GEOGRAPHIC INFORMATION SYSTEM
EMERGENCY SERVICES RESPONSE CAPABILITIES ANALYSIS

International Association of Fire Fighters
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BILLINGS FIRE DEPARTMENT

BILLINGS, MONTANA

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Dedication

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

Contents

Executive Summary

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Billings Fire Fighters, IAFF Local 521, to provide information and resources to decision makers in Billings regarding staffing and fire station locations. The population in the City of Billings and the demand on the fire department has grown in recent years. Since 2010, the city has experienced a 7.4% increase in population[1] and there is concern that some existing fire stations may now be out of place for optimal response coverage based on response to populations and demand within the city. The Billings firefighters believe additional fire stations and staff are needed within the response jurisdiction to better meet demand.

The Billings Fire Department provides fire suppression, disaster incident mitigation, Emergency Medical Services (EMS) response at the Basic Life Support (BLS) level, hazardous materials response, and technical rescue to the citizens of Billings and in the Billings Urban Fire Service Area (BUFSA) 24 hours per day, 7 days per week from seven fire stations. The department typically staffs 22 firefighters and one Battalion Chief per shift. In total the Billings Fire Department supports 3 Battalion Chiefs, 30 captains, 30 engineers, and 45 firefighters. The administrative day staff consists of 4 Deputy Fire Marshalls, 1 Assistant Fire Marshall, 1 Fire Marshall, 1 Assistant Chief, and the Fire Chief.

Each fire station deploys at least one staffed engine company. Engine 4, Station 4, is a quint, but typically operates as an engine. A quint is a hybrid vehicle, capable of operating in the capacity of either an engine ***or*** a ladder truck, but not both unless it is staffed with a minimum of eight firefighters. Engine 4 has a 75 foot aerial ladder and a shorter wheelbase than Truck 1, which allows for better access in restricted spaces. However, because Engine 4 is equipped with only a 75 foot aerial device it is limited in the ability to reach higher floors because the aerial ladder is significantly shorter than Truck 1's aerial device. In general, quints are restricted in the delivery due to a reduced complement of available hose and the number and types of ladders that can be carried.

Truck 1 deploys from Station 1 and as noted has a longer aerial ladder than Engine 4, is a larger vehicle, and needs more space to operate. Truck 1 also carries many specialized tools for ventilation and victim search and rescue that Engine 4 does not carry. Unlike Engine 4, Truck 1 is specifically assigned to perform critical fireground tasks related to ventilation, searching for trapped occupants, and occupant rescue.

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[1] U.S. Census Bureau. Census Viewer Billings Montana Population: Census 2010 and 2000 Interactive Map, Demographics, Statistics, Quicks Facts. http://censusviewer.com/city/MT/Billings

The fire department has 30 firefighters trained as paramedics. Due to the contractual agreement between American Medical Response (AMR) and the city, fire department apparatus cannot carry advanced life support (ALS) equipment on engines or perform ALS procedures on patients. However, firefighters are permitted to assist AMR paramedics with ALS-level operations once the ambulance arrives on scene.

Currently, all engines and the truck are staffed with three firefighters each. Because fire suppression apparatus are not staffed with a minimum of four fighters the department does not meet the objectives of the National Fire Protection Association (NFPA®) Standard 1710: *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, also known as NFPA 1710. As a result of fire suppression apparatus being staffed with three firefighters, the department can only assemble an effective response force of 15 firefighters on less than 6.0% of all roads in the city. Assembling a minimum of 15 firefighters arriving on scene within 8 minutes of travel time is considered the standard for safe, effective, and efficient operations at a typical residential structure fire.[2]

In addition to suppression apparatus being staffed with three firefighters, some fire stations house multiple apparatus that firefighters cross-staff depending on the type of emergency. Cross-staffing is a practice whereby firefighters must select the apparatus with which to respond based on the nature of the call. This practice can create delays in response, especially when firefighters are out of the station on one apparatus and must respond back to the station to board the appropriate apparatus for the call.

Beyond insufficient staffing there is also a need to build additional fire stations to meet demand and provide equitable coverage to the community. The city has experienced noteworthy population growth over the last several years and typically as population increase so does demand. As a means of determining where additional stations should be located, historical incident and response time data would be used to assess fire department performance; however, that type of data was not available at the time this study was conducted. Instead, U.S. Census population data was used as an alternate measure of performance analysis, as population increases are typically indicators of increased demand. By examining Census data, in conjunction with current station locations, road networks, historic traffic demand, and deployment practices, it could be determined where resources should be placed, including stations, apparatus, and personnel, using ESRI's Location-Allocation tool.

[2] NFPA defines a typical structure fire as a fire occurring in a 2,000 sq. ft. single-family home with no basement or exposures.

Location-Allocation is a GIS tool that defines where one or more facilities may be placed within a community based on designated demand. Based on the question of where to add additional resources to the Department, the tool was used in the analysis of relocating or adding additional fire stations in the response jurisdiction. U.S. Census population was used as the demand for allocating additional stations.

Key Findings

- Fire suppression apparatus are only staffed with three firefighters.
- Even though the department maintains 30 firefighter/paramedics, they are unable to function at the ALS level due to the contract between the city and AMR.
- Station 1, which is located downtown, has the highest incident call volume and the lowest average response time compared to the other fire stations.
- Station 7, which is located on the west side of Billings and covers rural portions of the community, has the lowest incident call volume and the highest average response time.
- Currently, the department can reach 43.1% of roads within the response jurisdiction within 4 minutes from existing fire stations. That is based on the assumption that units are available to respond immediately upon dispatch.
- Currently, the department can reach 5.2% of roads with a minimum of 4 firefighters within 4 minutes or less of travel time. If staffing is increased to a minimum of 4 firefighters on all fire suppression apparatus, the department would be able to assemble 4 firefighters within 4 minutes on 43.1% of roads. That equates to a 728% increase in road coverage.
- The department can assemble 15 firefighters within 8 minutes on 5.9% of roads.
- If staffing is increased to a minimum of 4 firefighters on all fire suppression apparatus, the department would be able to assemble 15 firefighters within 8 minutes on 19.7% of roads. This equates to a 233% increase in road coverage.
- Currently, the department is unable to assemble a minimum of 28 firefighters[3] at the scene of a medium-hazard structure fire[4] within 8 minutes. If staffing is increased to a

[3] The Billings Fire Department does not provide medical transport. Therefore, the department would be required to arrive with 24 firefighters, 1 incident commander, and 1 chief's aide, for a total of 26 personnel, to a medium-hazard structure fire. NFPA 1710, §5.2.4.2.1 (9) requires, "The establishment of an initial medical care component consisting of at 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. Where this level of emergency medical care is provided by outside agencies or organizations, these agencies and organizations shall be included in the deployment plan and meet these requirements".

[4] NFPA 1710 (2016) 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 square feet to 196,000 square feet (1203 square meters to 18,209 square meters) and NFPA 1710 (2016) 5.2.4.3.1 The initial full alarm assignment to a structure fire in a typical 1200 square feet (111 square meters) apartment within a three-story garden style apartment building.

minimum of 4 firefighters on all fire suppression apparatus, the department would still be unable to place a minimum of 28 firefighters on scene within 8 minutes, even though there would be a daily staff of 32 firefighters and one Battalion Chief.

GIS Location-Allocation Proposal 1: Keep Existing Stations and Add Stations Needed to Reach 90% of the City's Population within 4 Minutes

- Based on Geographic Information Systems (GIS) location-allocation analysis, the fire department would need 4 additional fire stations, in conjunction with existing fire stations, for a total of 11 fire stations, to respond to 90% of the population within the City of Billings within 4 minutes of travel time.
- With the additional stations the department would be able to reach 62.2% of roads in the response jurisdiction, which equates to a 30.7% increase in road coverage.

GIS Location-Allocation Proposal 2: Relocate All Stations Needed to Reach 90% of the City's Population within 4 minutes.

- Based on GIS location-allocation analysis, if the fire department was able to relocate all existing fire stations, a total of 10 fire stations would be needed to reach 90% of the population in the City of Billings within 4 minutes.
- With the 10 proposed station locations the department would be able to reach 64.9% of roads in the response jurisdiction, which is a 33.6% increase in road coverage.

GIS Location-Allocation Proposal 3: Relocate All Stations Needed to Reach 90% of the BUFSA's Population within 4 minutes.

- Based on GIS location-allocation analysis, the fire department would need 5 additional fire stations, in conjunction with existing fire stations, for a total of 12 fire stations, to respond to 90% of the population in the BUFSA within 4 minutes.
- With the additional stations the department would be able to reach 68% of roads within the response jurisdiction, which is a 36.6% increase in road coverage.

GIS Location-Allocation Proposal 4: Relocate All Stations Needed to Reach 90% of the BUFSA's Population within 4 minutes.

- Based on GIS location-allocation analysis, if the fire department was able to relocate all existing fire stations, a total of 12 fire stations would be needed to reach 90% of the population in the BUFSA within 4 minutes.
- With the 12 proposed station locations the department would be able to reach 71.5% of roads within the response jurisdiction, which is a 39.7% increase in road coverage.

Recommendations

- The department should increase staffing on all fire suppression apparatus to a minimum of four firefighters. Staffing fire suppression apparatus with a minimum of four firefighters would meet the minimum staffing objectives in NFPA 1710 and enhance safety and operational effectiveness and efficiency.
- Engine 1 and Truck 1 should be staffed with 6 firefighters daily due to proximity to high-rise and high occupancy buildings downtown and the high-hazard oil refinery adjacent to downtown.
- Engine 7 should be staffed with 5 firefighters daily due to Station 7 being geographically isolated from other fire stations.[5]
- The Billings Fire Department, City of Billings, and AMR should renegotiate the contract to allow firefighters to perform advanced life support interventions on patients prior to the arrival of AMR resources in order to provide the citizens of Billings with the best out-of-hospital care possible.
- The department should build new fire stations to increase coverage provided to the population of the response jurisdiction. Proposals for potential new stations were determined in four analysis, the results of which are discussed on the next few pages.
    - New fire stations should house apparatus determined to be appropriate based on the risks present in the community.
- The department should perform a risk assessment and critical task analysis. The risk assessment will identify all risks within the response jurisdiction and the critical task analysis will determine what resources are needed to mitigate those risks.
- The department should be involved with the City of Billings and surrounding communities concerning growth and development within the community. Both a risk

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[5] NFPA 1710 (2016) 5.2.3.1.2: "In jurisdictions with high number of incidents or geographical restrictions, as identified by the AHJ, the companies shall be staffed with a minimum of five on-duty members."
NFPA 1710 (2016) 5.2.3.1.2.1 "In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members."

assessment and a comprehensive growth plan will help the department decide where to place future fire department resources.

- The Billings Fire Department should maintain acceptable levels of both concentration and distribution 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.

GIS Location-Allocation Proposal 1: Keep Existing Stations and Add Stations Needed to Reach 90% of the City's Population within 4 Minutes.

The results of this location-allocation analysis revealed the proposed new stations should be located in the area of:

Proposed Station A	Bitteroot Dr. & Barret Rd.
Proposed Station B	W. Hilltop Rd. & Bazar Exchange
Proposed Station C	S. 32nd St. & W. Sweetwater Dr.
Proposed Station D	Rimrock Rd. & Reimer Park Dr.

GIS Location-Allocation Proposal 2: Relocate All Stations Needed to Reach 90% of the City's Population within 4 minutes.

Because it is not economically feasible to relocate all existing fire stations, the results of this location-allocation analysis revealed two current stations may be relocated and three new stations should be added. [6] Results from this portion of the analysis revealed that proposed stations should be located in the area of:

Station 2 Moved to Proposed Station H	Broadwater Ave. & 24th St. W.
Station 5 Moved to Proposed Station I	Monad Rd. & S. 32nd St. W.
Proposed Station A	Wicks Ln. & Hawthorne Ln.
Proposed Station C	Governors Blvd. & Aronson Ave.
Proposed Station G	Zimmerman Trail & Rimrock Rd.

[6] Current stations remained in place that were within ½ mile of proposed station locations. The exception was Station 7 since it is the newest station in the department.

GIS Location-Allocation Proposal 3: Relocate All Stations Needed to Reach 90% of the BUFSA's Population within 4 minutes.

The results of this location-allocation analysis revealed the proposed new stations should be located in the area of:

Proposed Station A	Bitteroot Dr. & Mading Dr.
Proposed Station B	W. Hilltop Rd. & Bazar Exchange
Proposed Station C	King Ave. E. & Calhoun Ln.
Proposed Station D	Grand Ave. & Zimmerman Ln.
Proposed Station E	King Ave. & S. Shiloh Rd.

GIS Location-Allocation Proposal 4: Relocate All Stations Needed to Reach 90% of the BUFSA's Population within 4 minutes.

Because it is not economically feasible to relocate all current fire stations, the results of this location-allocation analysis revealed 4 current stations may be relocated and 5 new stations should be added.[7] Results from this portion of the analysis revealed that proposed stations should be located in the area of:

Station 2 Moved to Proposed Station E	Broadwater Ave. & 24th St. W.
Station 3 Moved to Proposed Station G	Rimrock Rd. &13th St. W.
Station 4 Moved to Proposed Station F	Broadwater Ave. & 11th St. W.
Station 5 Moved to Proposed Station J	Monad Rd. & S. 32nd St. W.
Proposed Station A	Wicks Ln. & Hawthorn Ln.
Proposed Station C	Governors Blvd. & Aronson Ave.
Proposed Station H	Rimrock Rd. & Zimmerman Ave.
Proposed Station I	24th St. W. & Wyoming Ave.
Proposed Station L	S. 56th St. W & Neibaurer Rd.

[7] Current stations remained in place that were within ½ mile of proposed station locations. The exception was Station 7 since it is the newest station in the department.

Executive Summary Conclusion

The provision of fire protection and EMS response are essential services that municipalities must provide. However, in order for these services to be effective and efficient, they must be staffed and positioned appropriately to address emergencies in an equitable manner, when and where they occur. Based on the different scenarios to add additional stations, results show the Billings Fire Department currently lacks adequate distribution of resources. The Department must almost double its resources to effectively respond to the community it serves.

Fire department resources should be adequately deployed to respond to emergencies within the initial response times as outlined in NFPA 1710, and to emergencies occurring simultaneously. This is necessary to minimize the loss of life and the loss of property that the fire department is charged to protect. By increasing the current number of fire stations and deploying apparatus staffed in accordance with industry standards, fire suppression and emergency medical services provided by Billings Fire Department will likely improve.

Sending larger crew sizes on a single apparatus allows crews to assemble on scene more quickly during early stages of a fire when risks to both firefighters and building occupants are lower. Since fire growth is exponential, growing in a non-linear manner over time, extending the time for crew assembly by waiting for smaller crews to arrive from further away, causes on scene risk to escalate. The higher the risks at the time firefighters engage in fire suppression, the greater the chance of poor outcomes including civilian injury or death, fire fighter injury or death and property loss.

Billings Fire Department is as much a part of the community as any citizen. The fire department should work with the city and fire district to help improve fire department capabilities. The department's only obligation is to serve the community. Therefore, the region should work to keep those firefighters and citizens of Billings and surrounding area safe.

Background

The International Association of Fire Fighters (IAFF) Headquarters was engaged by the Billings Firefighters, IAFF Local 521, to create a data-driven document for decision makers in Billings to assist with informed decisions regarding the lack of distribution of resources responding within the city and rural response jurisdiction.

The Billings Fire Department is a career fire department located in Billings, Montana with coverage responsibilities to the city and some of the surrounding areas. The fire department's response jurisdiction for is approximately 90 square miles of land, which includes the City of Billings (43 square miles) and the Billings Urban Fire Service Area (BUFSA). As of the year 2016, the City of Billings had an estimated population of 110,323,[8] which is an increase from 104,170 as of the 2010 census. However, these numbers do not reflect the population is estimated to 140,000 on weekdays and 130,000 on the weekends[9] as commuters and visitors enter the area. The population in the BUFSA is estimated to be 10,000[10] year round residents.

A brief risk analysis was performed on the city to assess for clues that may suggest high demand or obstacles to incident management.

The City of Billings is a city in south central Montana. The city encompasses a large Conoco/Phillips 66 oil refinery,[11] large industrial and agricultural facilities, and high-rise buildings in the downtown area.[12] An assessment of the U.S. Census data sets from 2016 revealed that 22% of the City of Billings population was in a vulnerable category for age. This category consists of persons under the age of 5 (6.6%) and persons 65 years of age and older (15.5%), but does not include the special needs population.[13] Additionally, 8.1% of the population was living below the poverty level (2016).[14] Vulnerable populations are groups of

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[8] United States Census Bureau. American Fact Finder Community Facts. https://www.census.gov/quickfacts/fact/table/billingscitymontana/PST045216

[9] Information provided by Local 521.

[10] Information provided by Local 521

[11] Billings Refinery. http://www.phillips66.com/refining/billings-refinery

[12] NFPA 1710 (2016) 5.2.3.1.2.1 "In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these fire companies shall be staffed with a minimum of six on-duty members."

[13] U.S. Census American Fact Finder. Profile of General Population and Housing Characteristics: 2016. 2016 Demographic Profile. Billings City Montana. https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

[14] U.S. Census American Fact Finder. Poverty Status in the Past 12 Months. 2011-2016 American Community Survey 5-year estimates. Billings City Montana. https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml#

people that are at higher risk of suffering fire-related injury and death because of their inability, or reduced ability, to evacuate in an emergency without assistance.

There were 46,645 housing units in Billings, with the majority being single family residences (67.5%) and the remainder being multifamily (25.7%) and mobile homes (6.8%). Of these structures, 40.1% were of pre-1970 construction.[15] Typically, when there are high numbers of vulnerable citizens and older buildings constructed before many current fire codes were developed, there is an increased demand on emergency services. It should be noted that these statistics were only available for the City of Billings. Actual numbers may be higher since the fire department's response jurisdiction includes surrounding rural communities in the BUFSA.

The information provided in this document is designed to help decision makers understand the depth of fire department operations and how low staffing levels and a lack of resources negatively impact responders and citizens in the city.

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[15] U.S. Census American Fact Finder. Selected Housing Characteristics. 2011-2016 American Community Survey 5-year estimates. Billings City Montana.
https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

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 1,000º Fahrenheit. It is generally accepted in the fire service that for a medium growth rate fire,[16] flashover-the very rapid spreading of the fire due to super heating of room contents and other combustibles-can occur. Assuming an immediate discovery of a fire, followed by an un-delayed call to 9-1-1, and dispatch of emergency responders, flashover is likely to occur within 8 minutes of fire ignition. However, studies conducted by the Underwriters Laboratory (UL) and the National Institute of Standards and Technology (NIST) have proved that due to modern construction materials and room contents that act as fuel, flashover may occur much sooner.

