile Travel Times for First-Arriving Apparatus by Station, 2019 - 2021. This chart shows the department's 90th percentile travel times for the first-arriving unit by year from each fire station. The NFPA 1710 standard requires a 90th percentile travel time of not more than 240 seconds. The department's 90th percentile travel times increased from 2019 to 2021 and were above seven minutes (over 420 seconds) in 2020 and 2021. As incidents increase beyond the department's four-minute response capabilities, travel times to incidents will most likely increase. Additionally understaffed apparatus must wait for additional units arrive before beginning interior fire suppression tasks as outlined by NFPA objectives.

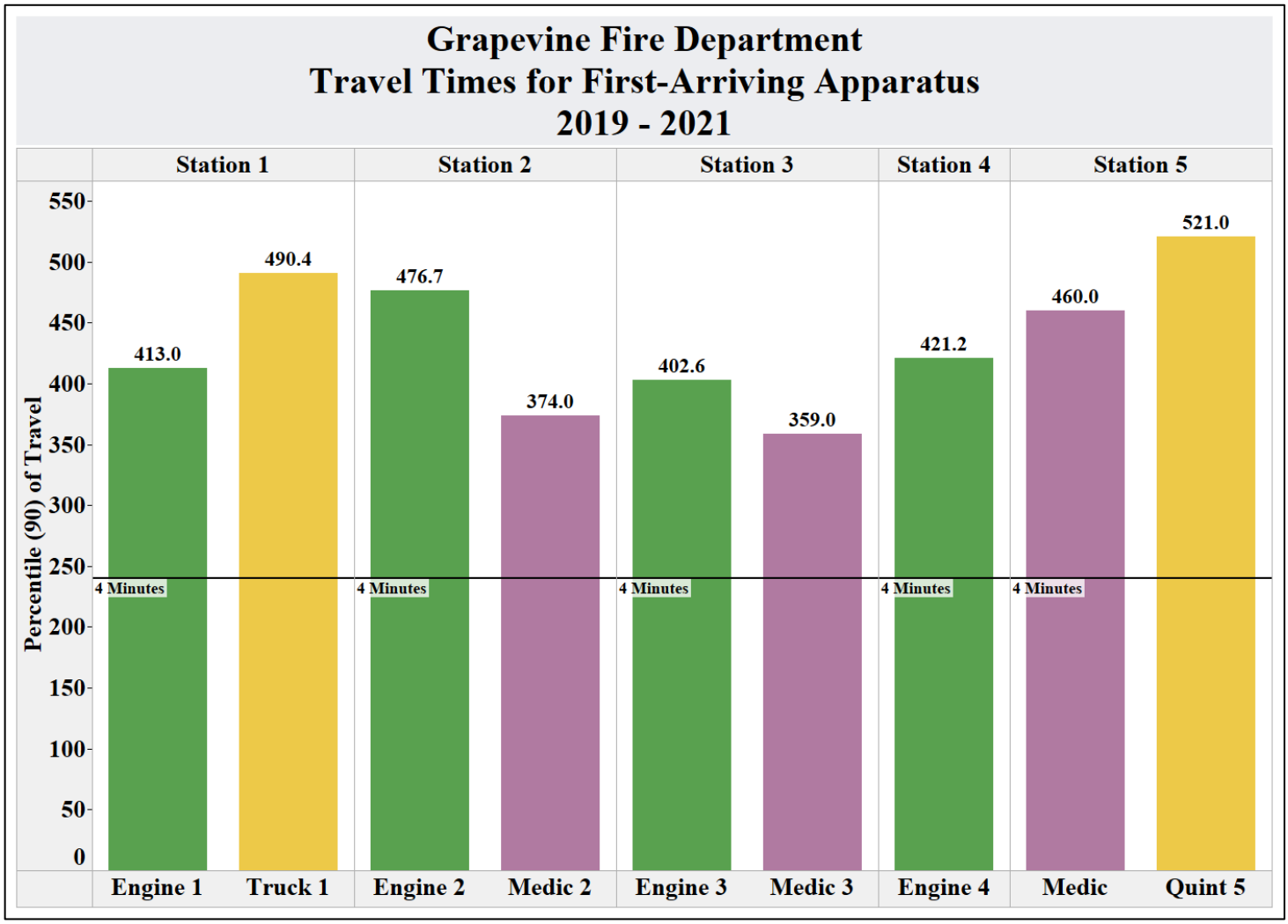


Chart 6: 90th Percentile Travel Times for First-Arriving Apparatus, 2019-2021. This chart shows the 90th percentile travel times for the first-arriving apparatus or medic units from 2019 to 2021. All staffed units had 90th percentile travel times over the NFPA standard (240 seconds). As apparatus respond to incidents further away from current station locations, travel times increase. Travel times that are consistently higher than this benchmark suggest that the department may need additional resources closer to areas with high demand.