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

This section will explain fire growth and the importance of a fire department response to a low-hazard structure fire. A low-hazard structure fire is defined as a fire that occurs in a typical, 2000 square foot single-family residential home with no basement or exposures.[17]

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

[17] NFPA 1710, 2016 ed.

Fire Growth

The Incipient Phase

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

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

The Free Burning Phase

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

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

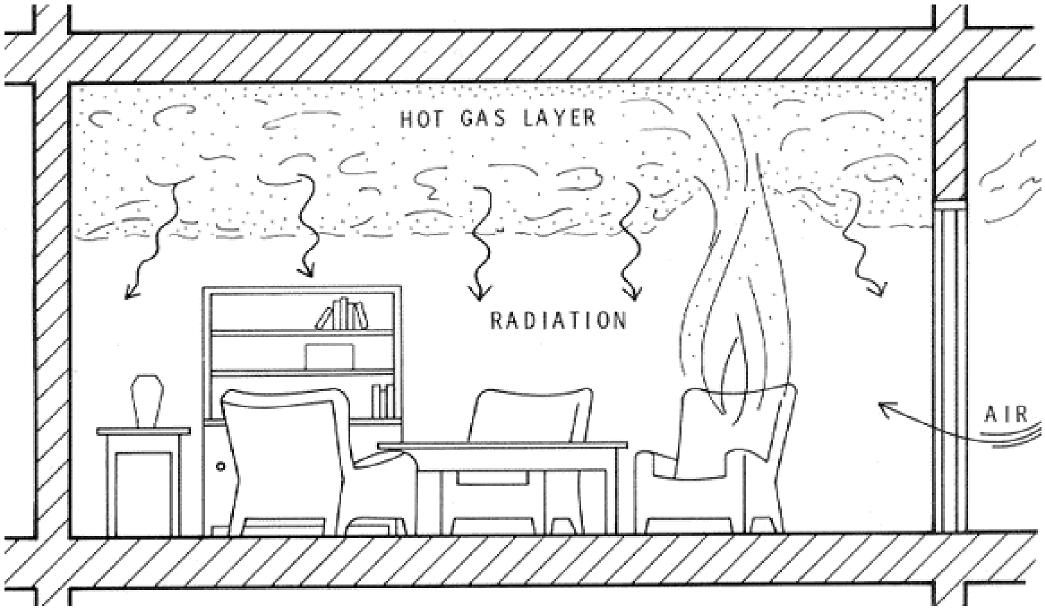

Figure 1: Fire Growth in a Compartment.[18] The above figure depicts the growth of fire in a compartment, which is an enclosed space or room in a building. In a compartment the walls, ceiling, floors, and objects absorb radiant heat produced by the fire. Unabsorbed heat is reflected back to the initial fuel source, which is depicted by the armchair above. This reflected heat continues to increase the temperature of the fuel source and therefore the rate of combustion. Hot smoke, combustible gases, and super-heated air will then rise to the ceiling and spread at first laterally across the ceiling, but later downward towards other fuel sources and the floor of the compartment. As this toxic, super-heated cloud touches cooler materials, the heat is conducted to them, thus increasing their temperature and eventually leading to pyrolysis, which is the process where a fuel source begins to release flammable vapor. This release of flammable vapor leads to further fire growth and eventually flashover. Flashover is the point at which all exposed fuel sources in a compartment ignite.

If there is sufficient oxygen, then the fire will continue to grow and the heating of the other combustibles in the room will continue to the point where they reach their ignition temperatures more or less simultaneously. If this occurs, all combustible materials in the room will spontaneously ignite. This transition from the burning of one or two objects to full room involvement is referred to as flashover.[19]

Flashover

Flashover, when it occurs, is the most significant event during a structure fire. As combustible gases are produced by the two previous stages they are not entirely consumed and are therefore available fuels. These available fuels rise and form a superheated gas layer at the ceiling that continues to increase, until it begins to bank down to the floor, heating all combustible objects

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

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

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

As has been noted, at the time of flashover, windows in the room will break. When these windows break, as a result of the increased pressure in the room, a fresh supply of air from outside of the building is available to help the fire grow and spread. Based on the dynamics of fire behavior in an unprotected structure fire, any decrease in emergency unit response capabilities will correlate directly with an increase in expected life, property, and economic loss.

The Importance of Adequate Staffing: Concentration

NFPA 1500 and 1710 both recommend that a minimum acceptable fire company staffing level should be four firefighters responding on, or arriving with, each fire suppression apparatus 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.[20] 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 these activities, 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, following page, responding companies staffed with four firefighters are capable of initiating critical fire ground operational tasks more efficiently than those with crew sizes below industry standards.

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

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

Table 1: Impact of Crew Size on a Low-Hazard Residential Fire.[21] 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. The Billings Fire Department staffs suppression apparatus with 3 firefighters.

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

With four-person crews, the effectiveness of first-arriving engine company interior attack operations *increases* by 12% to 29% efficiency compared to three- and two-person crews, respectively. The efficacy of search and rescue operations also *increases* by 4% to 28% with four-person crews compared to three- and two-person crews. Moreover, with a four-person crew, because the first-in unit is staffed with a sufficient number of personnel to accomplish its assigned duties, the second-in company does not need to support first-in company operations and is therefore capable of performing other critical fireground tasks that are likely to improve safety and outcomes.

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

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[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.

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 in the decrease of on-scene risk levels. In other words, the more firefighters available to respond and arrive early to a structure fire, the less time it takes to extinguish the fire and perform search and rescue activities, thus reducing the risk of injury and death to both firefighters and trapped occupants and reducing the economic loss to the property.

Overall Scene Time Breakdown by Crew Size		
Scenario	**Total Time**	**Efficiency**
4-Person Close Stagger	0:15:14	
3-Person Close Stagger	0:20:30	25% Less Efficient
2-Person Close Stagger	0:22:16	29% Less Efficient
4-Person Far Stagger	0:15:48	
3-Person Far Stagger	0:21:17	26% Less Efficient
2-Person Far Stagger	0:22:52	31% Less Efficient

Table 2: The Relationship between Crew Size and Scene Time. 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 7 minutes longer than units that arrive with four firefighters on each crew. Responding units arriving with only three firefighters on an apparatus are on the scene of a fire 5 to 6 minutes longer than units that arrive with four firefighters on each apparatus. In addition to crew size, the time between the arriving crews matters to overall effectiveness and total on scene time.

In the NIST study on the low-hazard residential fire, close stagger was defined as a 1-minute time difference in the arrival of each responding crew. Far stagger was defined as a 2-minute time difference in the arrival of each responding crew.[22] [23] 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.

[22] Ibid.

[23] 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 Fire Fighters.

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.[24]

In 2016 alone, 42% of all firefighter fatalities were related to overexertion.[25] There is strong epidemiological evidence that heavy physical exertion can trigger sudden cardiac events.[26] Smaller crews are responsible for performing a number of task that are designed to be performed by multiple people and frequently in teams of two. This means that firefighters on smaller crews are required to work harder than larger crews to accomplish multiple tasks. Additionally, as discussed earlier, firefighters on smaller crews will also be working longer than larger sized crews. Working harder and longer in high heat and dangerous, stressful environments increases the likelihood of firefighters suffering an injury, or worse dying, as a result of overexertion.

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

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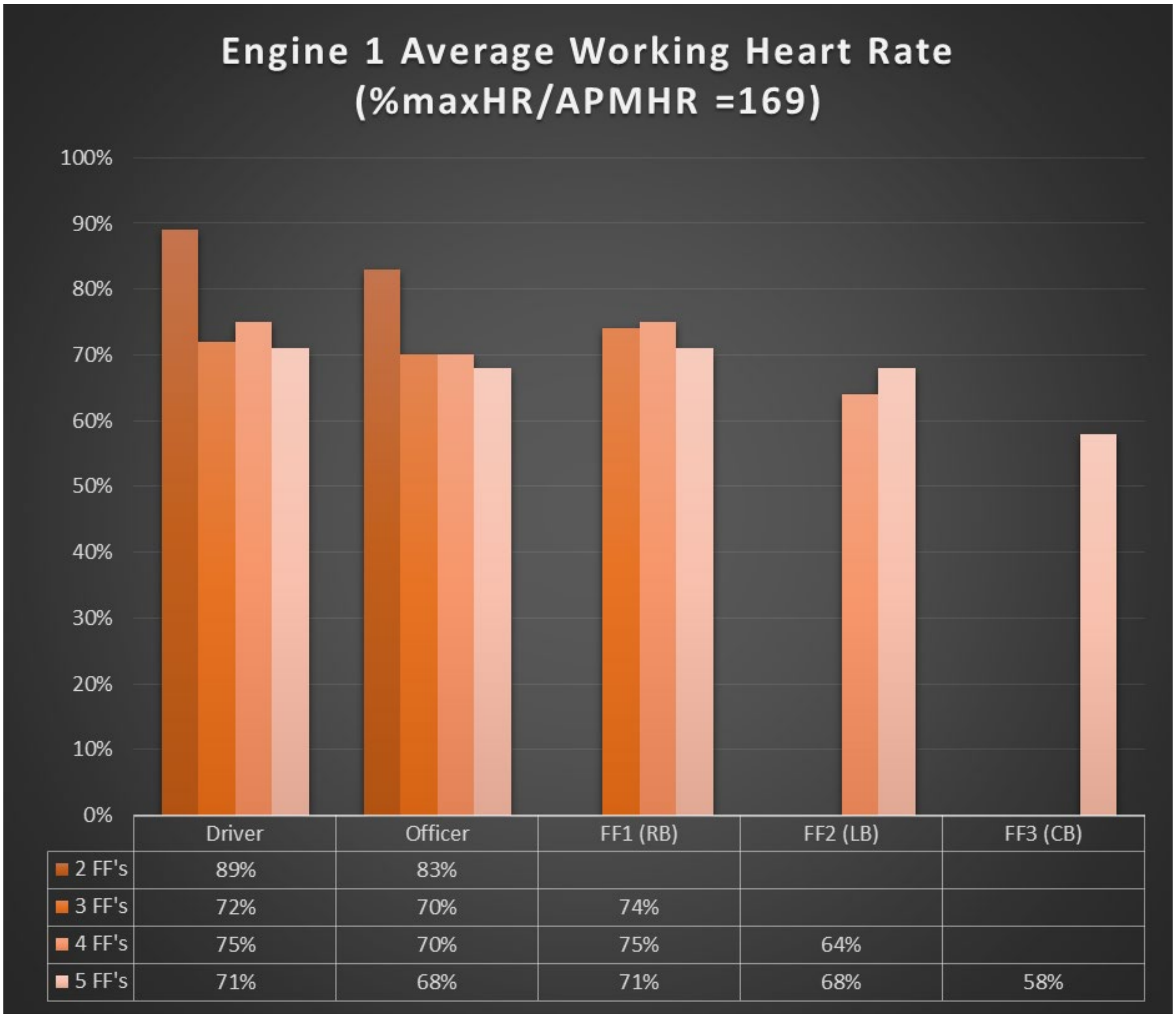
[24] Averill, J.D., et al. Report on Residential Fireground Field Experiments. NIST Technical Note 1661. National Institute of Standards and Technology; Gaithersburg, MD, April 2010.
[25] Fahy, R.F., LeBlanc, P.R., Molis, J.L. (June, 2015) Firefighter Fatalities in the United States-2016. NFPA.
[26] 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 (P1) with Different Crew Sizes by Riding Position.[27] *In Chart 1, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first engine company were above 80% of age-predicted maximum values when only 2 firefighters were working. When staffing was at 2 firefighters, the driver of the apparatus had an average peak heart rate of nearly 90% of the age-predicted maximum. This is largely due to the number of additional tasks the driver must perform to prepare the engine to pump water to the fire and then join the officer to stretch hose to the fire. As can be seen, the larger the crew size, the lower the heart rate.[28] 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.

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

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

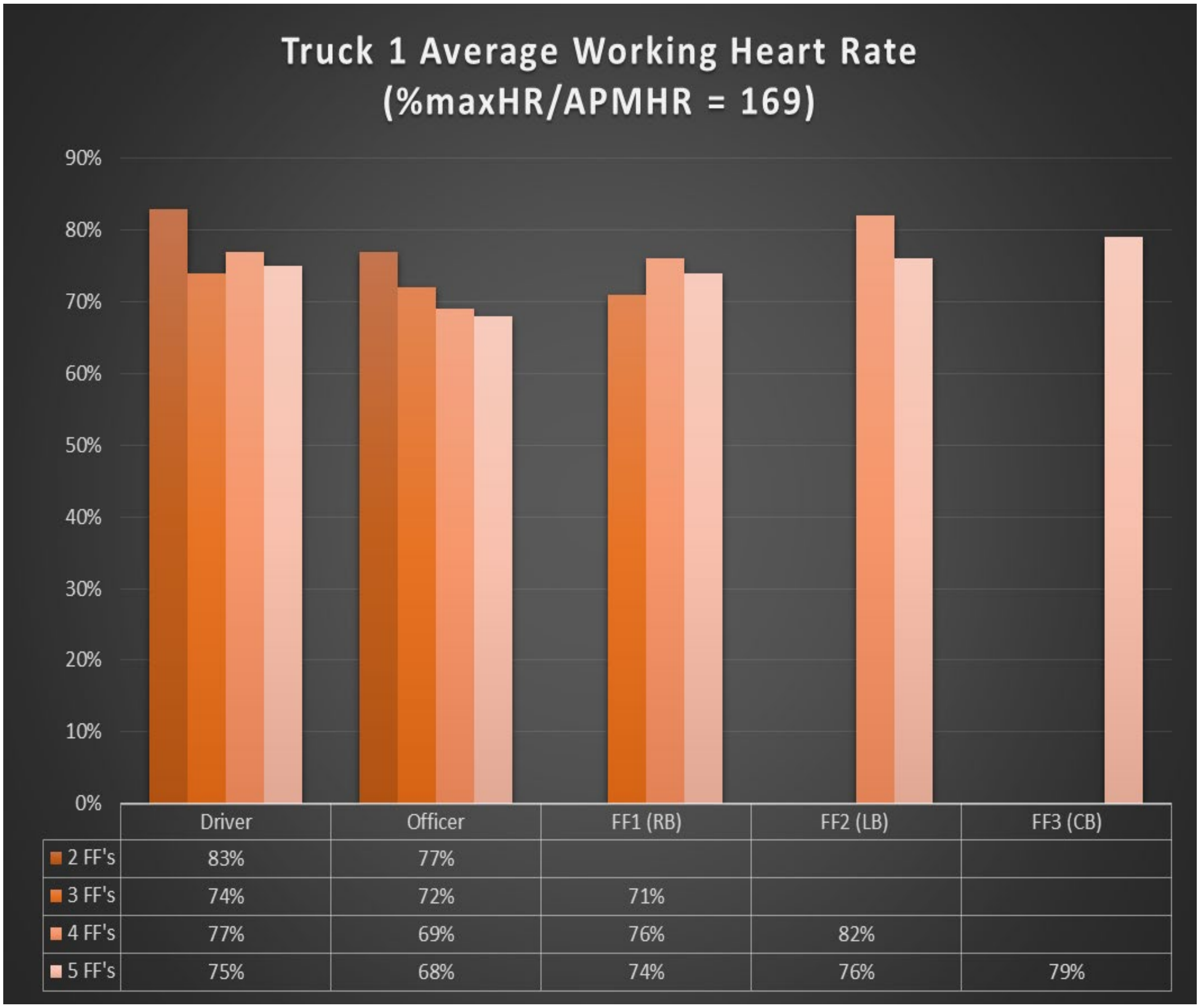

Chart 2: Average Peak Heart Rate of First Ladder (A1) with Different Crew Sizes by Riding Position.[29] *In Chart 2, heart rates are expressed as a percent of maximal age-predicted maximal HR.* The average heart rates for firefighters on the first ladder company were above 80% of age-predicted maximum values when only 2 firefighters were working.[30] 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.

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

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

The Importance of a Rapid Response

Uncontained fire in a structure grows exponentially, growing in size with every passing minute. Any delay in the initiation of fire suppression and rescue operations, such as the 5- to 7- minute delay that results from smaller sized crews of firefighters, translates directly into a proportional *increase* in expected property, life, and economic losses as is shown in Table 3, following page. It warrants emphasizing that if a structure has no automatic suppression or detection system, a more advanced fire may exist by the time the fire department is notified of the emergency and is able to respond. Fires of an extended duration weaken structural support members, compromising the structural integrity of a building and forcing operations to shift from an offensive to defensive mode.[31] 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 provided that the longer it takes for firefighters to rescue trapped occupants, the greater the risk posed to both the firefighters and occupants by increasing atmospheric toxicity in the structure.

[31] According to the NFPA, "it's important to realize that every 946.3 LPM (250 GPM) stream applied to the building can add up to one ton per minute to the load the weakened structure is carrying."

Rate Per 1,000 Fires			
Fire Extension in Residential Structures:	Civilian Deaths	Civilian Injuries	Average Property Damage
Confined fires (identified by incident type)	0.00	10.29	$212.00
Confined to object of origin	0.65	13.53	$1,565.00
Confined to room of origin, including confined fires by incident type[32]	1.91	23.32	$2,993.00
Beyond the room, but confined to floor of origin	22.73	64.13	$7,445.00
Beyond floor of origin	24.63	60.41	$58,431.00

Table 3: The Relationship between Fire Extension and Fire Loss.[33] The above table displays the rates of civilian injuries and deaths per 1,000 fires, as well as the average property damage. Following the far left column from top to bottom, each row represents a more advanced level of fire involvement in a residence. Typically, the more advanced the fire, the larger the delay in suppression. Assuming an early discovery of a fire, companies staffed with larger crew sizes help to minimize deaths, injuries, and property loss. This highlights why a 5- to 7- minute delay in suppression activities by smaller sized crews results in higher economic losses to a residence.

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 fire fighters 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.

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

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

An interior structural fire (*an advanced fire that has spread inside of the building where high temperatures, heat and dense smoke are normally occurring*) would present an IDLH atmosphere and, therefore, require the use of respirators. In those cases, at least two standby persons, in addition to the minimum of two persons inside needed to fight the fire, must be present before firefighters may enter the building.[34] [35] This requirement is mirrored in NFPA 1500, which states that "a rapid intervention team shall consist of at least two members and shall be available for rescue of a member or a team if the need arises. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the 'initial stage,' and at least one rapid intervention crew shall be required."

NFPA Standard 1710 also supports the OSHA Regulation by requiring a minimum of four personnel on all suppression apparatus. Portions of the 1710 Standard recommend that "fire companies whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with **a minimum of four on-duty members**,"[36] 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**."[37] For either fire suppression company, NFPA 1710 states that "In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ,[38] these companies shall be staffed with a minimum of five on-duty members" and "In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of six on-duty members."[39]

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[34] According to NFPA standards relating to fire fighter safety and health, the incident commander may make exceptions to these rules if necessary to save lives. The Standard does not prohibit fire fighters from entering a burning structure to perform rescue operations when there is a "reasonable" belief that victims may be inside.

[35] Paula O. White, letter to Thomas N. Cooper, 1 November 1995 (OSHA)

[36] NFPA 1710, § 5.2.3.1 and § 5.2.3.1.1.

[37] NFPA 1710, § 5.2.3.2 and § 5.2.3.2.1.

[38] Authority Having Jurisdiction.

[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.

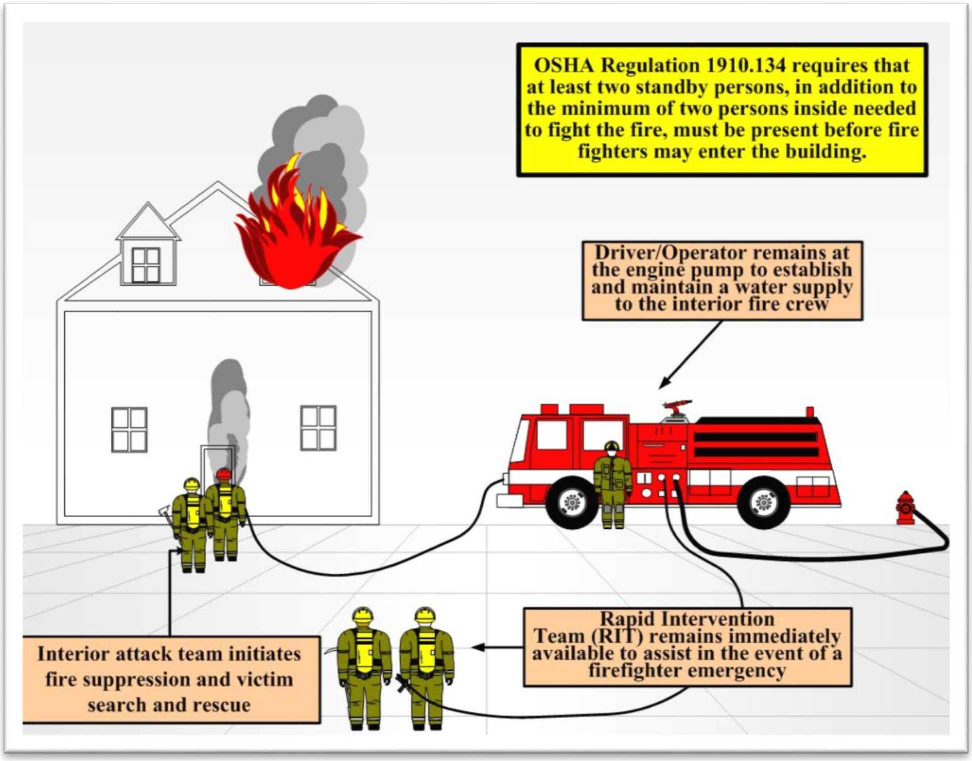

Figure 2: The OSHA "2 IN/2 Out" Regulation. The above figure depicts the number of firefighters required to meet OSHA Regulation 1910.134, which demands one firefighter outside for every firefighter inside. In this sense, the firefighters outside can support a secondary attack line and facilitate the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

A number of incidents exists in which the failure to follow the "2 In/2 Out" Regulation have contributed to firefighter casualties. For example, in Bridgeport, Connecticut in July 2010, two firefighters died following a fire where NIOSH later found that although a "Mayday" was called by the firefighters, it wasn't responded to promptly as there was no Incident Safety Officer or Rapid Intervention Team (RIT) readily available on scene. In a second case, two firefighters were killed in a fire in San Francisco, California in June 2011. The initial RIT was re-assigned to firefighting duties, and the back-up RIT did not arrive on scene until after the victims were removed.

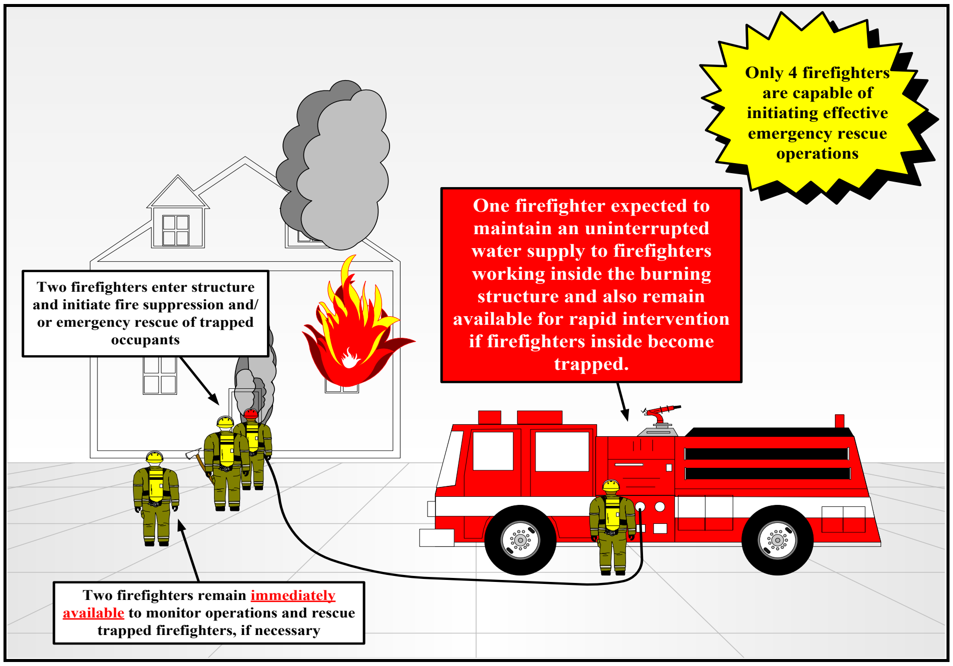

Figure 3: Emergency "2 In/2 Out" Operations. In the emergency model depicted above, the arriving fire apparatus is staffed with a crew of 4 personnel and operates under emergency conditions. In this case the driver/operator of the fire apparatus is also counted as a firefighter, which means that firefighter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

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

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

Initial Full Alarm Assignment

Single-Family Dwelling Initial 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 percent of the incidents… [and that the] initial full alarm shall provide for the following:

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

Table 4: NFPA 1710, §5.2.4.1.1. This breakdown of the expected capabilities of a full alarm assignment, in compliance with NFPA 1710, requires a minimum contingent of 15 fire suppression personnel. NFPA 1710 also requires that supervisory chief officers shall be assisted by a staff aide[40] which will increase on-scene staffing to 16 personnel required to arrive at the scene of a structure fire within 8 minutes of travel. Although not specifically discussed in the standard, an industry best practice is to have a second uninterrupted water supply which requires a second dedicated engine pump operator. This second, dedicated pump operator brings the total count of firefighters to 17.

[40] NFPA 1710, § 5.2.2.2.5

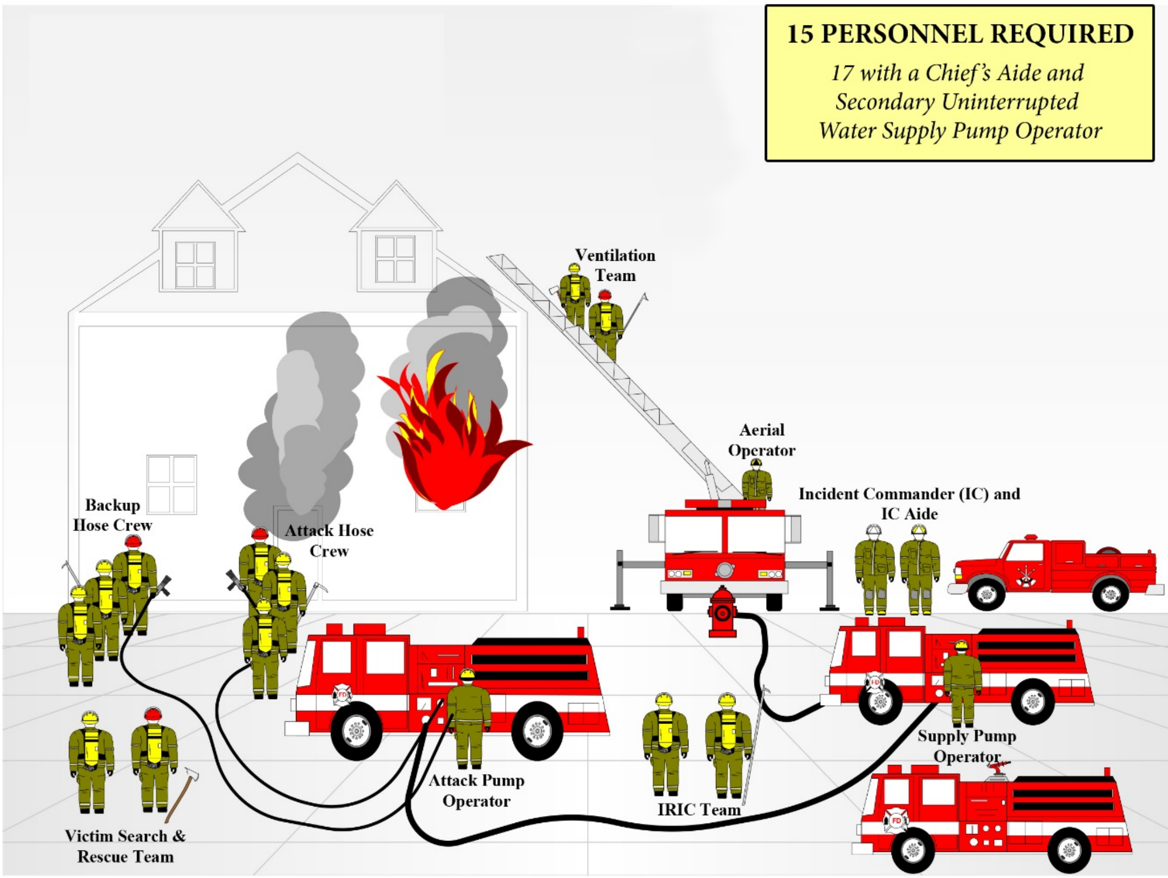

Figure 4: Initial Full Alarm Assignment, 8-Minute Travel Time. The above figure depicts the full alarm assignment discussed in NFPA 1710, with an additional firefighter to act as an incident commander aide, and another additional firefighter to act as a pump operator for a supply apparatus.

In addition, NFPA 1710, §5.2.4.5.2 states, "The fire department shall have the capability to deploy additional alarm assignments that can provide for additional command staff, members, and additional services, including the application of water to the fire; engagement in search and rescue, forcible entry, ventilation, and preservation of property; safety and accountability for personnel; and provision of support activities…"

The ability of adequate fire suppression forces to greatly influence the outcome of a structural fire is undeniable and predictable. Each stage of fire extension beyond the room of origin directly increases the rate of civilian deaths, injuries, and property damage.

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

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High-Rise Operations

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

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. The NFPA 101®, Life Safety Code, 2015 Edition and the International Code Council-published International Building Code both define a high-rise structure as a building more than 75 feet in height, measured from the lowest level of fire department vehicle access to the bottom of the highest occupied floor. High-rises, which are described in NFPA 1710, §A.3.3.28 as high-hazard occupancies, represent an extraordinary challenge to fire departments and are some of the most challenging incidents firefighters encounter.

High-rise buildings may hold thousands of people above the reach of fire department aerial devices, and the chance of rescuing victims from the exterior is greatly reduced once a fire has reached flashover. The risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above grade level.[41] This is especially true once firefighters are operating above the reach of Ladder devices 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 Ladder company operations must be coordinated.

High-rise buildings present a unique threat to the fire service. Multi-floor fires such as the Interstate Building fire, One Meridian Plaza fire, World Trade Center collapse, Cook County Administration Building fire, and Deutsche Bank Building fire each represented serious challenges to the operational capabilities of a modern fire department. According to the NFPA, between 2009 and 2013, there were an estimated 14,540 reported high-rise structure fires per year that resulted in annual losses of 4 civilian deaths, 520 civilian injuries, and $154 million dollars in direct property damage per year. Office buildings, hotels, dormitories, apartment

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

buildings, and health care facilities accounted for nearly three quarters (73%) of these high-rise fires.[42]

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

High-Rise Firefighting Tactics

As has been stated, in a high-rise fire, the risk to firefighters and occupants increases in proportion to the height of the building and the height of the fire above ground level. As the level of the fire floor gets higher, firefighters are required to carry more equipment further and must rely more on the building's standpipe system. A standpipe system is a piping system with discharge outlets at various locations usually located in stairwells on each floor in high-rise buildings that is connected to a water source with pressure supplemented by a fire pump[43] 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, fire may have expanded well past the area of origin. This means that firefighters can encounter a large volume of fire and darkened conditions when they arrive on the involved floors. This can be further complicated if the building is not equipped with a sprinkler system. Additionally, open-layout floor plans such as office buildings with cubicle farms can challenge both the standpipe's flow capacity and fire department resources in regards to search, rescue, and hoseline deployment. The most effective way to extinguish a high-rise fire is by mounting an offensive attack as early as possible, because in the vast majority of historic high-rise fires, the best life safety tactic is extinguishing the fire. Good high-rise firefighting tactics and firefighter/occupant safety cannot be separated. As with a residential structure fire, the first arriving suppression apparatus should be on the scene within four minutes of travel time. However, when responding to any high-hazard buildings or structures, which include high-rises, first responding fire apparatus should be staffed with five to six firefighters per NFPA 1710, upon determination of the AHJ.

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[42] Ahrens, Marty (2016) High-Rise Building Fires NFPA

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

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

Search and Rescue

Search and rescue are critical fireground tasks that comprise a systematic approach to locating possible victims and removing those victims from known danger to a safe area. In a residential structure fire, searches are normally conducted by a crew of two firefighters, supplemented by an attack or ventilation crew. However, high-rise structures pose challenges regarding search and rescue that are not typically encountered in residential housing. For commercial high-rises and wide-area structures, large open areas and cubicle farms require additional search and rescue teams so that thorough searches can occur over a larger area than found in most residences. In addition to these larger areas, search and rescue can be further complicated because conscious victims may retreat to areas in an attempt to find shelter from the 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 property's commercial or residential designation, it is essential for there to be more than one search and rescue team operating per involved floor to quickly locate victims in large surface areas. It is also necessary for additional search and rescue teams to search the floors above the fire and the highest floor of the building, due to how fire and smoke spread to the rest of the building. Search and rescue teams should also be supplemented with evacuation management teams to assist injured or disabled victims down the stairwells so searching can continue. Because of the larger search area, NFPA 1710 requires a minimum of four firefighters for searching and a minimum of four firefighters for evacuation management teams.

Fire Extinguishment

Fire extinguishment is a critical factor, since the intensity and size of the fire will determine the extent to which combustion gases are heated and how high they will rise inside the building.

Building suppression systems, both active and passive, can impact fire growth, occupant safety, and firefighter safety and effectiveness. Such features include active fire detection and automatic sprinkler systems and 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 standpipes 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.

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

Support

As has been discussed, fire suppression in a high-rise or high-hazard structure requires the establishment of a supply chain to shuttle equipment to different locations. Additionally, with increased resources and personnel, there is an increased need for additional supervision and accountability.

One critical support variable in high-rise fire operations is the availability of reliable elevators. If firefighters can safely use the elevators to move people and equipment, fire-ground logistics may be significantly improved. When the fire is located several floors above ground level, there is a strong inclination to use the elevators. However, fire service access elevators[44] may not be available in all buildings. Therefore, adequate stairways are necessary for firefighters to transport equipment and reach the fire floor for suppression.

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

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

- In jurisdictions with a high number of incidents or geographical restrictions, as identified by the AHJ, these companies shall be staffed by a minimum of five on-duty members.[45]
- In jurisdictions with tactical hazards, high-hazard occupancies, or dense urban areas, as identified by the AHJ, these companies shall be staffed with a minimum of six on-duty members.[46]

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 a number of factors: fireground staffing available to conduct an interior attack, a sustained water supply, the ability to conduct ventilation, and risk vs. benefit

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[44] A fire service elevator is designed to operate in a building during a fire emergency and complying with the Montana Building Code, the Montana Fire Code and the TTSSA (Technical Standards and Safety Authority).
[45] NFPA 1710. §5.2.3.1.2
[46] NFPA 1710. §5.2.3.1.2.1, §5.2.3.2.2, and §5.2.3.2.2.1.

analysis regarding firefighter and occupant safety. Table 5, on the following page, displays the minimum number of firefighters required to arrive in the first full alarm assignment to a high-rise fire.

Assignment	Required Personnel
Incident Command	1 Incident Commander 1 Incident Command Aide
Uninterrupted Water Supply	1 Building Fire Pump Observer 1 Fire Engine Operator
Water Flow from Two Handlines on the Involved Floor	4 Firefighters (2 for each line)
Water Flow from One Handline One Floor Above the Involved Floor	2 Firefighters
Rapid Intervention Crew(RIC) Two Floors Below the Involved Floor	4 Firefighters
Victim Search and Rescue Teams	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 a 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 5: Number of Firefighters for an Initial Full Alarm to a High-Rise Fire. High-rise firefighting poses many unique obstacles and challenges above those found in a residential structure fire. Hose cannot be deployed directly from fire apparatus and needs to be carried, with other equipment, to the location of the fire. Search and rescue is impacted by large areas and accessibility concerns. Additionally, because of delays in access, firefighters are likely to encounter a high volume of fire which will necessitate a supply chain to equip ongoing suppression efforts. A single alarm response to a high-rise building minimally requires 43 responders, consisting of 36 firefighters, 1 incident commander, and 6 officers.

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Fire Department EMS Operations

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

The Billings Fire Department provides EMS first response at the BLS level. Although thirty firefighters are trained to the paramedic level and are assigned to engine companies, they are not permitted to carry ALS supplies or render ALS care, even if the engines arrive before the AMR ambulances. Once AMR units arrive on scene, firefighters are allowed to assist with ALS care.

There are six main components of an EMS incident from start to finish.[47] 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.[48] This is likely due to the fact that fire stations housing first responder units, which are equipped and staffed with multi-role firefighter/emergency medical service technicians and supplies, are more centrally located and are able to affect a quicker response and provide life-saving procedures in advance of an ambulance. This reinforces why it is in the best interest of the public good for the fire department to provide EMS transport as well as first response.