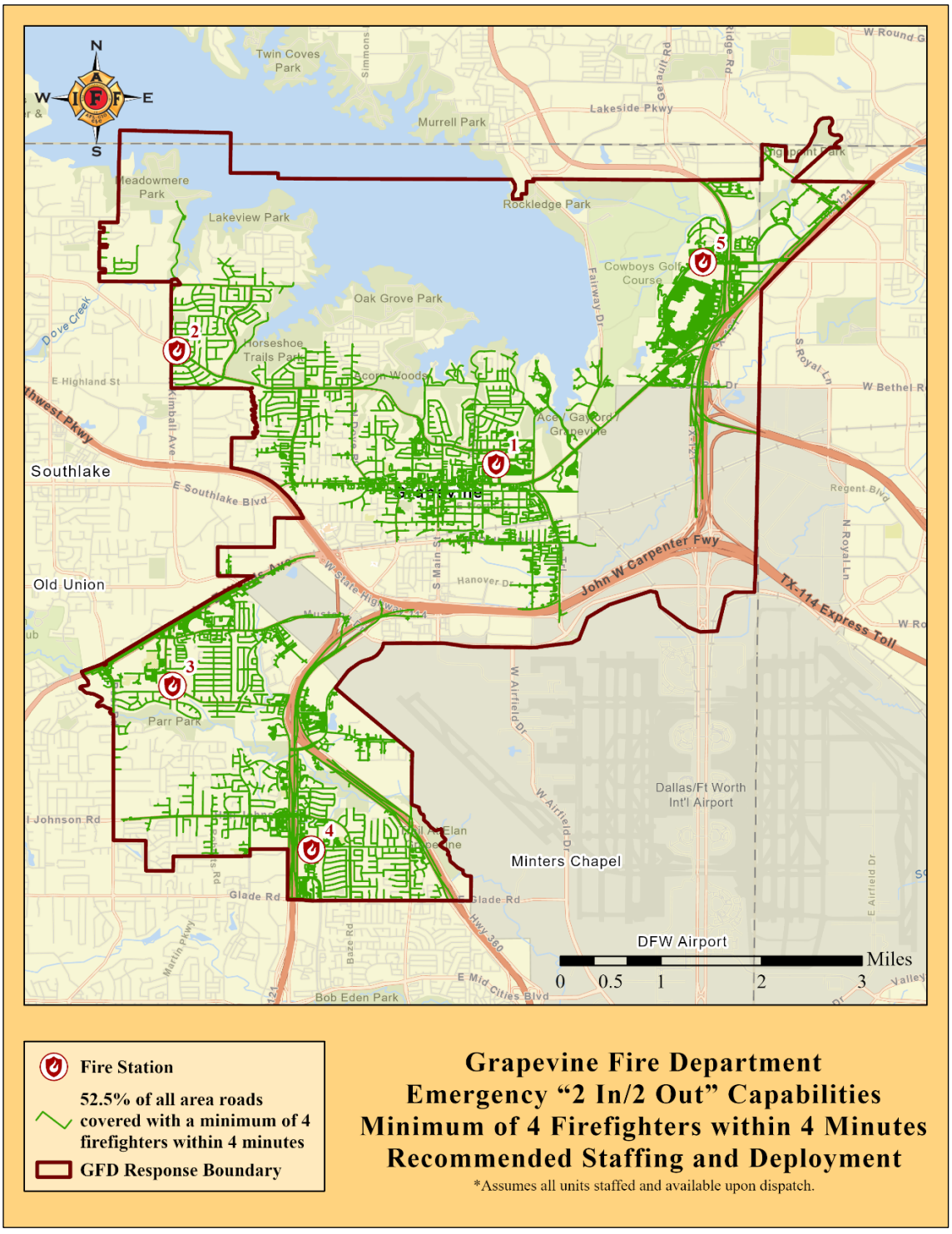
Emergency Response Capabilities - Recommended Staffing and Deployment

Increased staffing and apparatus will bring the Grapevine Fire Department closer to meeting industry standard performance objectives and allow for safer and more effective firefighting operations. In this portion of the study, a staffing and deployment scenario was examined where all fire companies are staffed with four firefighters[83]. This portion also include the addition of Medic 4, at Station 4, staffed with two firefighter/paramedics at all times. In this scenario, typical on-duty staffing would *increase* by 7 firefighters. The following table specifies the locations of fire stations and the recommended units and staff deploying from those stations.

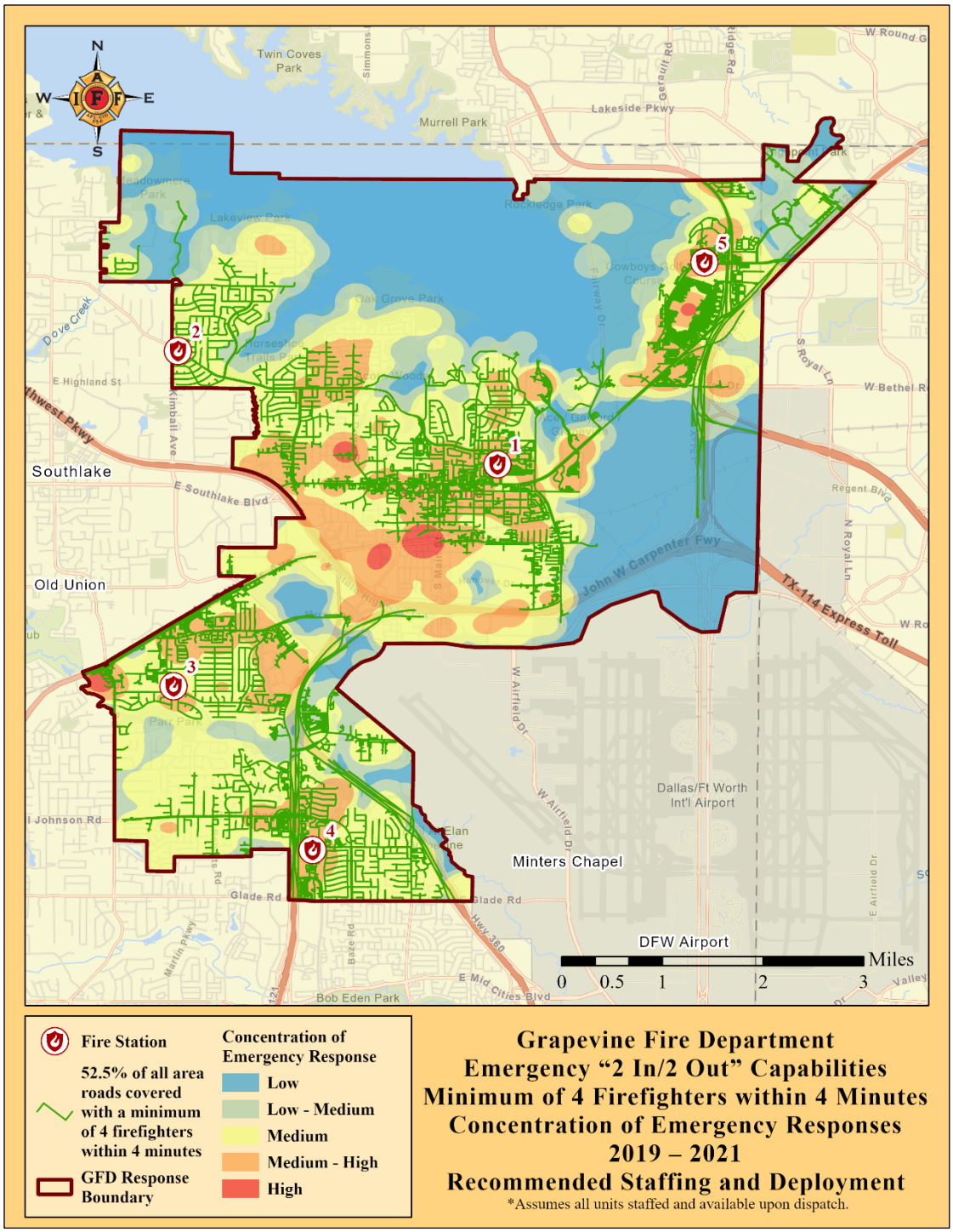
Station #	Address	City	Apparatus	Staffing
1	701 Turner Rd	Grapevine	Truck 1 Engine 1 Dive 1 Battalion 1	**1 Captain, 3 Firefighters** **1 Captain, 3 Firefighters** Specialized Dive Response with Truck 1 personnel **1 Battalion Chief**
2	3091 Dove Rd	Grapevine	Engine 2 Medic 2 Marine 1 Marine 2 Marine 3	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics** Specialized Marine Response with Engine 2 personnel
3	3100 Timberline Dr	Grapevine	Engine 3 Medic 3	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics**
4	4500 Merlot Ave	Grapevine	Engine 4 Medic 4 Rescue 56	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics** Specialized Rescue Response with Engine 4 personnel
5	2801 N. Grapevine Mills Blvd	Grapevine	Quint 5 Medic 5 Brush 5	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics** Specialized Wildland Response with Quint 5 personnel

Table 8: Recommended Fire Station Locations and Staffing. The above table displays where apparatus would be housed and the recommended minimum on-duty career firefighter staffing. Staffing modifications are highlighted in yellow.

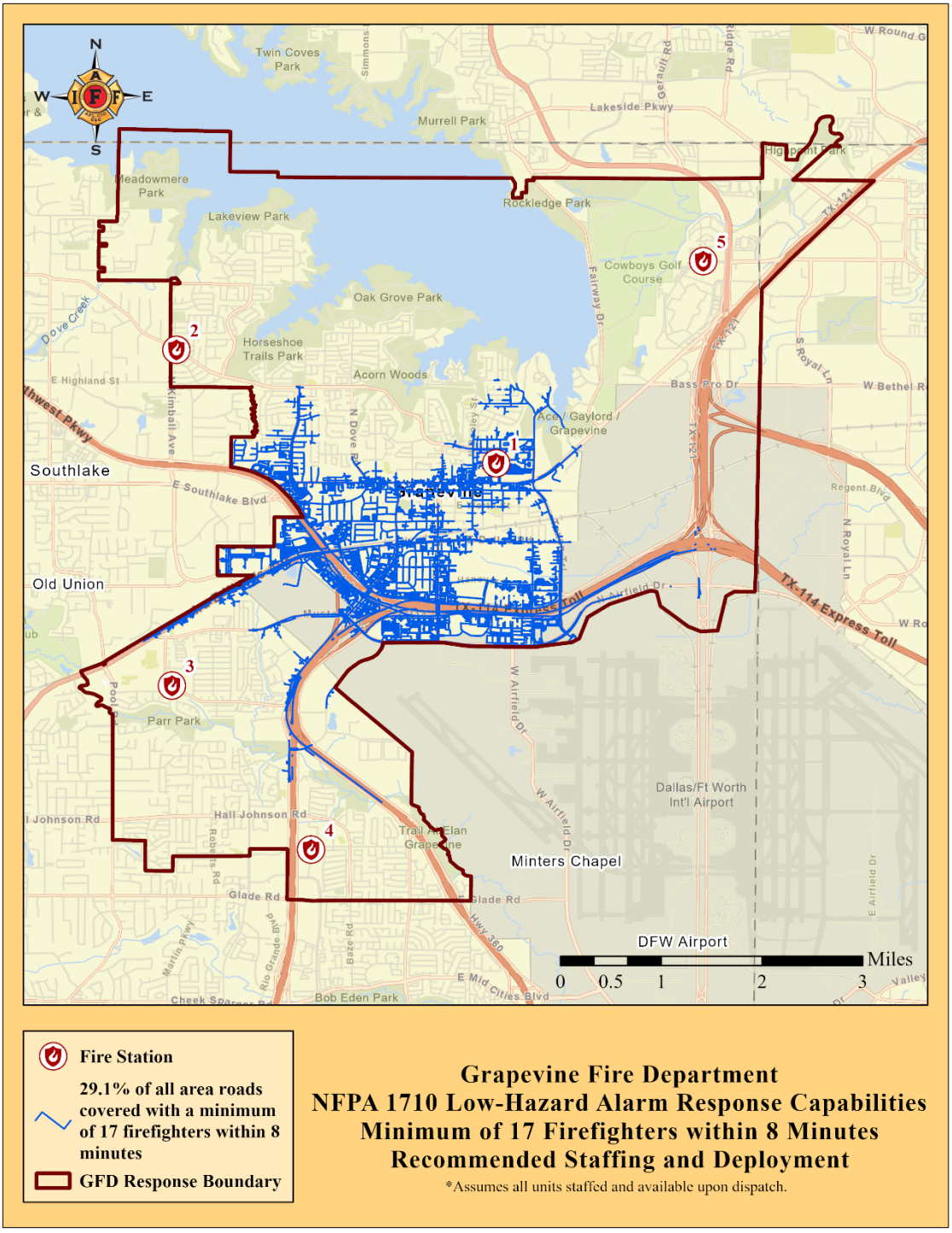
[83] NFPA 1710, § 5.2.3.1 and §5.2.3.1.1