The benefit of supporting EMS transport within fire department operations is that fire departments are already geared towards rapid response and rapid intervention. Strategically located stations and personnel are positioned to deliver time critical response and effective fire suppression and are therefore equally situated to provide effective response to time critical

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[47] The Star of Life, designated by Leo R. Schwartz, Chief of EMS Branch, National Highway Traffic Safety Administration (NHTSA) in 1997.

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

requests for EMS service. Both fire suppression and EMS response are required by industry standards to have adequate personnel and resources operating on scene within 8 minutes.[49] In both fire suppression and EMS incidents, time is directly related to the amount of damage, either to the structure or the patient.

When ambulance response is prolonged in Billings, 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 two leading cause of death in United States, after cancer. Experts agree that an ACS event should receive definitive care from a hospital within one hour of onset of symptoms. One study found that definitive care for ACS within one hour of onset improves survivability by 50% and 23% if definitive care was given within 3 hours.[54]

Strokes, which are the number three cause of death in the United States, as well as a leading cause of disability, also benefit from expedient treatment in definitive care. Ischemic stroke, which is a stroke caused from a blood clot, can be effectively treated if definitive care is received within 3 to 4.5 hours[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

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[49] NFPA 1720: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

[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.

Recurrent Stroke (STARS) registry shows that the median door to needle time is 96 minutes or 1 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 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 ambulance 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 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-backed 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 was 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.

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[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
[58] National Institute of Standards and Technology Report on Residential EMS Field Experiments 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

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 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.

[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

Staffing and Deployment Analysis

Before discussing the staffing and deployment analysis of the Billings Fire Department, it is important to understand the intricacies of distribution and concentration. Although adequate staffing is a key element contributing to positive outcomes, fire station locations and apparatus deployment are equally important.

The Importance of Adequate Resources: Distribution

Distribution involves locating geographically distributed, ideal first-due resources for all-risk initial intervention. Distribution describes first due arrival. Station locations are needed to assure rapid deployment for optimal response to routine emergencies within the response jurisdiction. Distribution can be evaluated by the percentage of the jurisdiction covered by the first-due units within adopted public policy service level objectives.[63] In this report, distribution was measured by the percentage of roads that are covered from each fire station within 4- and 8-minute travel times.

Distribution study requires geographical analysis of first due resources. Distribution measures may include:[64]

- Population per first due company
- Area served per first-due company (square miles)
- Number of total road miles per first-due company (miles)
- Dwelling unit square footage per first due company
- Maximum travel time in each first-due company's protection area
- Catchment areas (4-minute road response from all fire stations) to determine gap areas and overlaps of first-due resources
- Areas outside of actual performance

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[63] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.
[64] Commission on Fire Accreditation International, 5th Edition. 2008. Page 52.

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, Ladder, Hazmat unit, etc.)

A major item to be considered in the distribution of resources is travel time. It should be a matter of public policy that the distribution of fire stations in the community is based on the element of travel time and the response goal. Travel time should be periodically sampled and analyzed to determine whether or not the fire department is achieving a reasonable response performance to handle emergencies.[65]

Evaluating a small number of incidents for response time performance does not reflect the true performance of the department. Analyzing incident demand measured over a 3-5 year period will provide a more accurate assessment of the delivery system performance. Completing the same analysis over a period of time will allow for trend analysis as well.[66]

[65] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53
[66] Commission on Fire Accreditation International, 5th Edition. 2008. Page 53

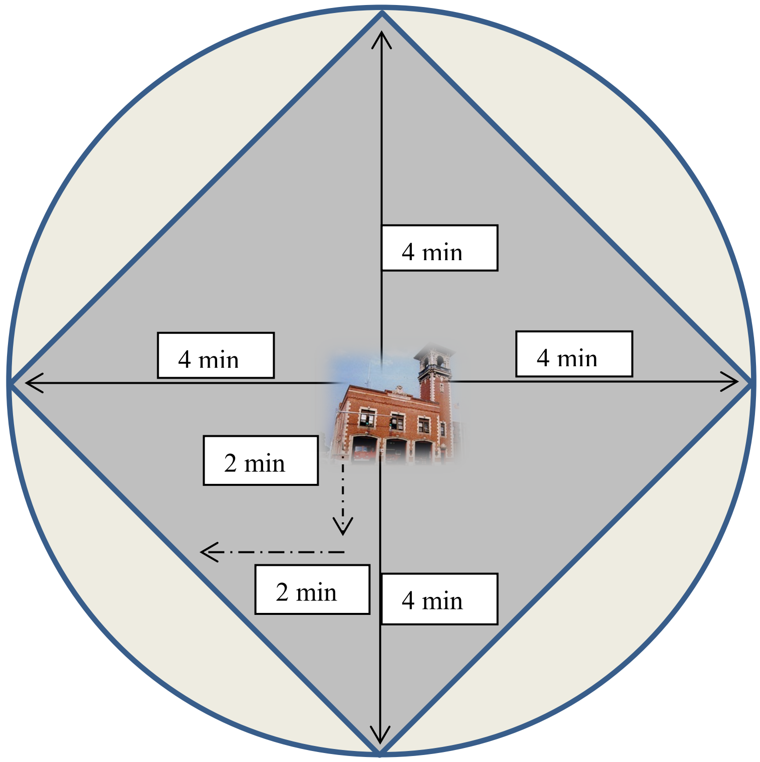

Figure 5: Normal Distribution Model for an Initial 4-Minute Response Area.[67] As depicted in the above figure, fire stations and emergency resources should be distributed throughout a community so that citizens receive equitable coverage and protection. However, there are additional points of concern when modeling a response district such as road network, traffic patterns, and building occupancies.

Distribution strives for an equitable level of outcome: everyone in the community is within the same distance from a fire station. Distribution is based on probabilities 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 city 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 with shorter travel times. But, would citizens in lower risk areas accept longer travel times? Additionally, EMS response times based on medical emergencies will drive equal distribution in the community and negate distribution based on risk, as the risk is equal.

First unit arrival times are the best measure of distribution. It should be noted that if an area experiences fire unit arrival times outside the adopted performance measure, in this case 4-minute travel time per NFPA 1710, it does not necessarily mean it has a distribution issue.[68]

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

Other issues occur such as reliability, call processing times and turnout times, and traffic which can affect the overall performance of response times.

An effective response force for a fire department is impacted not only by the spacing of fire stations but also by the type and amount of apparatus and personnel staffing the stations. To assemble the necessary apparatus, personnel, and equipment within the prescribed timeframe, all must be close enough to travel to the incident, if available upon dispatch. The placement and spacing of specialty equipment is always challenging.[69] Specialty units tend to be heavy rescue and hazmat units or command personnel. Most often there are less of these types of equipment and personnel compared to the first-line response of engines and ladder trucks. Selecting where to put specialty units requires extensive examination of current and future operations within the fire department and a set goal of response time objectives for all-hazards emergencies within a 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.[70]

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

Billings Fire Department Emergency Incidents and Response Analysis

The charts in this section, presented on the following pages, show the number of emergency incidents and the response time performance by each fire station. Fire stations and individual apparatus with heavy call volumes and/or long response times may be indicators that additional resources are needed.

An incident refers to an emergency, or emergencies, to which individual or multiple fire department mobile and personnel resources are dispatched to intervene and mitigate an emergent situation. An incident may require a single or multiple apparatus. A response refers to an individual unit being dispatched and traveling to the scene of an incident.

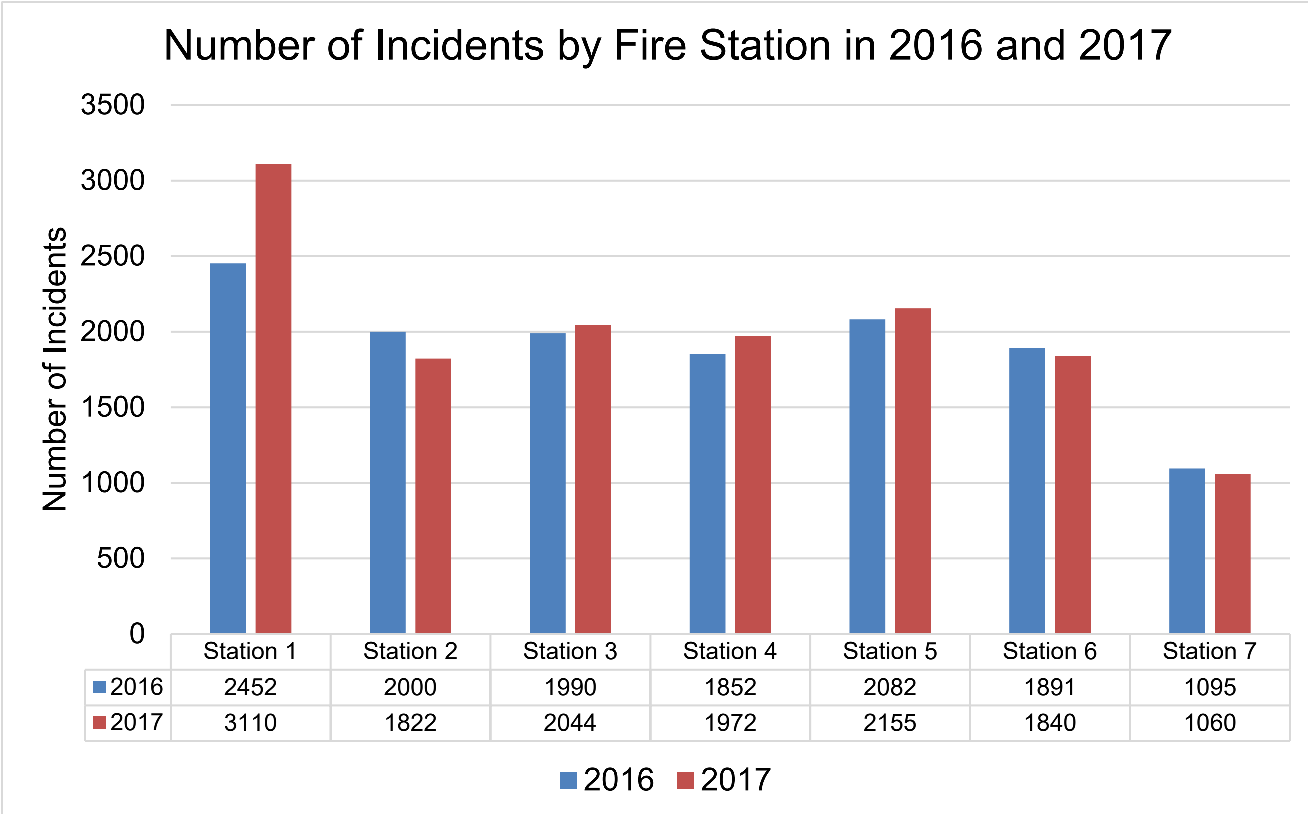

Figure 6: Number of Incidents by Fire Station in 2016 and 2017. The above chart depicts the incidents responded to in 2016 and 2017 by fire station.[71] The number of incidents indicates the service demand on the fire department in different areas of the city. Station 1 had the largest increase in the number of incidents from 2016 to 2017, while Station 2 saw a decrease.

[71] Information provided by Local 521

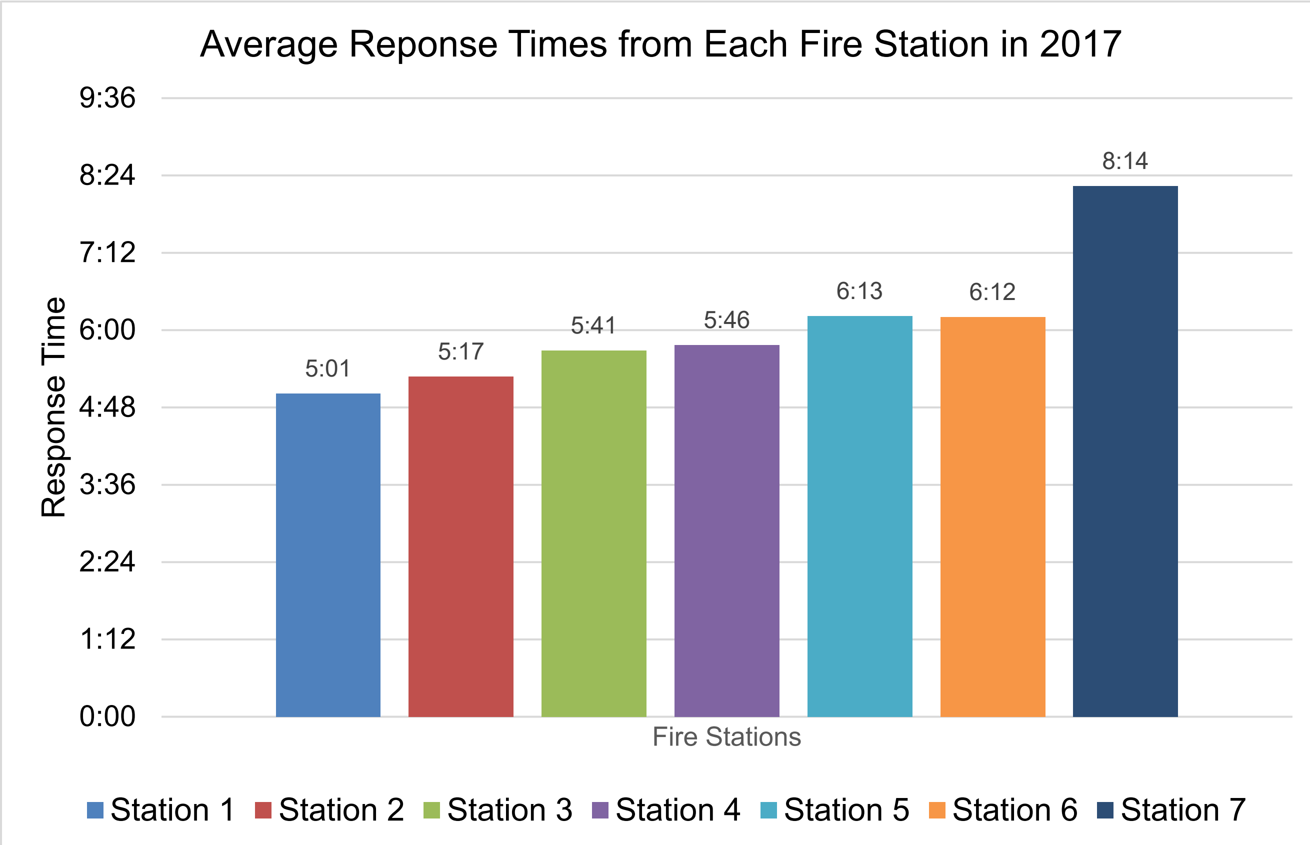

Figure 7: Average Response Times from Each Fire Station in 2017. The above chart depicts average response times from each fire station in 2017.[72] Response times are calculated from initial call to arrival on scene.

[72] Information provided by Local 521

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Mapping Analysis of the Billings Fire Department

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

Station	Address	Apparatus	Staffing
1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	3 Firefighters 3 Firefighters 1 Battalion Chief
2	501 S. 28th St.	Engine 2 Rescue 2	3 Firefighters Cross-staffed
3	1928 17th St. W.	Engine 3 Squad 3	3 Firefighters Reserve
4	475 6th St. W.	Engine 4 (Quint) MAC 4-Mobile Air Van Squad 4	3 Firefighters Special Request Reserve
5	605 S. 24th St. W.	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat Vehicle	3 Firefighters Reserve Special Request Special Request Special Request
6	1601 St. Andrews Dr.	Engine 6 Brush 6	3 Firefighters Special Request
7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	3 Firefighters Reserve Special Request Reserve

Table 6: Current Fire Station Locations. The above table displays where apparatus are housed and the typical daily staffing. A special request is an apparatus that responds to emergencies that have a low probability of occurring but have a high consequence result.

Travel times were modeled using ESRI ArcPro version 2.0 and ESRI StreetMap Premium version 17.1. Fire stations were identified on GIS maps as starting points with vehicles traveling at posted road speeds using historical traffic patterns occurring on Wednesdays at 5:00 PM.

Prior to drawing conclusions from the mapping analysis, the following issues should be taken into consideration:

- Modeled travel speeds are based on reasonable and prudent road speeds. Actual response speeds may be slower, and the associated travel times greater, with any unpredictable impedances including, but not limited to:
    - Traffic Incidents: Collisions and vehicle breakdowns causing lane blockages and driver distractions.
    - Work Zones: Construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present.
    - Weather: Severe weather and precipitation impacting roads may result in extra travel time and altered trip patterns.
    - Special Events: Demand may change due to identifiable and predictable causes.
    - Traffic Control Devices: Poorly timed or inoperable traffic signals, railroad grade crossings, speed control systems, and traveler information signs contribute to irregularities in travel time.
    - Inadequate Road or Transit Capacity: The interaction of capacity problems with the aforementioned sources causes travel time to expand much faster than demand.[73]

- Larger emergency vehicles are generally more cumbersome and require greater skill to maneuver. Therefore, response by these vehicles may be more negatively affected by weight, size, and in some cases, inability to travel narrow surface streets.
- 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.
- The reliability of a community's hydrant system to supply water to fire apparatus.
- Weather conditions

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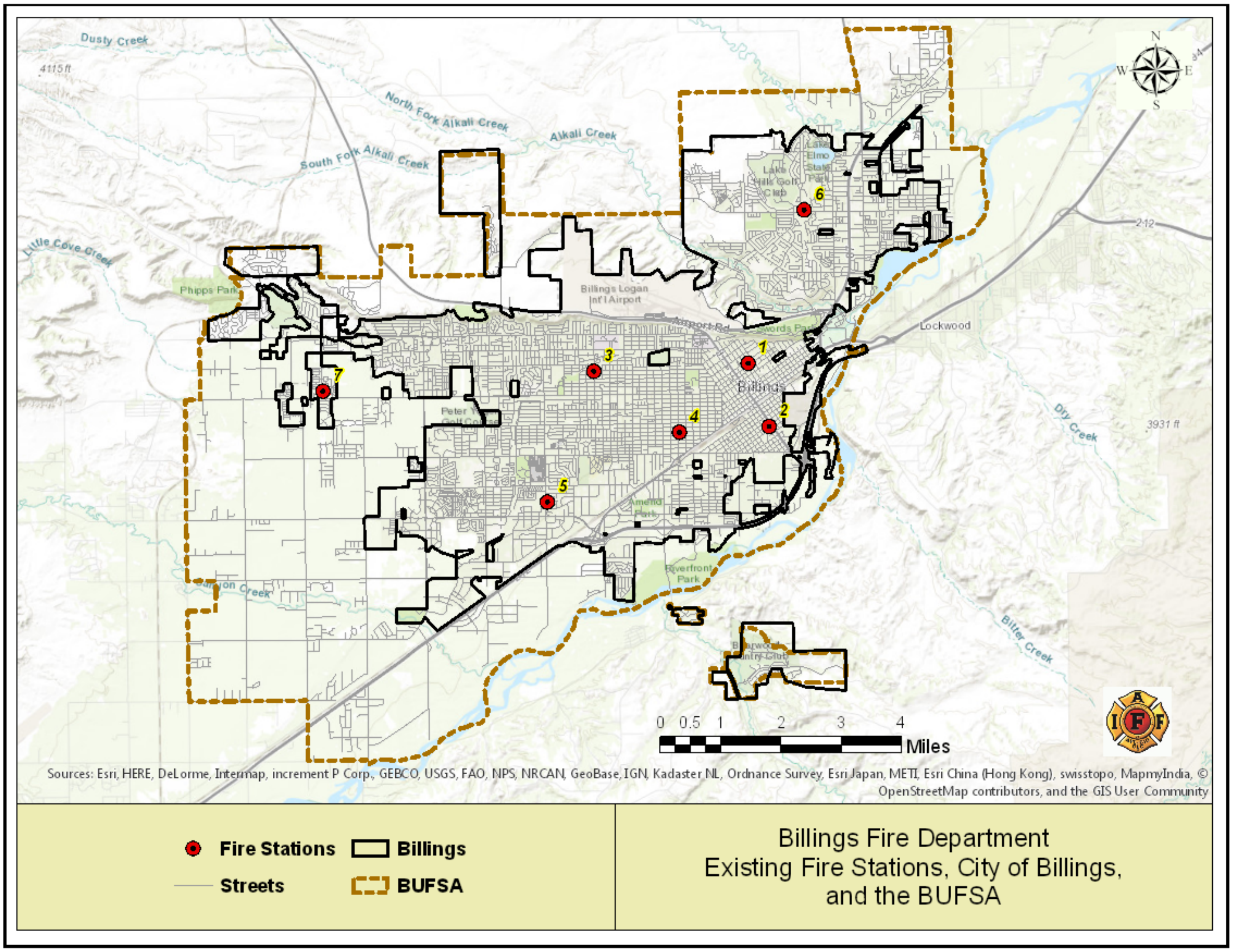
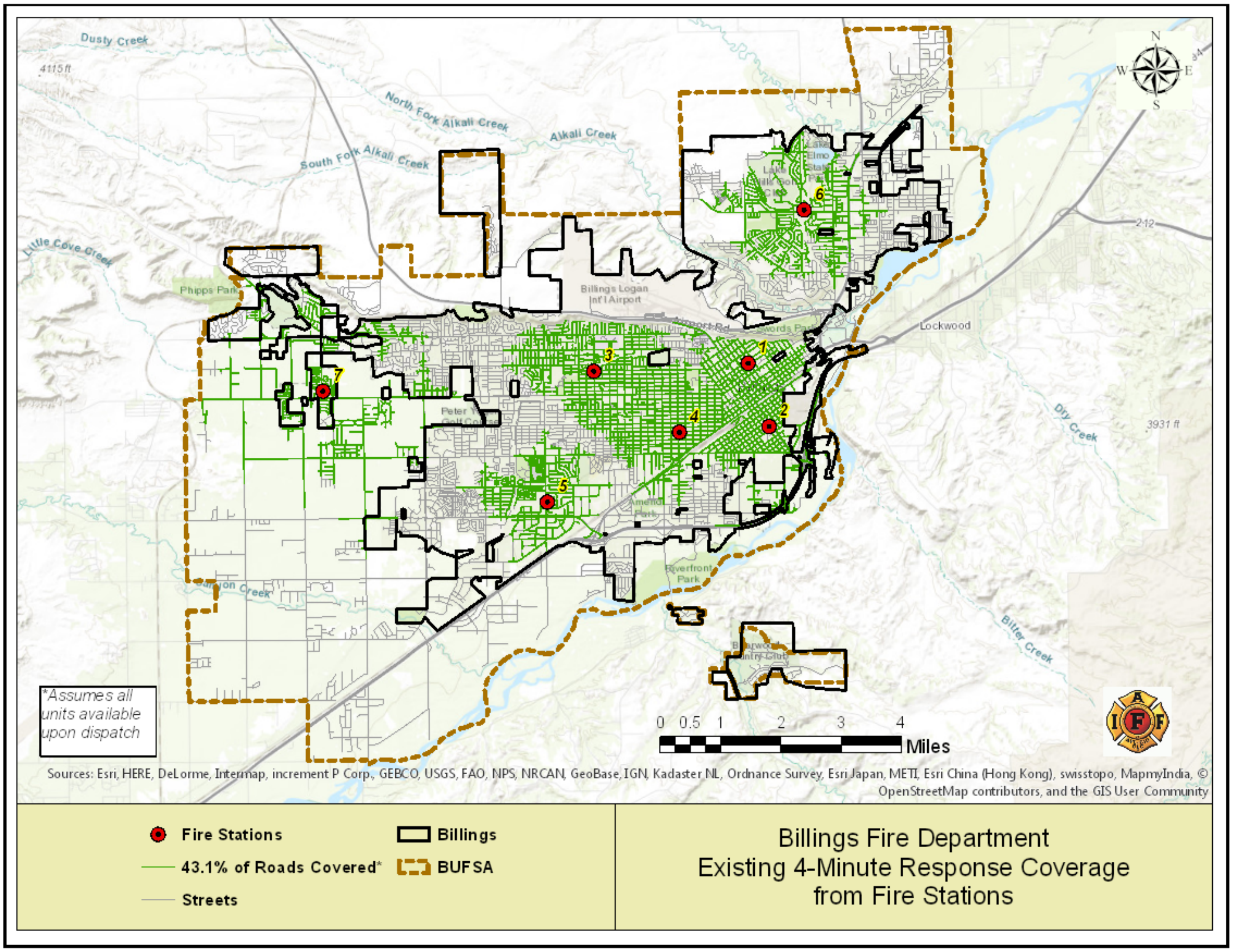
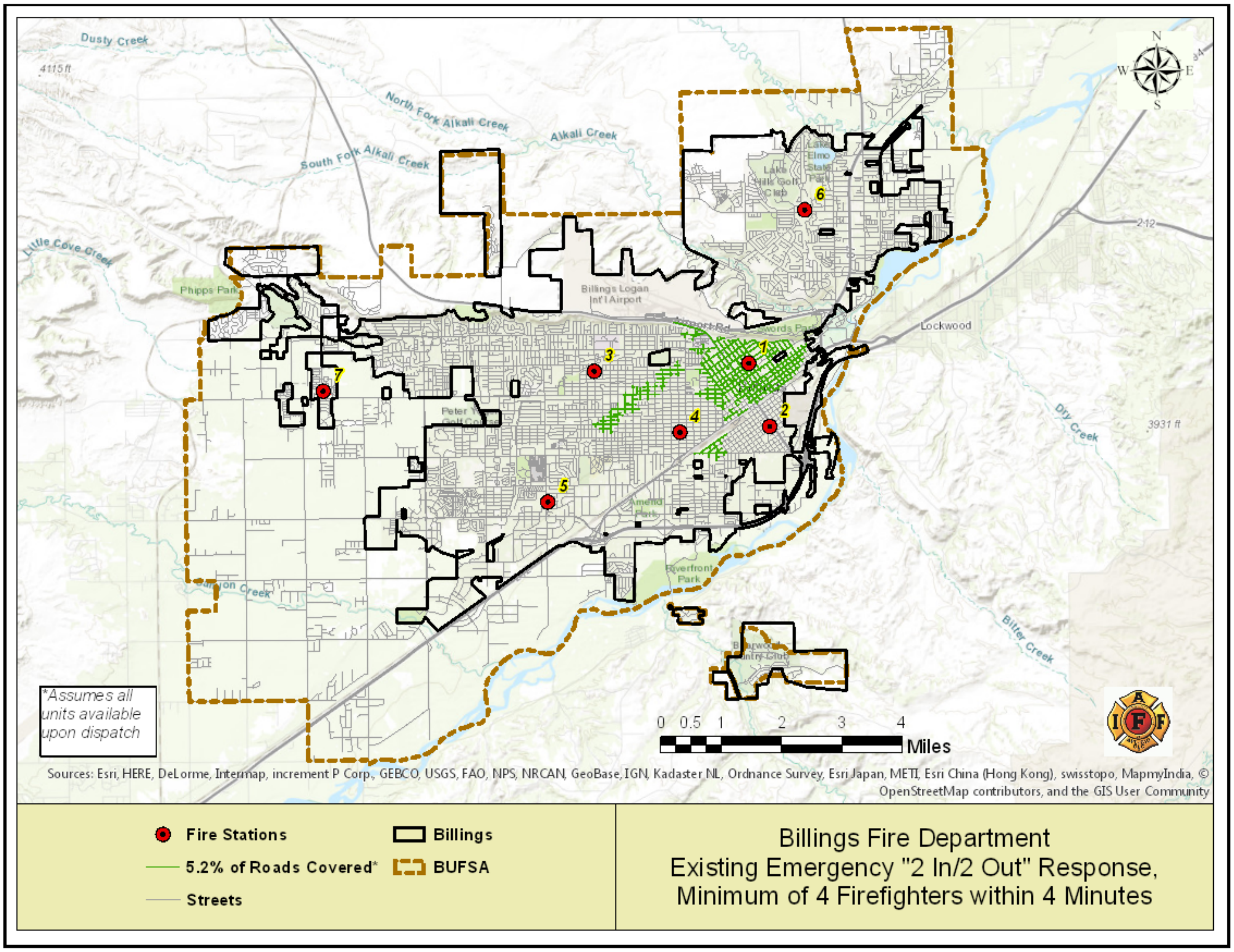
[73] David Shrank and Tim Lomax, The 2003 Urban Mobility Report, (Montana Transportation Institute, Montana A&M University: September 2003).



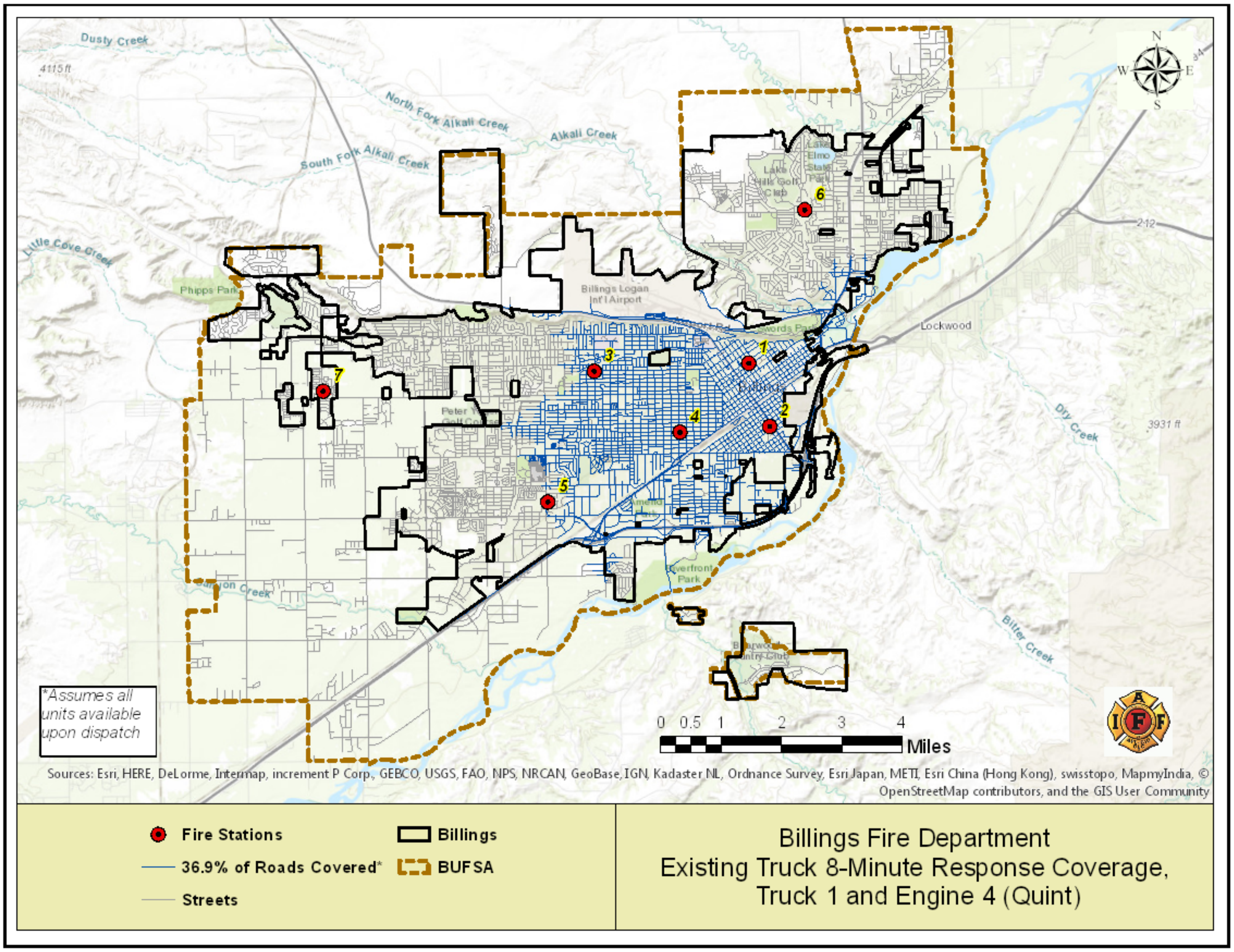
Map 1: Existing Fire Stations, City of Billings, and the BUFSA. Map 1 identifies the existing fire stations and response area for Billings and the BUFSA. The Billings Fire Department currently responds from 7 fire stations. The City of Billings is approximately 43 square miles and the total area including the BUFSA is approximately 90 square miles.



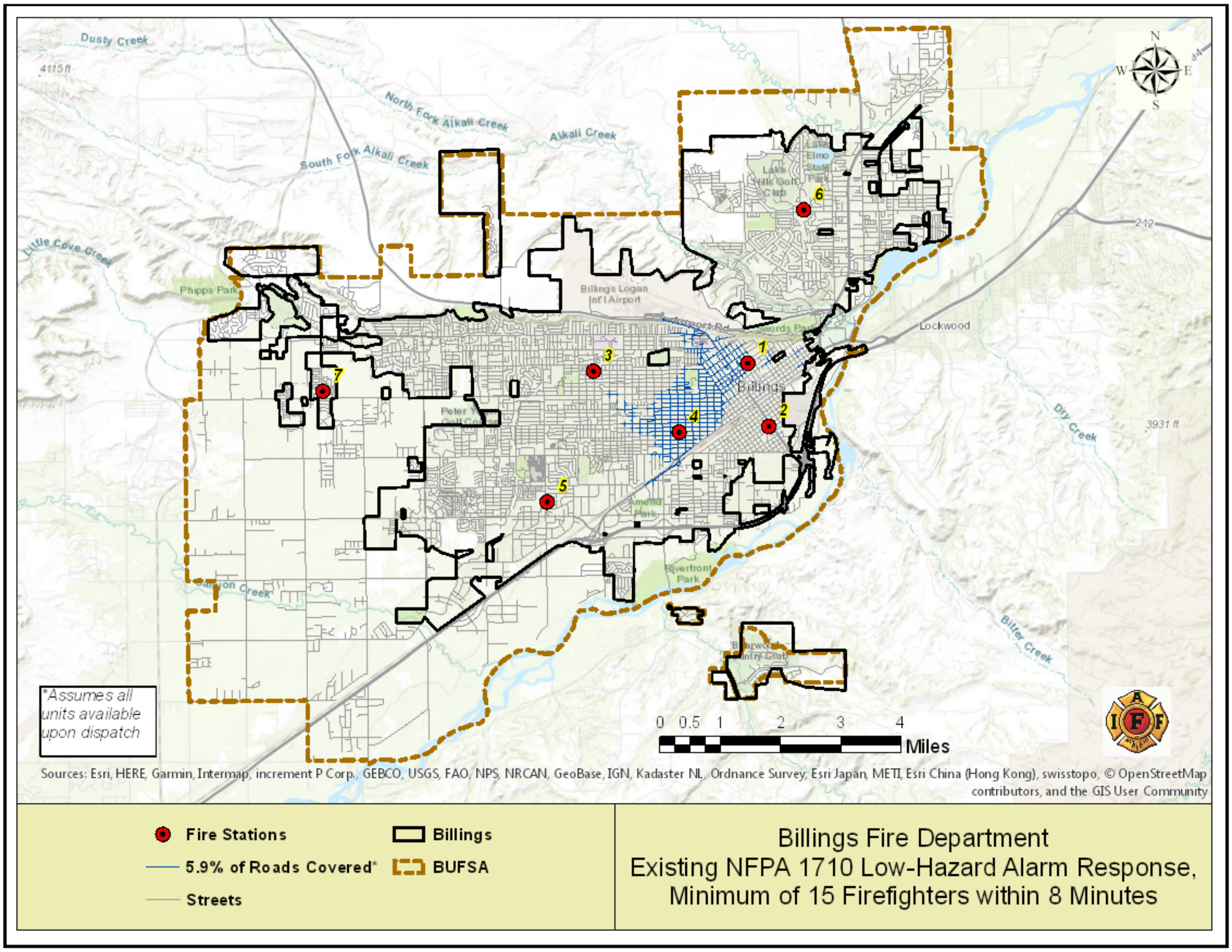
Map 2: Existing 4-Minute Response Coverage from Fire Stations. Map 2 identifies those roads in the BUFSA where companies can currently respond within 4 minutes or less of travel from existing fire stations. Currently, units are capable of responding on 43.1% of roads within the response jurisdiction, assuming units are available to respond immediately upon dispatch.



Map 3: Existing Emergency "2 In/2 Out" Response, Minimum of 4 Firefighters within 4 Minutes. Map 3 identifies those roads where a minimum of 4 firefighters can assemble on scene within 4 minutes to meet the objectives of NFPA 1710 and OSHA's "2 In/2 Out" Regulation. Currently, 4 firefighters can assemble on 5.2% of all roads located in the response jurisdiction in 4 minutes or less of travel time, assuming units are available to respond immediately upon dispatch.



Map 4: Existing Truck 8-Minute Response Coverage, Truck 1 and Engine 4 (Quint). Map 4 identifies those roads in the BUFSA where Truck 1 and Engine 4, a quint, can respond within 8 minutes. Currently, Engine 4 and Truck 1 would be capable of responding on 36.9% of roads within the response jurisdiction, assuming they are available to respond immediately upon dispatch.