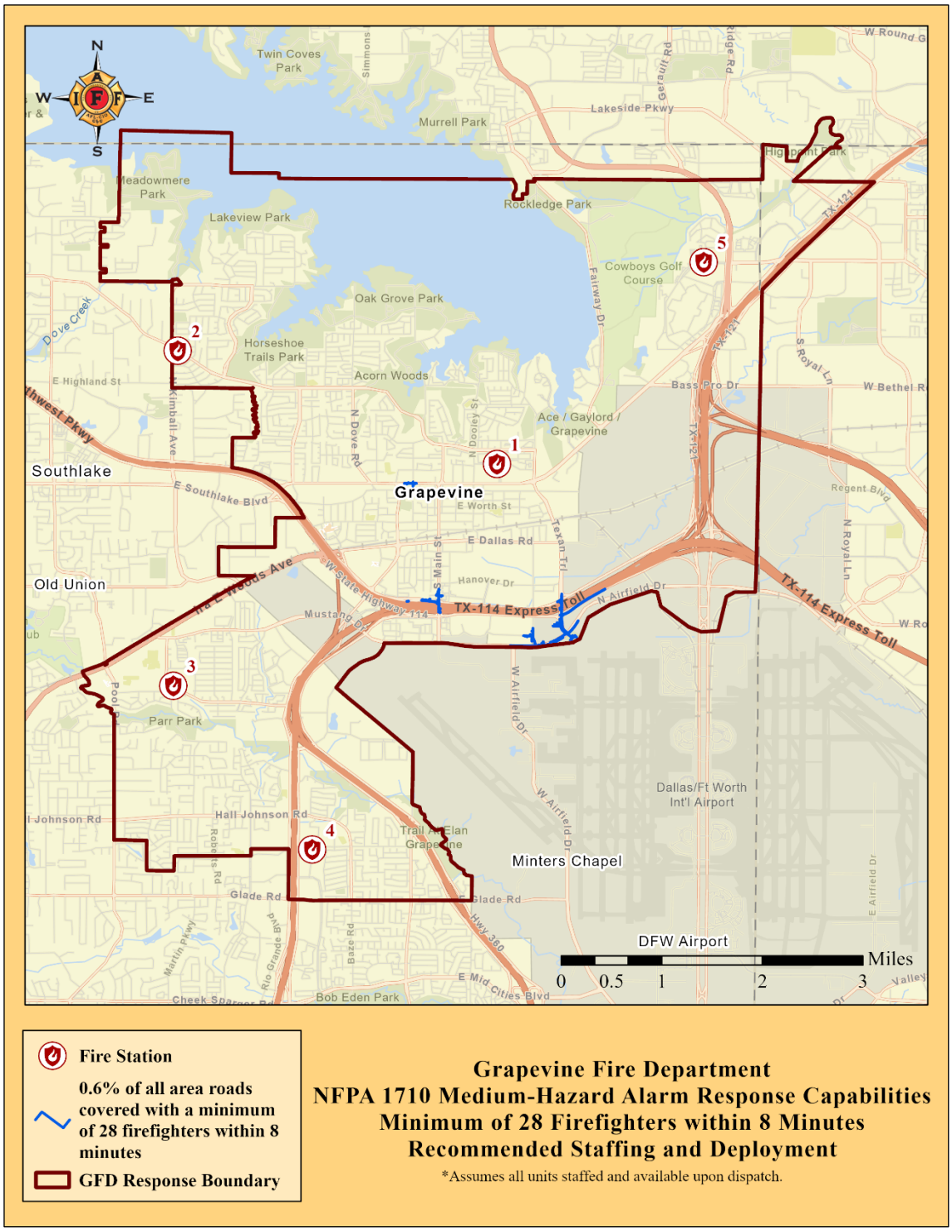
Map 13: Emergency "2 In/2 Out" Capabilities, Minimum of 4 Firefighters within 4 Minutes, Recommended Staffing and Deployment. Map 13 identifies those roads where fire apparatus will likely be able to reach within four minutes and establish a minimum of four personnel on scene. Pursuant to implementing the recommended staffing, the Grapevine Fire Department will likely be capable of assembling at least four firefighters on 52.5% of roads within the department's response area within four minutes. This translates to an 27.4% ***increase*** in response capabilities above current conditions, which would include more areas near Station 4.



Map 14: Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes, Concentration of Emergency Responses 2019 - 2021, Recommended Staffing and Deployment. Map 14 depicts the concentration of emergency responses from 2019 through 2021 overlaid with "2 In/2 Out" response capabilities pursuant to implementing the recommended staffing. The department would likely be able to respond with a minimum of four firefighters within four minutes to 52.5% of area roads. Response coverage would include southern portions of Grapevine with medium to high concentrations of response demand currently outside the department's initial four-minute response capabilities.



Map 15: NFPA 1710 Low-Hazard Alarm Response, Minimum of 17 Firefighters within 8 Minutes, Recommended Staffing and Deployment. Map 15 identifies those roads where a minimum of 17 firefighters will likely have the ability to assemble on scene within eight minutes of travel. Pursuant to implementing the recommended staffing, fire companies will likely be capable of assembling a minimum of 17 firefighters on 29.1% of roads within the department's response area within eight minutes assuming all fire apparatus and squad units are staffed, in station, and available to respond immediately upon dispatch. This translates to an 36.2% **increase** in response capabilities above current conditions.



Map 16: NFPA 1710 Medium-Hazard Alarm Response Capabilities, Minimum of 28 Firefighters within 8 Minutes, Recommended Staffing and Deployment. Map 16 identifies those roads where a minimum of 28 firefighters will likely be able to assemble on scene within eight minutes of travel. Pursuant to implementing the recommended staffing, the Grapevine Fire Department will likely be capable of assembling a minimum of 28 firefighters on 0.6% of roads within the department's response area within eight minutes. Currently, the Grapevine Fire Department **cannot** provide the assembly of 28 firefighters on any area roads within eight minutes.

Location-Allocation Analysis: Additional Station

At the request of Local 3113, GIS analysis was performed to determine the optimal station location of an additional that, along with the department's current stations, would maximize response coverage. ArcGIS's Location-Allocation tool within the Network Analyst toolset generates optimal sites to locate a station or stations. The Location-Allocation[84] tool can present multiple resource scenarios in an objective manner, thus providing decision makers with the flexibility to choose the best deployment options for their municipality. Depending on the factors input into the Location-Allocation tool, different optimal locations for stations will be output. For example, entering travel times of four or eight minutes may result in different station locations. Location-allocation is a process that helps decision makers answer questions; however, it does not *completely* answer the question. The software outputs a recommendation of a location or locations based on time requirements and demand points. Other factors may play a role in final station location that go beyond this analysis such as frequency of simultaneous calls for service, available space for apparatus in fire stations, and land availability. It is also important to note that as population increases, it is likely that demand for emergency services will also increase.

Location-Allocation Methodology

The Location-Allocation tool uses demand points as features that are allocated to each individual fire station. It utilizes the desired number of fire stations to determine the optimal locations that enable the department to cover the most demand points within a defined time parameter. The demand points used for the location-allocation analysis were incident location data from January 1, 2019 through December 31, 2021, and road network data (street points) within the Grapevine Fire Department's response boundary.

The variables representing demand were used as described here:

1) CAD data from January 1, 2019 through December 31, 2021: This variable accounts for the coverage of actual incidents.

2) Road network data (street points): This variable accounts for the coverage of roads. Road network points consider recently developed areas when identifying the optimal location for fire stations. Recently developed areas most likely have not experienced a high volume of incidents in the past. By using street points, these areas will be considered as areas that may need a fire station.

[84] Refers to algorithms used primarily in a geographic information system to determine an optimal location for one or more facilities that will service demand from a set of fire station locations.