Map 5: Existing NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes.
Map 5 identifies those roads where a minimum of 15 firefighters can assemble on scene within 8 minutes to meet the objectives of NFPA 1710. Currently, because suppression apparatus are only staffed with three firefighters the department can only assemble 15 firefighters on 5.9% of all roads located in the response jurisdiction within 8 minutes or less of travel time, assuming units are available to respond immediately upon dispatch.

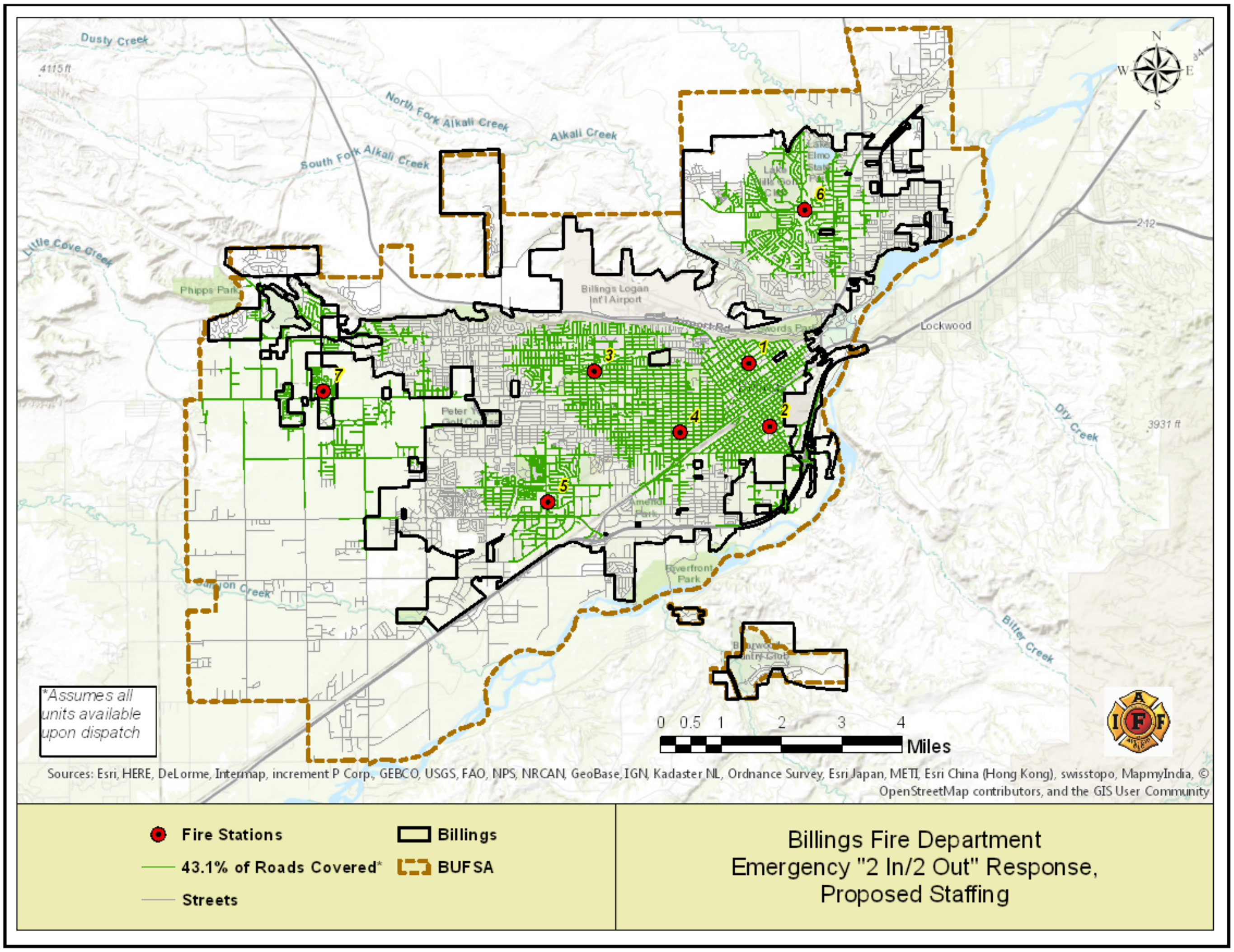
Proposed Emergency Response Capabilities- Recommended Staffing

For this portion of the study, an alternate staffing scenario was examined. In this proposal, fire suppression apparatus would each deploy with four firefighters[74]. The following maps depict the changes in coverage areas likely to occur pursuant to implementing the recommended staffing.

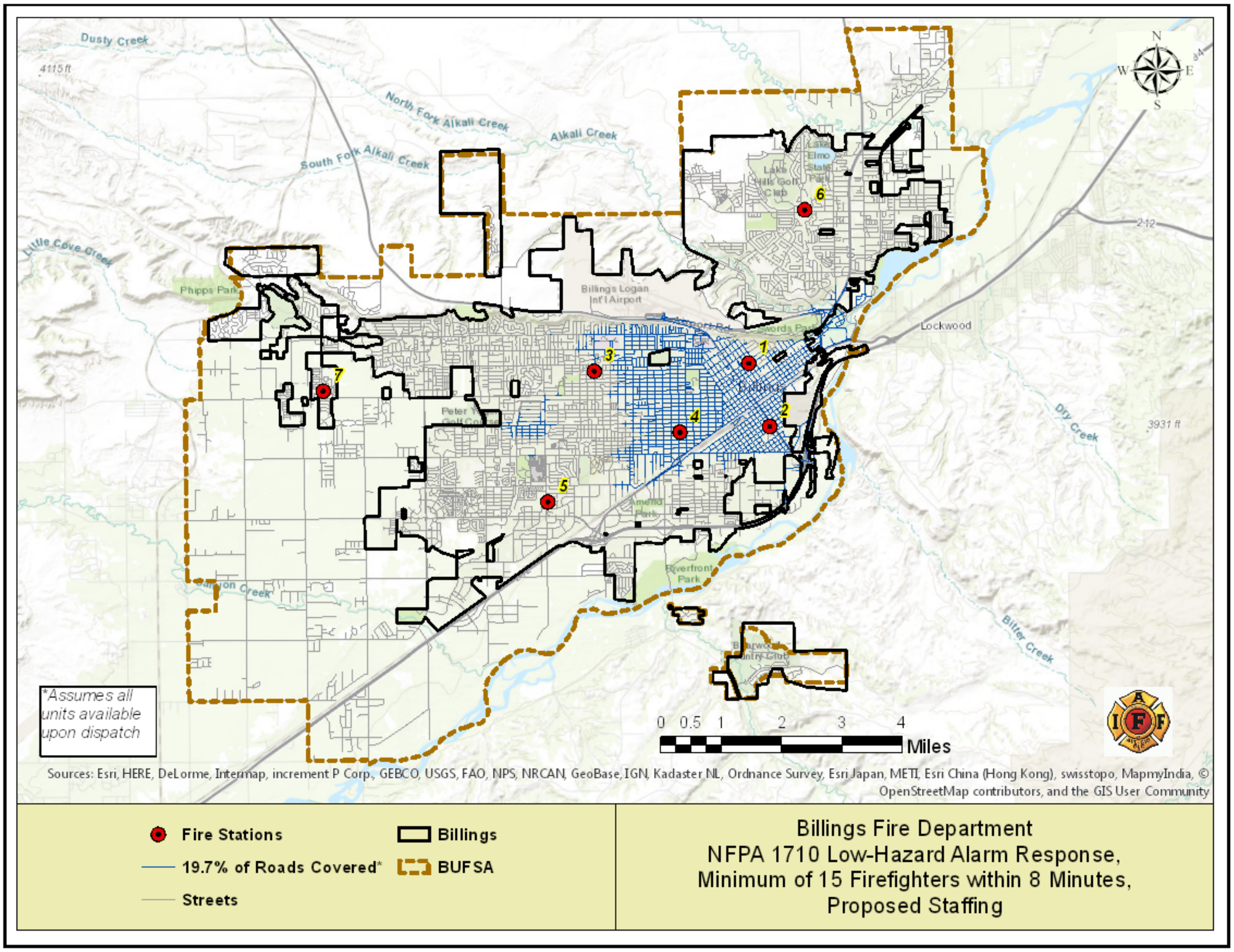
Station	Address	Apparatus	Staffing
1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	4 Firefighters 4 Firefighters 1 Battalion Chief
2	501 S. 28th St.	Engine 2 Rescue 2	4 Firefighters Cross-staffed
3	1928 17th St. W.	Engine 3 Squad 3	4 Firefighters Reserve
4	475 6th St. W.	Engine 4 (Quint) MAC 4-Mobile Air Van Squad 4	4 Firefighters Special Request Reserve
5	605 S. 24th St. W.	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat Vehicle	4 Firefighters Reserve Special Request Special Request Special Request
6	1601 St. Andrews Dr.	Engine 6 Brush 6	4 Firefighters Special Request
7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	4 Firefighters Reserve Special Request Reserve

Table 7: Fire Stations and Proposed Staffing. The above table displays where apparatus are housed and the proposed typical daily staffing to meet the objectives of NFPA 1710 regarding the minimum number of firefighters per apparatus.

[74] NFPA 1710 (2016) 5.2.3.1.2 and 5.2.3.1.2.1.



Map 6: Emergency "2 In/2 Out" Response, Proposed Staffing. Map 6 identifies those roads where a minimum of 4 firefighters would be able to assemble on scene within 4 minutes if fire suppression apparatus were staffed with 4 personnel each. Under the proposal, 4 firefighters would be able to assemble on 43.1% of all roads located in the BUFSA in 4 minutes or less of travel time, assuming units are available to respond immediately upon dispatch. This is an 87.9% increase in road coverage above current conditions.



Map 7: NFPA 1710 Low-Hazard Alarm Response, Minimum of 15 Firefighters within 8 Minutes, Proposed Staffing. Map 7 depicts those roads where the fire department would be able to respond with at least fifteen personnel within an 8-minute time frame in accordance with NFPA 1710. If all fire suppression units were to be staffed with a minimum of 4 personnel, 19.7% of all roads in the BUFSA would receive a sufficient number of personnel within 8 minutes of receiving an alarm, assuming units are available to respond immediately upon dispatch. This is a 70% increase in road coverage above current conditions.

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ArcGIS Location-Allocation Tool

Within the ArcGIS Network Analyst toolset, the Location-Allocation tool can create suitable location(s) for a facility or multiple facilities that provide a service within a community. Different facilities require different locations based on the services they provide and to whom they serve. In the case of locating fire stations, a community must carefully place fire stations in areas to reach the most people within the shortest amount of time with the right amount of resources. In order to determine the best possible number and locations of stations to meet demand, the Location Allocation tool was used to perform an analysis to create various facility configurations for the Billings Fire Department.

The Location-Allocation tool is helpful as it allows decision makers to have flexibility and offers the ability to present several different resource scenarios in an objective manner. Location-allocation can show where to place any number of fire stations needed or planned for the community. Location-allocation can keep specific fire stations in their current locations and look at relocating other fire stations for improved performance. The Location-Allocation tool can also site entirely new locations for all existing fire stations based on established demand points.

Depending on what scenario inputs are utilized while setting up the Location-Allocation tool, different locations can result from each scenario. For example, entering travel times of 4 minutes or 8 minutes may result in different station locations. Changing demand point criteria may also result in completely different station locations. Location-Allocation is a tool that helps decision makers answer questions; however it is not a tool that *completely* answers the questions. The software outputs a recommendation of a location or locations based on time requirements by demand points. It is a starting point for determining the number of fire stations needed based on chosen demand. Other factors may play a role in final station locations that go beyond GIS capabilities such as anticipated community risk, frequency of simultaneous calls for service, level of service demanded by the community, and available land. The fire department (both administration and frontline personnel), and the community should all have input and come to an agreement on where to place any new fire stations within the jurisdiction.

The Location-Allocation tool uses demand points as features that are to be allocated to each individual fire station. For this analysis, U.S. Census population blocks from 2010 were used as demand points. The Location-Allocation tool was then asked to determine the placement of any number of points, in this case fire stations, which would be needed to reach the maximum amount of the demand points within a 4-minute travel time.

Other demand points that could be used in the analysis, if data are available, are historical incident locations, future population growth predictions, and city planning and zoning proposals. Historical incident data shows where demand concentrations have occurred. Future population growth predictions, in conjunction with the city's planning and zoning strategies, could be used to determine areas of future demand that may occur as the community expands into new areas. Historical incident data and future growth are critical elements when deciding where to place fire stations.

GIS Location-Allocation Proposal 1: Keep Existing Stations and Add Stations Needed to Reach 90% of the City's Population within 4 Minutes

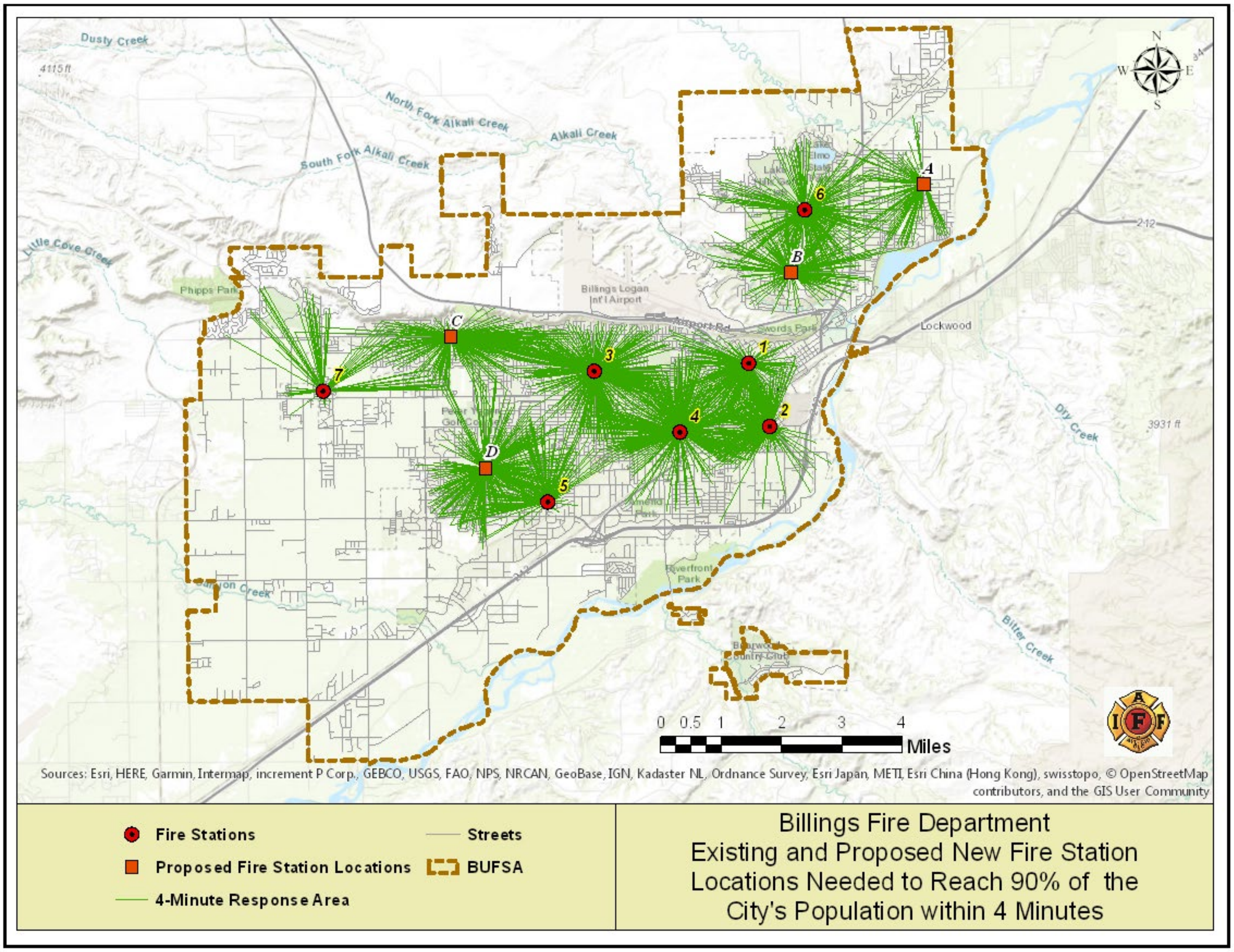
In this scenario, an alternate staffing and deployment scenario was examined showing the total number of fire stations needed to reach 90% of the City's population and keeping existing fire station locations. Using the results of the location-allocation analysis, four additional fire stations were added to the department. For the subsequent analysis that followed this particular proposal it was assumed that each station would deploy at least one engine company staffed with a minimum of four firefighters. If city decision makers were to implement this proposal, proposed stations may need additional apparatus to meet demand. As a means of determining what apparatus should be located in the proposed stations, the department should conduct an assessment of risks, hazards, and demand.

Station	Address	Apparatus	Staffing
1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	4 Firefighters 4 Firefighters 1 Battalion Chief
2	501 S. 28th St.	Engine 2 Rescue 2	4 Firefighters Cross-staffed
3	1928 17th St. W.	Engine 3 Squad 3	4 Firefighters Reserve
4	475 6th St. W.	Engine 4 (Quint) MAC 4-Mobile Air Van Squad 4	4 Firefighters Special Request Reserve
5	605 S. 24th St. W.	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat Vehicle	4 Firefighters Reserve Special Request Special Request Special Request
6	1601 St. Andrews Dr.	Engine 6 Brush 6	4 Firefighters Special Request

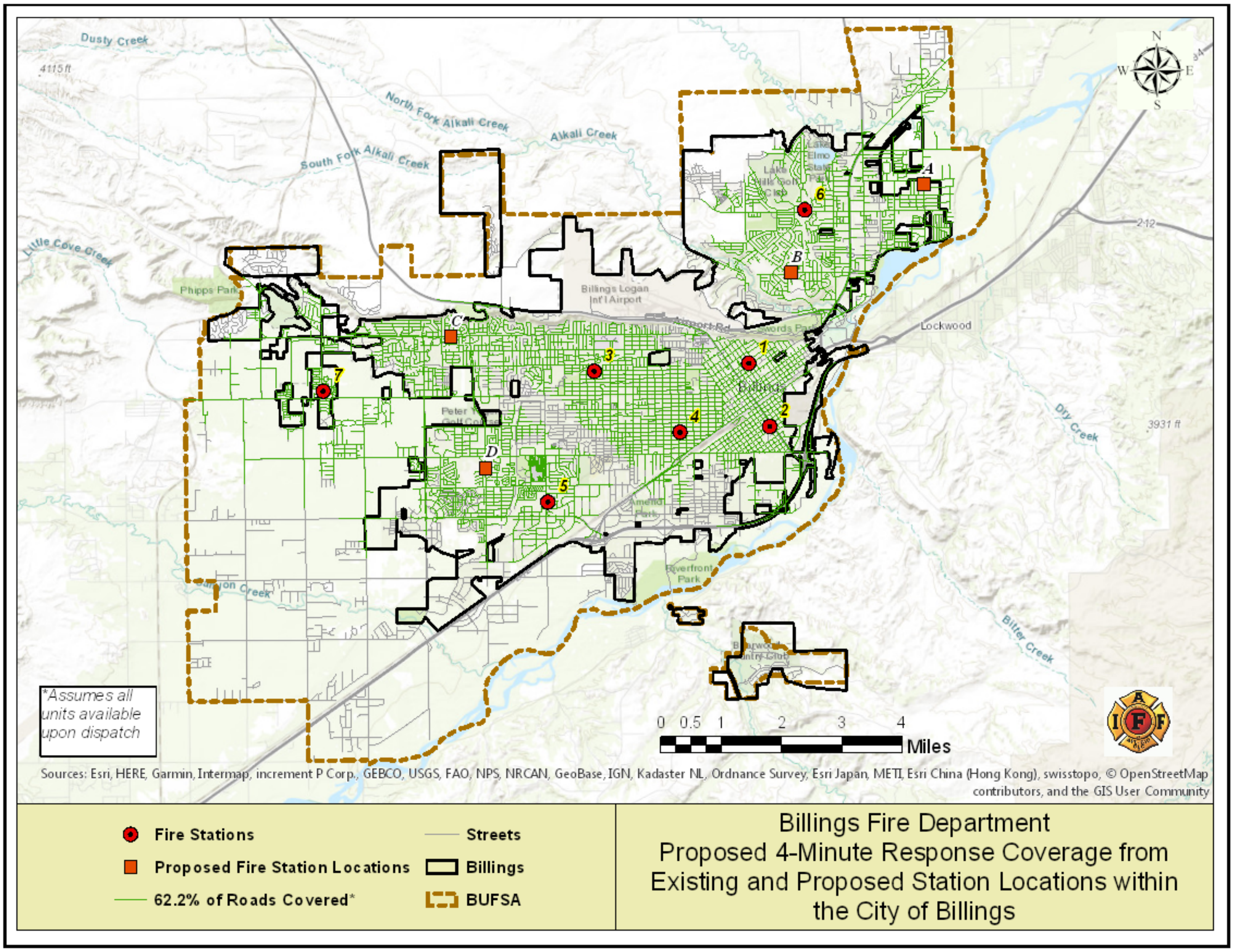
Table 8: Additional Stations Needed to Reach 90% of the City's Population within 4 Minutes. The above table displays where apparatus would be housed and the proposed typical daily staffing.

Station Continued	Address Continued	Apparatus Continued	Staffing Continued
7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	4 Firefighters Reserve Special Request Reserve
Proposed Station A	Bitterroot Dr. & Barrett Rd. -108.445385, 45.833732	Engine	4 Firefighters
Proposed Station B	W. Hilltop Rd. & Bazar Exchange -108.491181, 45.81289	Engine	4 Firefighters
Proposed Station C	Rimrock Rd. & Reimers Park Dr. -108.608318, 45.798553	Engine	4 Firefighters
Proposed Station D	S. 32nd St. W. & Sweetwater Dr. -108.5969, 45.766891	Engine	4 Firefighters

Table 8 Continued: Additional Stations Needed to Reach 90% of the City's Population within 4 Minutes. The above table displays where apparatus would be housed and the proposed typical daily staffing. Proposed stations are approximate addresses with the x, y coordinates of the location. Proposed stations may need additional apparatus to meet demand beyond an engine. As a means of determining what apparatus should be located in the proposed stations, the department should conduct an assessment of risks, hazards, and demand for the initial response area each station may serve.



Map 8: Existing and Proposed New Fire Station Locations Needed to Reach 90% of the City's Population within 4 Minutes. Map 8 depicts the results of the Location-Allocation analysis, which determined to keep the existing stations in addition to 4 additional fire stations that would be needed to reach 90% of the population in the City of Billings within a 4 minute travel time.



Map 9: Proposed 4-Minute Response Coverage from Existing and Proposed Station Locations within the City of Billings. Map 9 identifies those roads where companies would likely be able to reach within 4 minutes of travel and where a minimum of 4 firefighters would be able to assemble on scene. Units from these stations would be capable of responding on 62.2% of roads within the response jurisdiction, which is a 30.7% increase in road coverage above existing conditions.

GIS Location-Allocation Proposal 2: Relocate All Stations Needed to Reach 90% of the City's Population within 4 minutes.

In this scenario, an alternate staffing and deployment scenario was examined showing the total number of fire stations needed to reach 90% of the City's population by relocating all fire stations. Using the results of the Location-Allocation analysis, it was determined that 10 new fire stations would be needed to reach 90% of the population in Billings within 4 minutes. Current fire station locations were not considered. In this scenario, new proposed stations would deploy one engine staffed with a minimum of four firefighters, however additional apparatus staffed within industry standards may be needed based on fire department recommendations after a risk assessment. Current stations that would be relocated would transfer current staff and apparatus to the new fire station.

Based on the results, it is neither economically feasible nor needed for a city or fire department to relocate every fire station and create 10 new fire stations, however the analysis may reveal if current stations are out of place for optimal response within the jurisdiction. The following maps provide visualization which existing stations can remain in place, which should be relocated, and new stations that are needed to be built.

Determining factors were needed to assess which current stations could remain in place or need to be relocated. A straight line distance of ½ mile was used to measure current stations from proposed stations. If stations fell within half a mile of each other, the current station was recommended to remain in place. One half mile, or approximately six blocks was used, since 4-minute travel coverage is most often approximately the same for two points from distances within ½ mile of each other. Current stations that were beyond half a mile of proposed stations are recommended to be relocated.

- Based on the results, 5 current stations located within ½ mile of proposed fire stations are recommended to remain in place: Station 1, Station 3, Station 4, Station 6, and Station 7.

Current stations that were beyond half a mile of proposed stations are recommended to be relocated. The exception in this case is Station 7, since it is the newest station in the department and covers the rural area of the response jurisdiction, therefore has the lowest call volume. It is not economically feasible to move Station 7 within a mile of the proposed location.

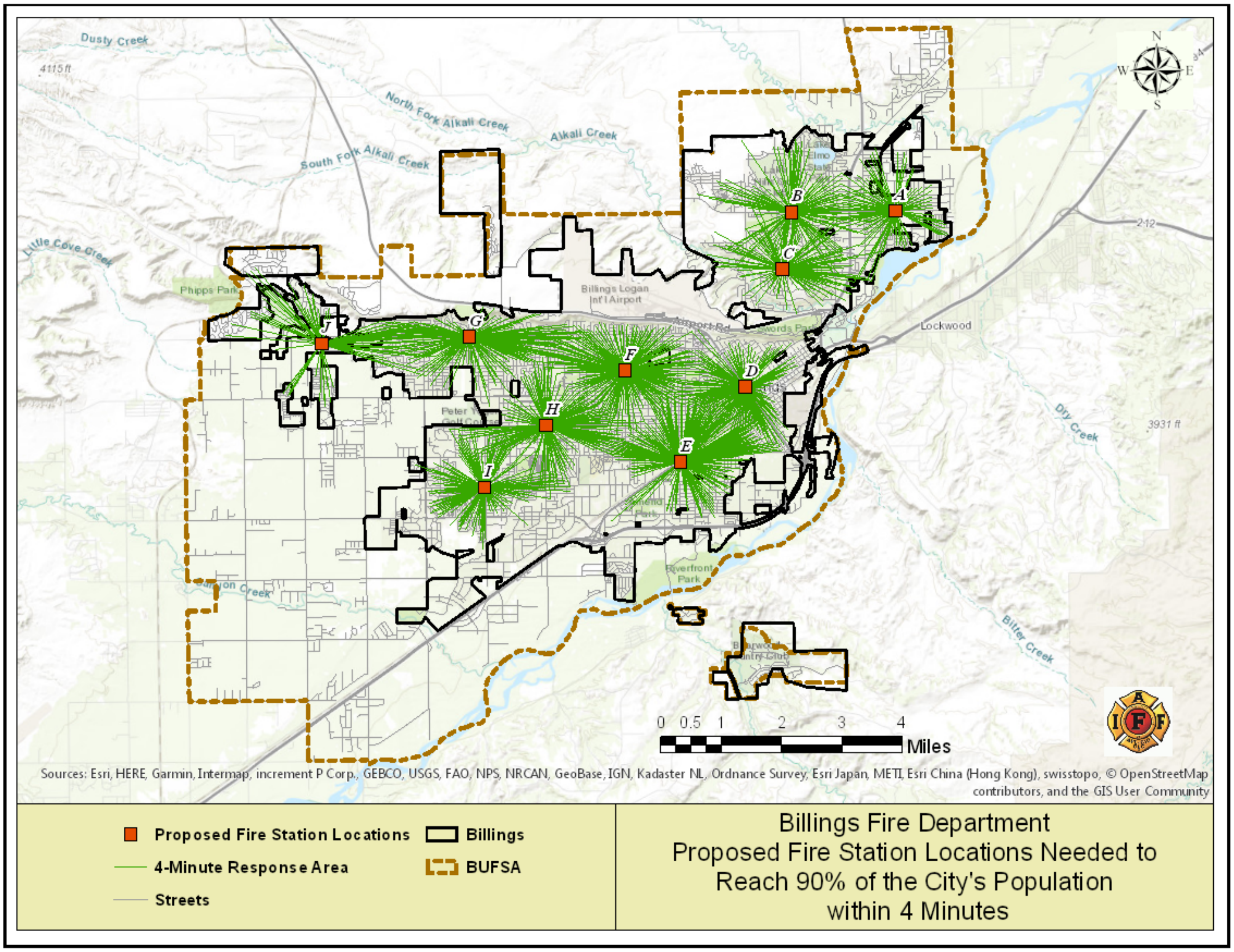
- Based on the results, 2 fire stations that are beyond half a mile of proposed fire stations and should be relocated. Station 2 is recommended to be relocated to Proposed Station H. Station 5 is recommended to be relocated to Proposed Station I.

Based on the criteria to reach 10 total stations, 3 additional stations are needed.

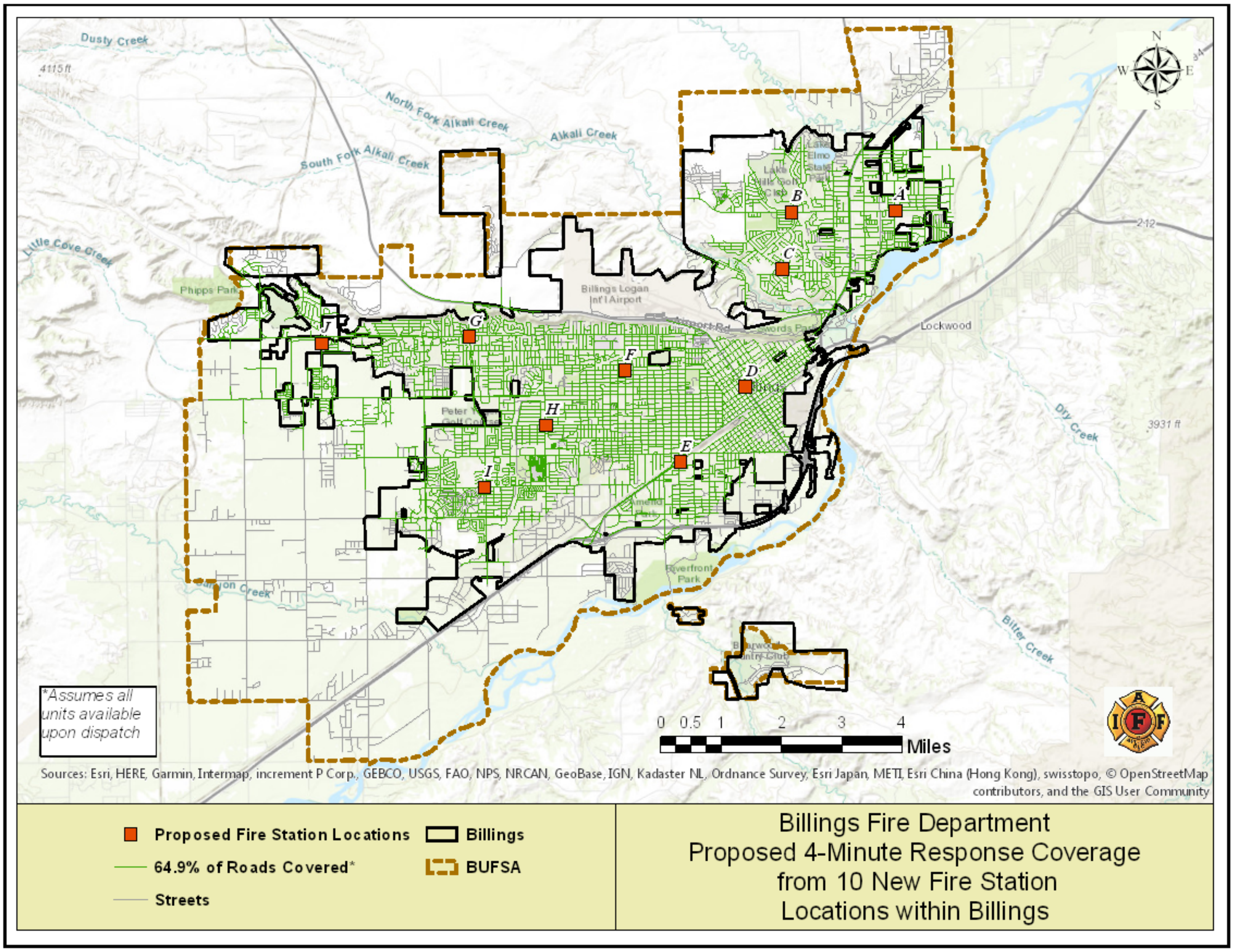
- The new stations to be added to the department are Proposed Station A, Proposed Station C, and Proposed Station G.

Proposed Stations	Approximate Address	Proposed Apparatus	Proposed Staffing
Station 1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	4 Firefighters 4 Firefighters 1 Battalion Chief
Station 3	1928 174th St. W.	Engine 3 Squad 3	4 Firefighters Reserve
Station 4	475 6th St. W.	Engine 4 MAC 4-Mobile Air Van Squad 4	4 Firefighters Special Request Reserve
Station 6	1601 St. Andrews Dr.	Engine 6 Brush 6	4 Firefighters Special Request
Station 7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	4 Firefighters Reserve Special Request Reserve
Proposed Station H (From Station 2)	Broadwater Ave. & 24th St. W. -108.576083, 45.776995	Engine 2 Rescue 2	4 Firefighters Cross-staffed
Proposed Station I (From Station 5)	Monad Rd. & S. 32nd St. W. -108.59736, 45.76228	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat	4 Firefighters Reserve Special Request Special Request Special Request
Proposed Station A	Wicks Ln. & Hawthorne Ln. -108.455178, 45.82741	Engine	4 Firefighters
Proposed Station C	Governors Blvd. & Aronson Ave. -108.49541, 45.814465	Engine	4 Firefighters
Proposed Station G	Zimmerman Trail & Rimrock Rd. -108.60193, 45.798484	Engine	4 Firefighters

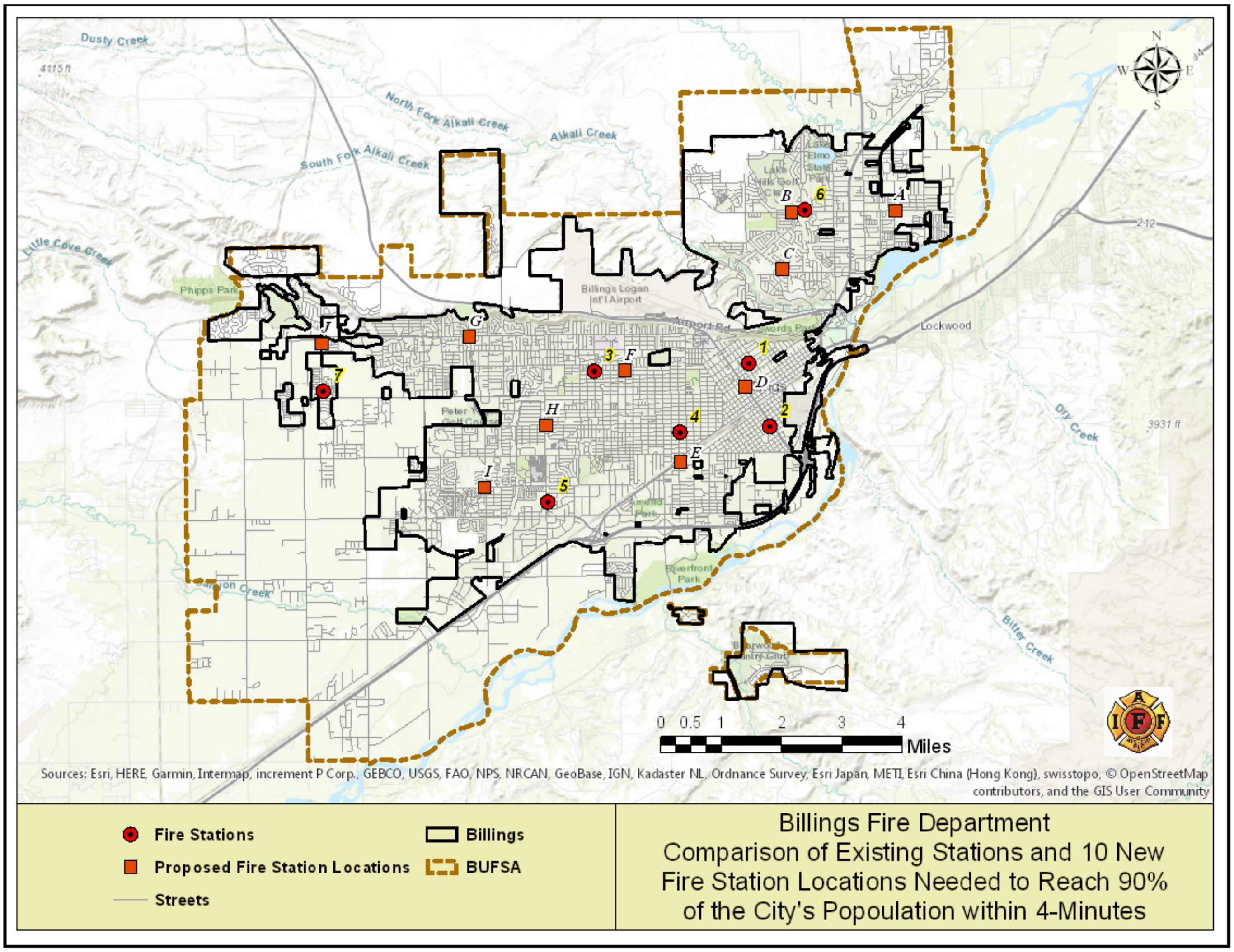
Table 9: Recommended Existing and New Stations Needed to Reach 90% of the City's Population within 4 Minutes. The above table displays the 10 combined current and proposed new fire stations along with existing and proposed minimum apparatus and staffing to reach 90% of the city's population within 4 minutes. New stations would be need in the area of Broadwater Ave & 24th St. W., Monad Road & S 32nd St. W., Wicks Lane & Hawthorne Lane, W. Govenors Blvd., & Aronson Ave., and Zimmerman Trail, & Rimrock Road.