Using these two variables, the Location-Allocation tool calculates where fire stations should be located to ensure the department can arrive on scene to the greatest amount of demand points within four minutes of travel, assuming all units are available to respond immediately upon dispatch.

Maximize Coverage

Maximize Coverage,[85] a method within the Location-Allocation tool, is frequently used to locate fire stations because emergency services are required to arrive at all demand points within a specified travel time. Maximize coverage identifies the best location for a fire station based on its ability to deploy apparatus to arrive at the most demand points. Note that it is important for all organizations, and critical for emergency services, to have accurate and precise data so that analysis results correctly model real-world results.

The following list describes how the Maximize Coverage tool handles demand:

- Any demand point outside all facilities' (fire station) impedance cutoffs (travel time) is not allocated to any facility (fire station).

- A demand point inside the impedance cutoff (travel time) of one facility (fire station) has all its demand weight allocated to that facility (fire station).

- A demand point inside the impedance cutoff (travel time) of two or more facilities (fire stations) has all its demand weight allocated to the nearest facility (fire station) only.

[85] https://pro.arcgis.com/en/pro-app/tool-reference/ready-to-use/itemdesc-solvelocationallocation.htm

Emergency Response Capabilities - Recommended Staffing and Deployment with Additional Station

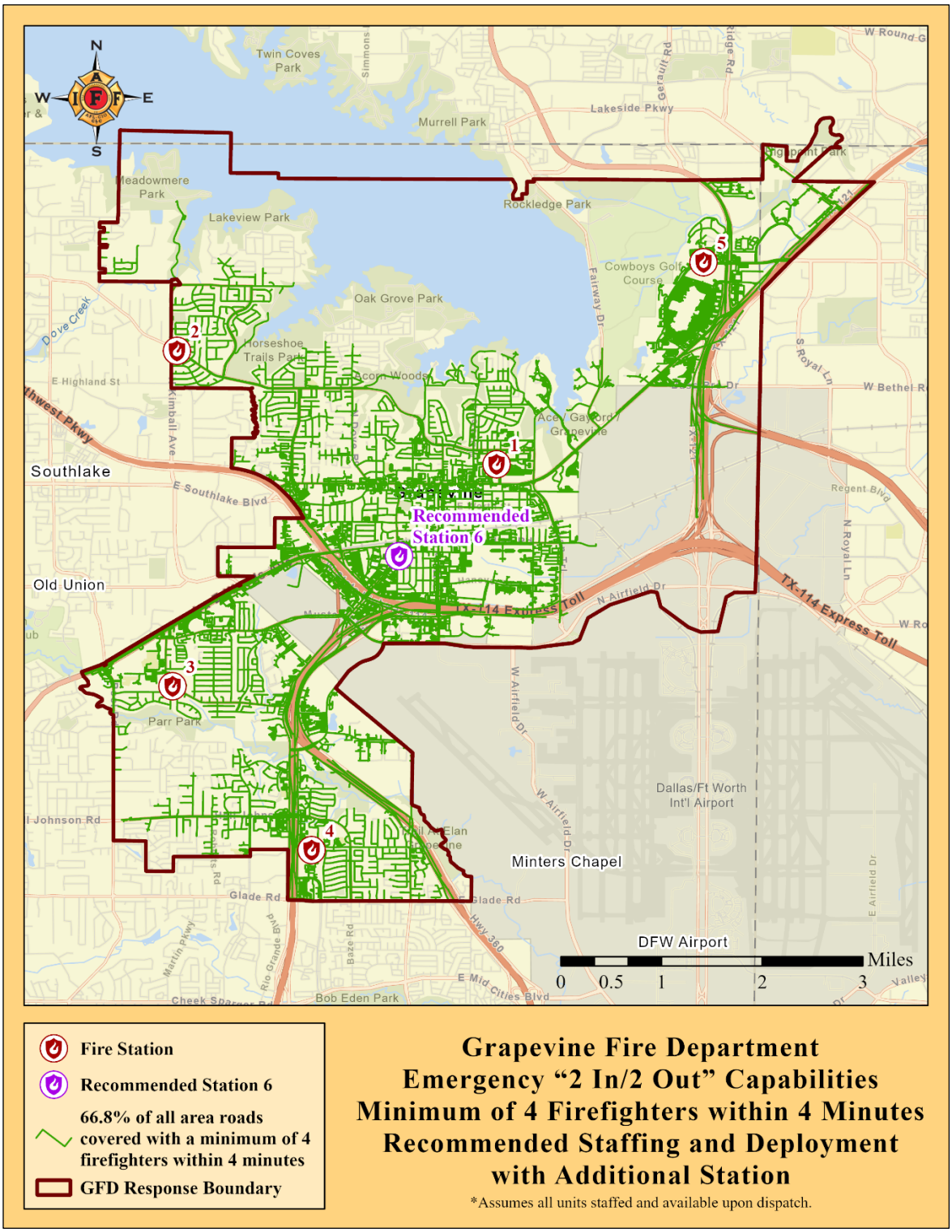
This portion of the study will include previously examined recommendations along with long-term recommendation. This scenario includes all fire companies are staffed with four firefighters[86] and medic units are staffed with two firefighters at all times.

Increased staffing and an additional station will enhance the Grapevine Fire Department's ability to meet increasing demand while also bringing them far more closer industry standard performance objectives and allowing for safer and more effective firefighting operations. Long-term recommendations include an additional station, Station 6, housing an engine company near/at the intersection of *William D Tate Avenue and W Nash Street*, as determined by the location-allocation analysis. The following table specifies the locations of fire stations and the recommended units and staff deploying from those stations.

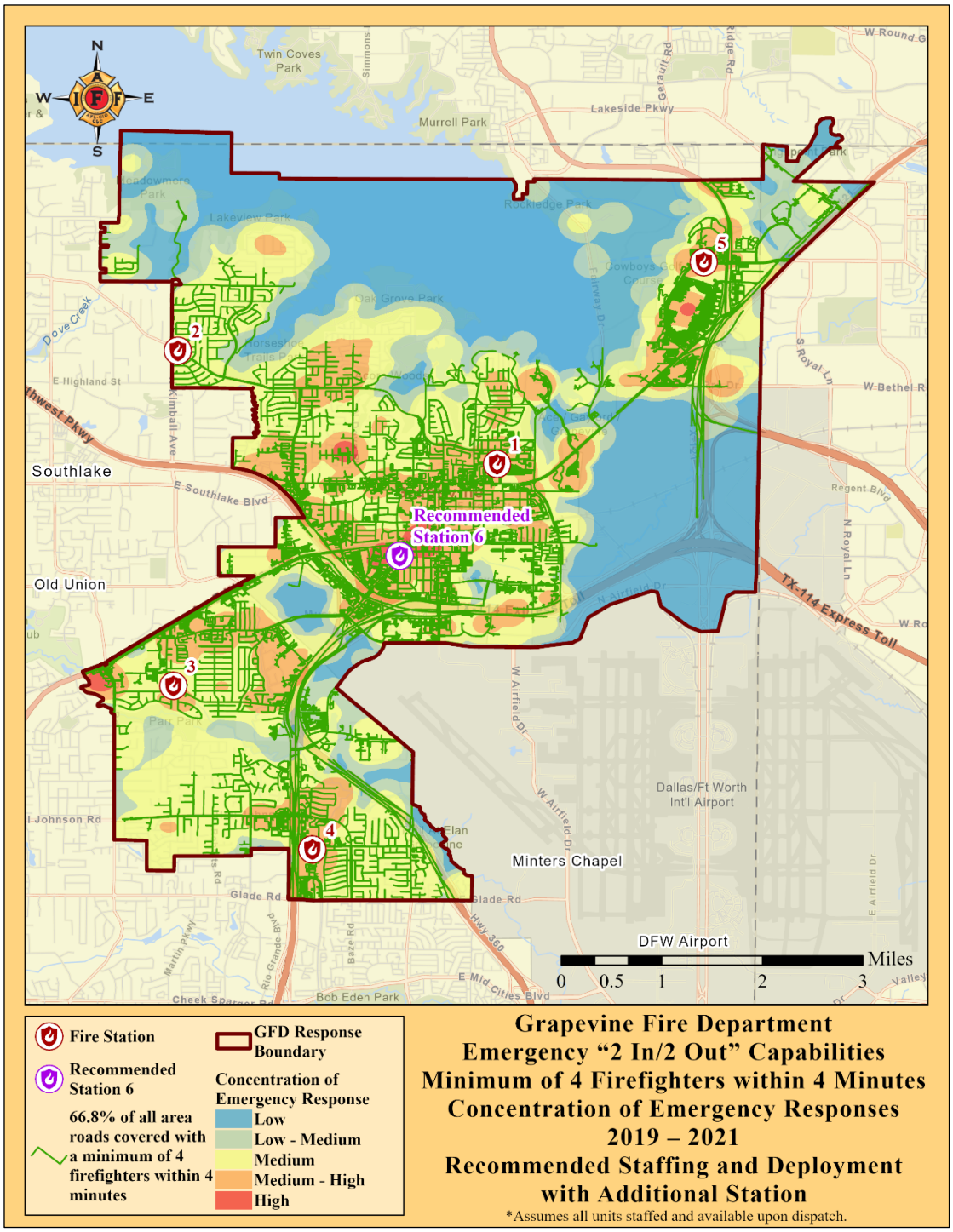
[86] 87 NFPA 1710, § 5.2.3.1 and §5.2.3.1.1

Station #	Address	City	Apparatus	Staffing
1	701 Turner Rd	Grapevine	Truck 1 Engine 1 Dive 1 Battalion 1	**1 Captain, 3 Firefighters** **1 Captain, 3 Firefighters** Specialized Dive Response with Truck 1 personnel **1 Battalion Chief**
2	3091 Dove Rd	Grapevine	Engine 2 Medic 2 Marine 1 Marine 2 Marine 3	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics** Specialized Marine Response with Engine 2 personnel
3	3100 Timberline Dr	Grapevine	Engine 3 Medic 3	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics**
4	4500 Merlot Ave	Grapevine	Engine 4 Medic 4 Rescue 56	**1 Captain, 3 Firefighters** **2 Firefighters/Paramedics** Specialized Rescue Response with Engine 4 personnel
5	2801 N. Grapevine Mills Blvd	Grapevine	Quint 5 Medic 5 Brush 5	**1 Captain, 3 Firefighters** **2 Firefighter/Paramedics** Specialized Wildland Response with Quint 5 personnel
6	*William D Tate Avenue and W Nash Street*	Grapevine	Engine 6	**1 Captain, 3 Firefighters**

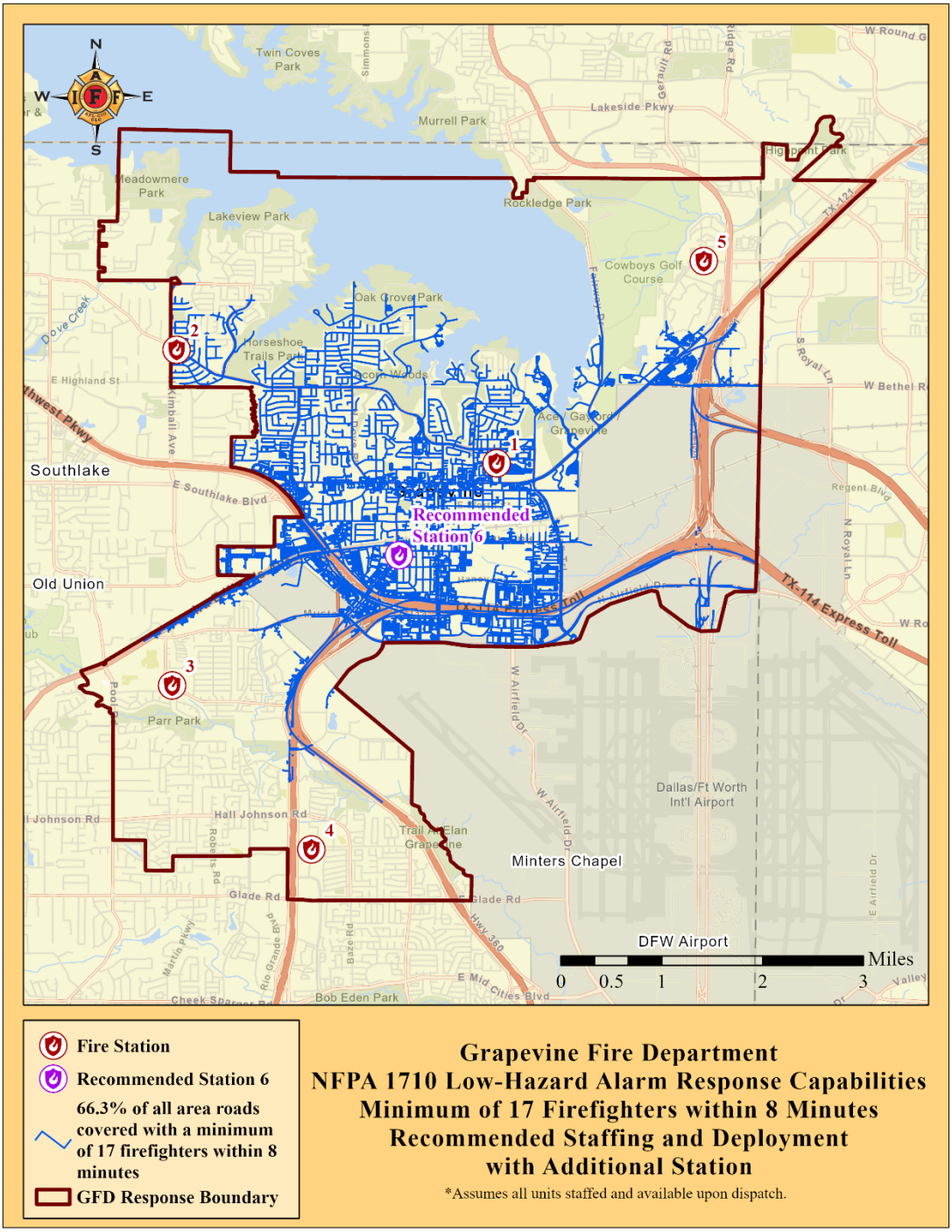
Table 9: Long-Term Recommended Fire Station Locations and Staffing. The above table displays where apparatus would be housed and the recommended minimum on-duty career firefighter staffing. Staffing modifications are highlighted in yellow.



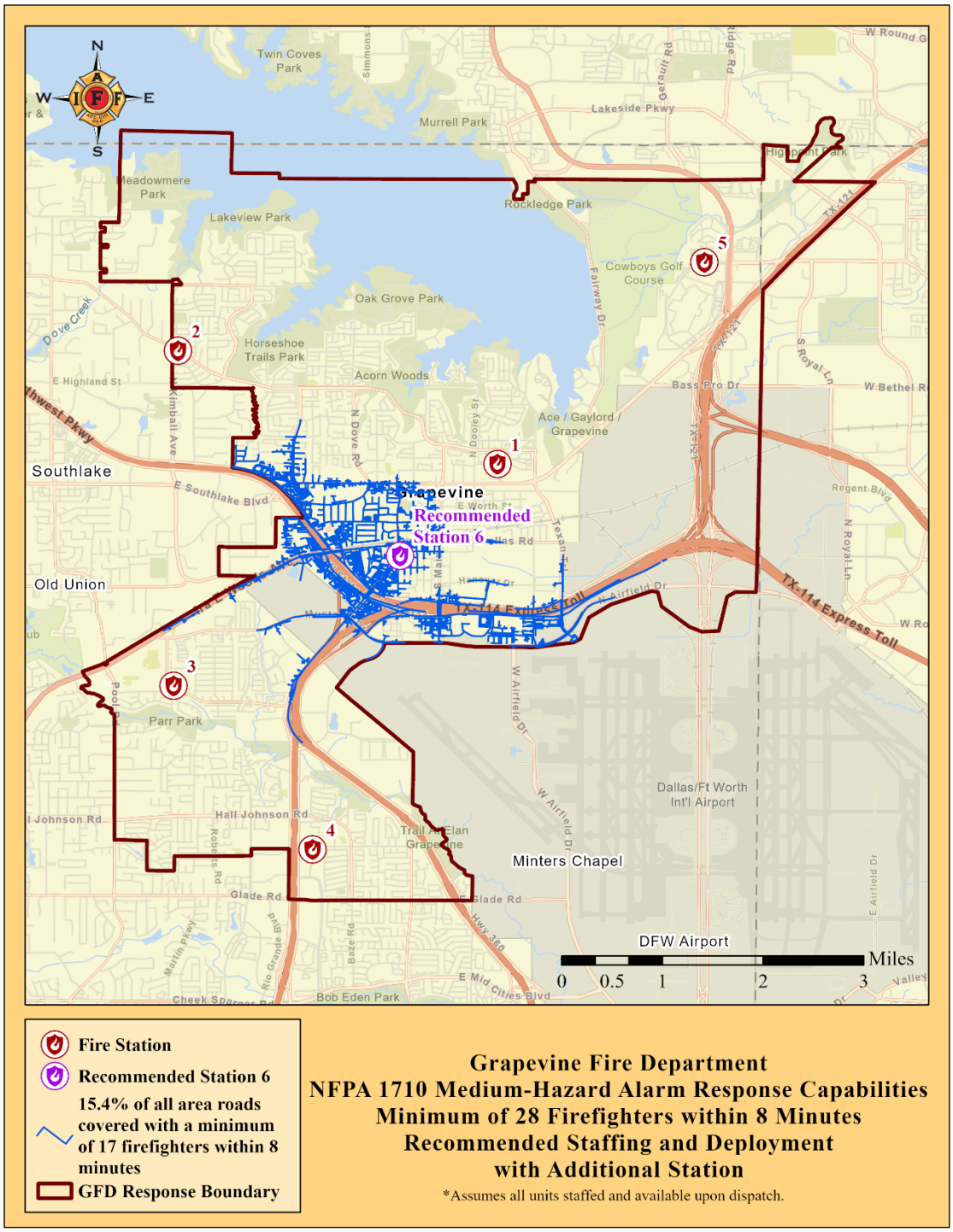
Map 17: Emergency "2 In/2 Out" Capabilities, Minimum of 4 Firefighters within 4 Minutes, Recommended Staffing and Deployment with Additional Station. Map 17 identifies those roads where fire apparatus will likely be able to reach within four minutes and establish a minimum of four personnel on scene. Pursuant to implementing the recommended staffing and additional Station 6, the Grapevine Fire Department will likely be capable of assembling at least four firefighters on 66.8% of roads within the department's response area within four minutes.



Map 18: Emergency "2 In/2 Out" Operations, Minimum of 4 Firefighters within 4 Minutes, Concentration of Emergency Responses 2019 - 2021, Recommended Staffing and Deployment with Additional Station. Map 18 depicts the concentration of emergency responses from 2019 through 2021 overlaid with "2 In/2 Out" response capabilities pursuant to implementing the recommended staffing and additional Station 6. The department would likely be able to respond with a minimum of four firefighters within four minutes to 66.8% of area roads. Response coverage would include southern and central portions of Grapevine with high concentrations of response demand currently outside the department's initial four-minute response capabilities.



Map 19: NFPA 1710 Low-Hazard Alarm Response, Minimum of 17 Firefighters within 8 Minutes, Recommended Staffing and Deployment with Additional Station. Map 19 identifies those roads where a minimum of 17 firefighters will likely have the ability to assemble on scene within eight minutes of travel. Pursuant to implementing the recommended staffing and additional Station 6, fire companies will likely be capable of assembling a minimum of 17 firefighters on 66.3% of roads within the department's response area within eight minutes assuming all fire apparatus and squad units are staffed, in station, and available to respond immediately upon dispatch. This translates to an 210.8% **increase** in response capabilities above current conditions.



Map 20: NFPA 1710 Medium-Hazard Alarm Response Capabilities, Minimum of 28 Firefighters within 8 Minutes, Recommended Staffing and Deployment with Additional Station. Map 20 identifies those roads where a minimum of 28 firefighters will likely be able to assemble on scene within eight minutes of travel. Pursuant to implementing the recommended staffing and additional Station 6, the Grapevine Fire Department will likely be capable of assembling a minimum of 28 firefighters on 15.4% of roads within the department's response area within eight minutes. Currently, the Grapevine Fire Department **cannot** provide the assembly of 28 firefighters on any area roads within eight minutes.

Conclusion

In conclusion, regardless of the type of response, fire suppression units are not always staffed in compliance with industry standards for safe, efficient, and effective response to fires or rescue situations. When suppression units are not staffed with a minimum of four firefighters, they do not meet the company staffing objectives outlined in NFPA 1500 and NFPA 1710. Additionally, Grapevine Fire Department's current response capabilities do not meet travel time objectives included in the industry standard NFPA 1710, which directs the first unit staffed with a minimum of four firefighters to arrive on scene within four minutes of travel, the second unit to arrive on scene within six minutes, and the assembly of 17 firefighters at a low-hazard structure fire within eight minutes for 90% of incidents.

GIS analysis modeled where the lack of resources affects the department's current response coverage capabilities. Call data was also examined to identify the need for more staffing using metrics including the increasing travel time of the first-arriving apparatus from 2019 to 2021. Many areas with high concentrations of responses from the GFD were found to be uncovered by a fire company within four minutes. The Grapevine Fire Department staffs most frontline fire apparatus with three firefighters. When staffed with only three firefighters, first-arriving apparatus must wait for additional personal to arrive before making entry for interior fire suppression at structure fire incidents.

Mapping analysis showed that existing response capabilities to typical residential building structures (low-hazard), and multi-residential buildings (medium-hazard) buildings are not serviced with sufficient firefighter personnel within safe and effective time frames. Engine apparatus are not with four firefighters. Emergency incident responses requiring fire apparatus procedures depend on supplemental staff also responsible for medic units, which has significant negative impacts on availability and response times. Staffing four firefighters on fire apparatus at all times would improve and ensure response coverage from each fire station, while also increasing the number of personnel available for efficient and effective fireground operations. The addition of a new station at near the intersection of *William D Tate Avenue and W Nash* should decrease fire company travel times to incidents that occur outside of the current initial four-minute response. Additionally, an additional medic unit at Station 4 would reduce the workload on firefighter-medic personnel, particularly in stations closer to Station 4.

Deficiencies in staffing and apparatus contribute to delays in fire suppression, rescue, and EMS response. The department's current insufficiencies indicate the need for additional resources. As resources become scarce as demand increases, performance will worsen. This increases the risk of death or injury due to fire for both citizens and firefighters in Grapevine. It also increases the risk of considerable property loss for housing units and businesses in many areas within the

response boundary. To improve its response capabilities, GFD should staff all suppression and rescue units with a minimum of four firefighters at all time in accordance with NFPA 1710.

The risk assessment of incident demand identified areas where emergencies have typically occurred in the past and where they are likely to occur in the future. The 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 demand54s 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 multiple 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 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.[87]

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

- **4.1.2.1** The fire department shall establish the following performance objectives for the first-due response zones that are identified by the AHJ:
    - (3) 240 seconds or less travel time for the arrival of the first engine company at a fire suppression incident[88]
    - (4) 360 seconds or less travel time for the arrival of the second company with a minimum staffing of four personnel at a fire suppression incident
    - (5) For other than high-rise, 480 seconds or less travel time for the deployment of an initial full alarm assignment at a fire suppression incident
    - (6) For high-rise, 610 seconds or less travel time for the deployment of an initial full alarm assignment at a fire suppression incident
    - (7) 240 seconds or less travel time for the arrival of a unit with first responder with automatic external defibrillator (AED) or higher-level capability at an emergency medical incident
    - (8) 480 second or less travel time for the arrival of an advanced life support (ALS) unit at an emergency incident, where this service is provided by the fire department provided a first responder with an AED or basic life support (BLS) unite arrived in 240 seconds or less travel time.

- **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.

[87] NFPA 1710, 2020
[88] All travel time objectives are to be achieved 90% of the time.

- **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 Engine Companies.** Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue, shall be known as engine companies shall be staffed with a minimum of four on-duty personnel.

    - 5.2.3.1.1 These companies shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.1.2 In first-due response zones with a high number of incidents, geographical restrictions, geographic isolation, or urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of five on-duty members.
    - 5.2.3.1.2.1 In first-due response zones 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.

- **5.2.3.2 Ladder/Truck Companies.** 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 known as ladder or truck companies… shall be staffed with a minimum of four on-duty personnel.

    - 5.2.3.2.1 These companies shall be staffed with a minimum of four on-duty personnel.
    - 5.2.3.2.2 In first-due response zones with a high number of incidents, geographical restrictions, geographic isolation, or urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of five on-duty members.
    - 5.2.3.2.2.1 In first-due response zones 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.

- **5.2.3.4 Fire Companies with Quint Apparatus**

    - 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** 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	***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)	4 Firefighters
Required Minimum Personnel for Full Alarm	**16 Firefighters & 1 Incident Commander**

- **5.2.4.2 Open-Air Strip Shopping Center Initial Full Alarm Assignment Capability**
  - 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.

And

- **5.2.4.3 Apartment Initial Full Alarm Assignment Capability**
  - 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[89]	2 Firefighters
Required Minimum Personnel for Full Alarm	**27 Firefighters** **1 Incident Commander**

[89] 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 High-Rise Initial Full Alarm Assignment Capability.**
  - 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**

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