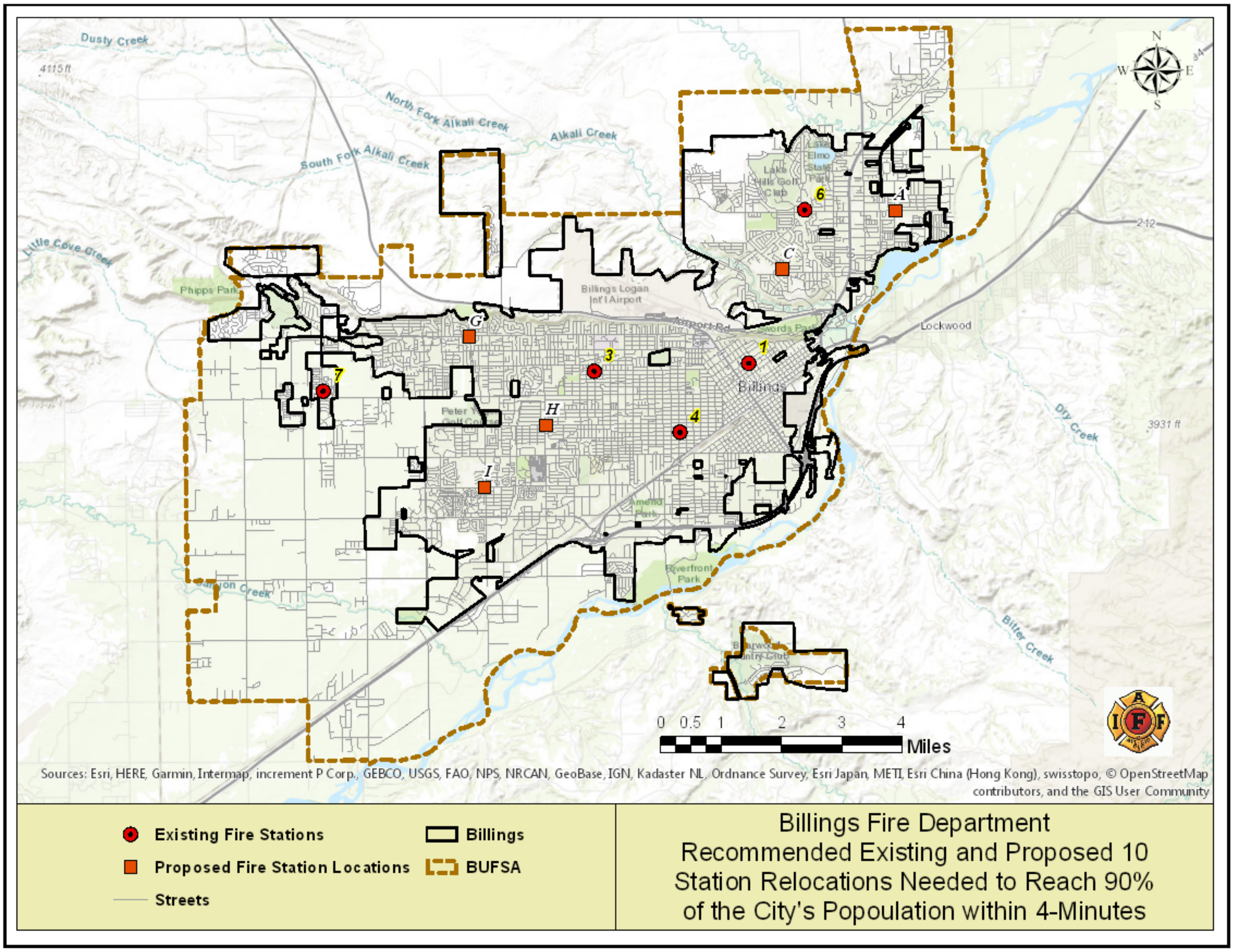
Map 10: Proposed New Fire Station Locations Needed to Reach 90% of the City's Population within 4 Minutes. Map 10 depicts the results of the location-allocation analysis, which determined where fire stations would be needed in order to reach the 90% of the population in Billings within a 4-minute travel time if all stations were relocated and new stations were added to address population. If the Billings Fire Department could relocate all fire stations, 10 fire stations would be needed to reach 90% of the population within Billings within 4 minutes of travel time.



Map 11: Proposed 4-Minute Response Coverage from 10 New Fire Station Locations within Billings. Map 11 identifies those roads where companies would be able to reach within 4 minutes of travel from the 10 proposed new fire station locations and where a minimum of 4 firefighters would be able to assemble on scene. Units would be capable of responding on 64.9% of roads within the response jurisdiction within 4 minutes, which is a 33.6% increase in road coverage above current conditions.



Map 12: Comparison of Existing Stations and 10 New Station Locations Needed to Reach 90% of the City's Population within 4 Minutes. Map 12 depicts the locations of existing fire stations in relation to the locations of the 10 new fire stations, as determined by the location-allocation analysis.



Map 13: Recommended Existing and Proposed 10 Station Locations Needed to Reach 90% of the City's Population within 4 Minutes. Map 13 depicts the recommended relocations of existing and proposed fire stations needed to reach 90% of the city's population within 10 minutes.

GIS Location-Allocation Proposal 3: Keep Existing Stations and Add Stations Needed to Reach 90% of the BUFSA's Population within 4 Minutes

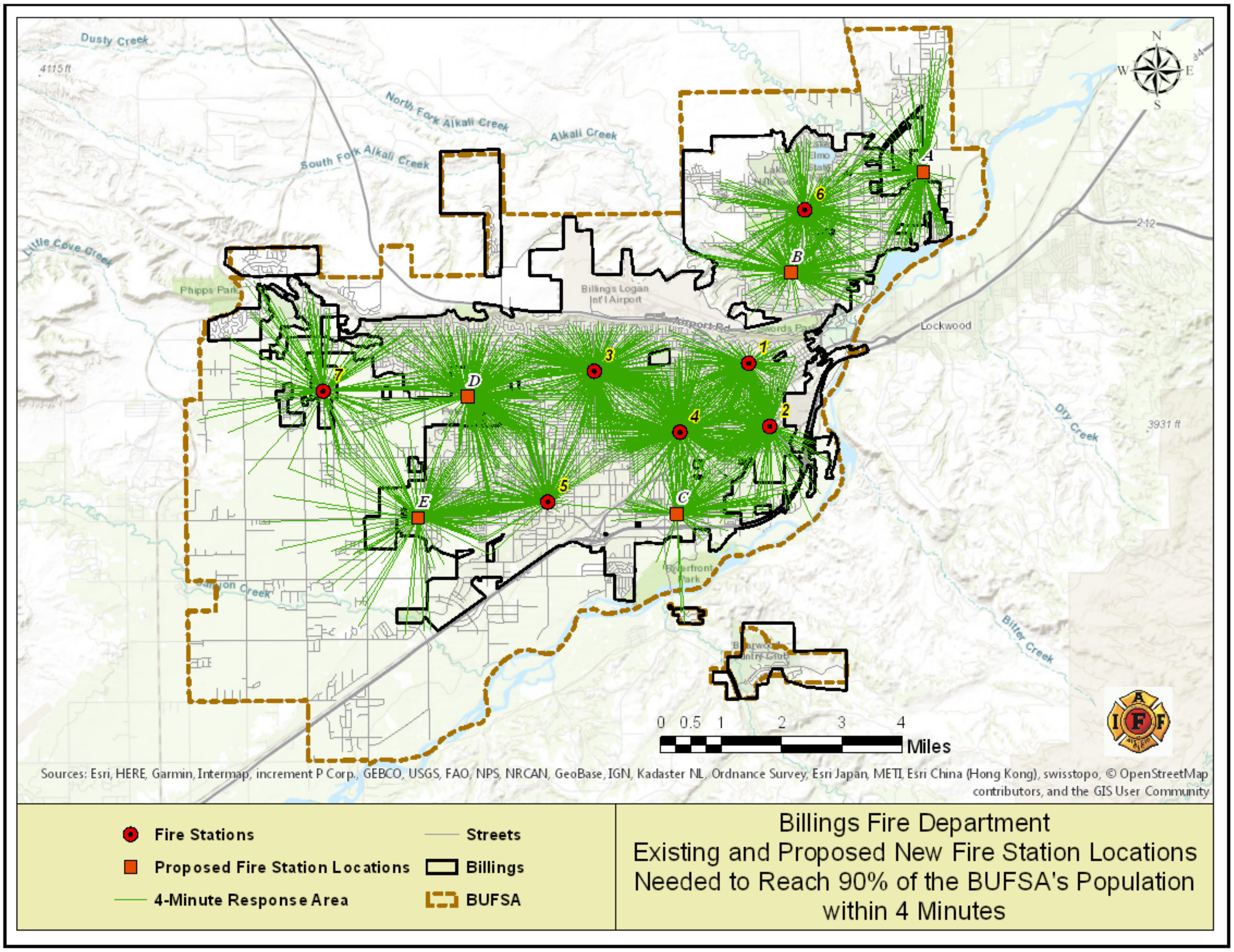
In this scenario, an alternate staffing and deployment scenario was examined showing the total number of fire stations needed to reach 90% of the BUFSA'S population and keeping existing fire station locations. Using the results of the location-allocation analysis, it was determined that five additional fire stations would be needed to reach 90% of the BUFSA's population within a 4-minute travel time. Each station would deploy at least one apparatus staffed with a minimum of four firefighters. If city decision makers were to implement this proposal, proposed stations may need additional apparatus to meet demand. As a means of determining what apparatus should be located in the proposed stations, the department should conduct an assessment of risks, hazards, and demand.

Station	Address	Apparatus	Staffing
1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	4 Firefighters 4 Firefighters 1 Battalion Chief
2	501 S. 28th St.	Engine 2 Rescue 2	4 Firefighters Cross-staffed
3	1928 17th St. W.	Engine 3 Squad 3	4 Firefighters Reserve
4	475 6th St. W.	Engine 4 (Quint) MAC 4-Mobile Air Van Squad 4	4 Firefighters Special Request Reserve
5	605 S. 24th St. W.	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat Vehicle	4 Firefighters Reserve Special Request Special Request Special Request
6	1601 St. Andrews Dr.	Engine 6 Brush 6	4 Firefighters Special Request

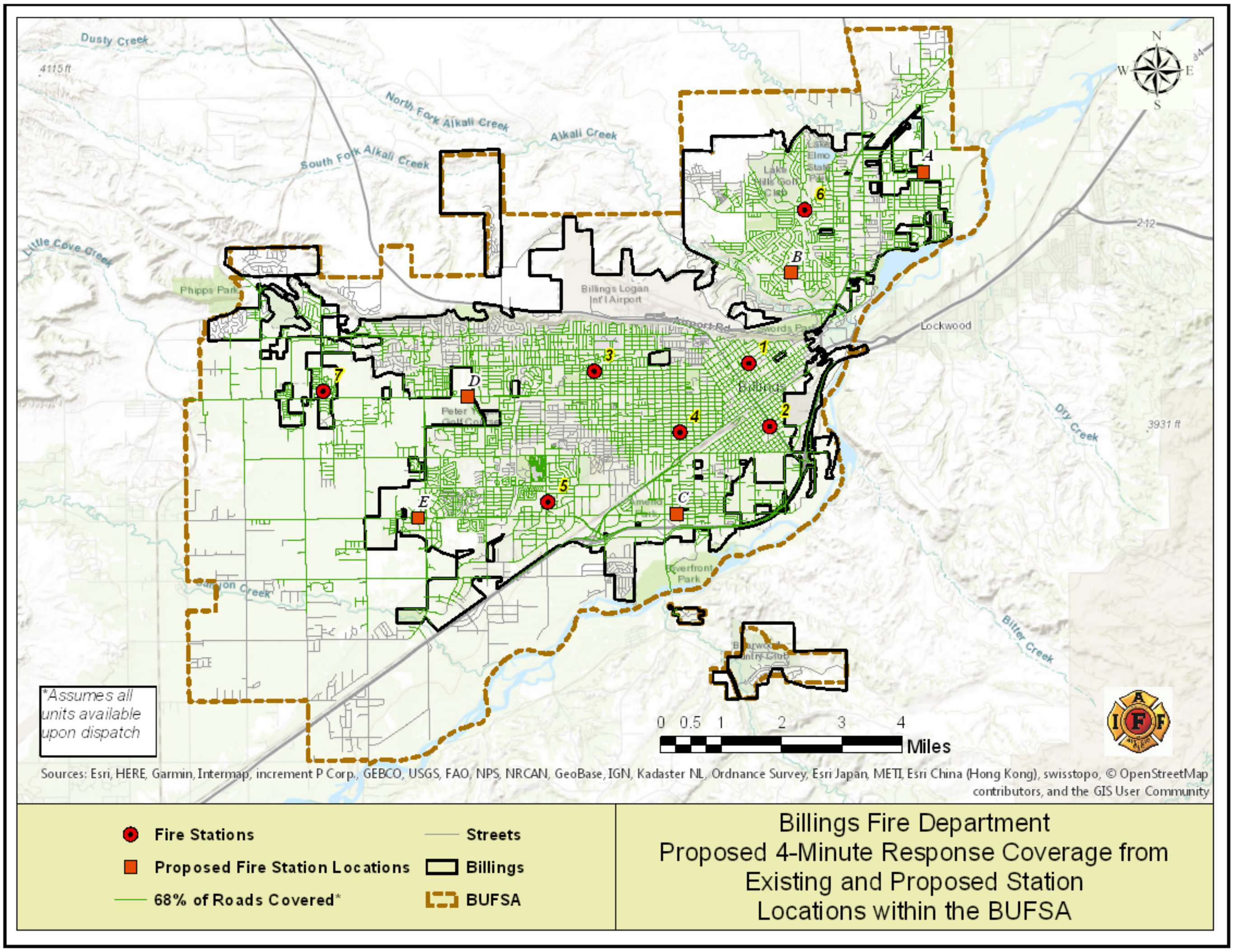
Table 10: Additional Stations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. The above table displays where apparatus would be housed and proposed minimum apparatus and staffing.

Station Continued	Address Continued X, Y Coordinates	Apparatus Continued	Staffing Continued
7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	4 Firefighters Reserve Special Request Reserve
Proposed Station A	Bitterroot Dr. & Mading Dr. -108.445433, 45.836645	Engine	4 Firefighters
Proposed Station B	W. Hilltop Rd. & Bazar Exchange -108.491181, 45.81289	Engine	4 Firefighters
Proposed Station C	King Ave. E. & Calhoun Ln. -108.531511, 45.75538	Engine	4 Firefighters
Proposed Station D	Grand Ave. & Zimmerman Ln. -108.602725, 45.7841	Engine	4 Firefighters
Proposed Station E	King Ave. & Shiloh Rd. -108.620153, 45.7551	Engine	4 Firefighters

Table 10 Continued: Additional Stations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. The above table displays where apparatus would be housed and proposed minimum apparatus and staffing. Proposed stations are approximate addresses with the x, y coordinates of the location. Proposed stations may need additional apparatus to meet demand beyond an engine. As a means of determining what apparatus should be located in the proposed stations, the department should conduct an assessment of risks, hazards, and demand for the initial response area of the city each station may serve.



Map 14: Existing and Proposed New Fire Station Locations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. Map 14 depicts the results of the location-allocation analysis, which determined where 5 additional fire stations would be needed in order to reach 90% of the population in the BUFSA within 4 minutes of travel time.



Map 15: Proposed 4-Minute Response Coverage from Existing and Proposed Station Locations within the BUFSA. Map 15 identifies those roads where companies would reach within 4 minutes of travel time from current and proposed fire station locations located in BUFSA and where a minimum of 4 firefighters would be able to assemble on scene. Units from these stations would be capable of responding on 68% of roads within the response jurisdiction, which is a 36.3% increase in road coverage above current conditions.

GIS Location-Allocation Proposal 4: Relocate All Stations Needed to Reach 90% of the BUFSA's Population within 4 minutes.

In this scenario, an alternate staffing and deployment scenario was examined showing the total number of fire stations needed to reach 90% of the BUFSA's population by relocating all fire stations. Using the results of the Location-Allocation analysis, it was determined that 12 new fire stations would be needed to reach 90% of the population in BUFSA within 4 minutes. Current fire station locations were not considered. In this scenario, new proposed stations would deploy one engine staffed with a minimum of four firefighters, however additional apparatus staffed within industry standards may be needed based on fire department recommendations after a risk assessment. Current stations that would be relocated would transfer current staff and apparatus to the new fire station.

Based on the results, it is neither economically feasible nor needed for a city or fire department to relocate every fire station and create 12 new fire stations, however the analysis may reveal if current stations are out of place for optimal response within the jurisdiction. The following maps provide visualization which existing stations can remain in place, which should be relocated, and new stations that are needed to be built.

Determining factors were needed to assess which current stations could remain in place or need to be relocated. A straight line distance of ½ mile was used to measure current stations from proposed stations. If stations fell within half a mile of each other, the current station was recommended to remain in place. One half mile, or approximately six blocks was used, since 4-minute travel coverage is most often approximately the same for two points from distances within ½ mile of each other. Current stations that were beyond half a mile of proposed stations are recommended to be relocated.

- Based on the results, 3 current stations located within ½ mile of proposed fire stations or are recommended to remain are Station 1, Station 6, and Station 7.

Current stations that were beyond half a mile of proposed stations are recommended to be relocated. The exception in this case is Station 7, since it is the newest station in the department and covers the rural area of the response jurisdiction, therefore has the lowest call volume. It is not economically feasible to move Station 7 within a mile of the proposed location.

- Based on the results, 4 fire stations that are beyond half a mile of proposed fire stations and may be relocated are Station 2 may be relocated to proposed Station E. Station 3 may be relocated to proposed Station G. Station 4 may be relocated to proposed Station F. Station 5 may be relocated to proposed Station J.

Based on the criteria to reach 12 total stations, 5 additional stations are needed.

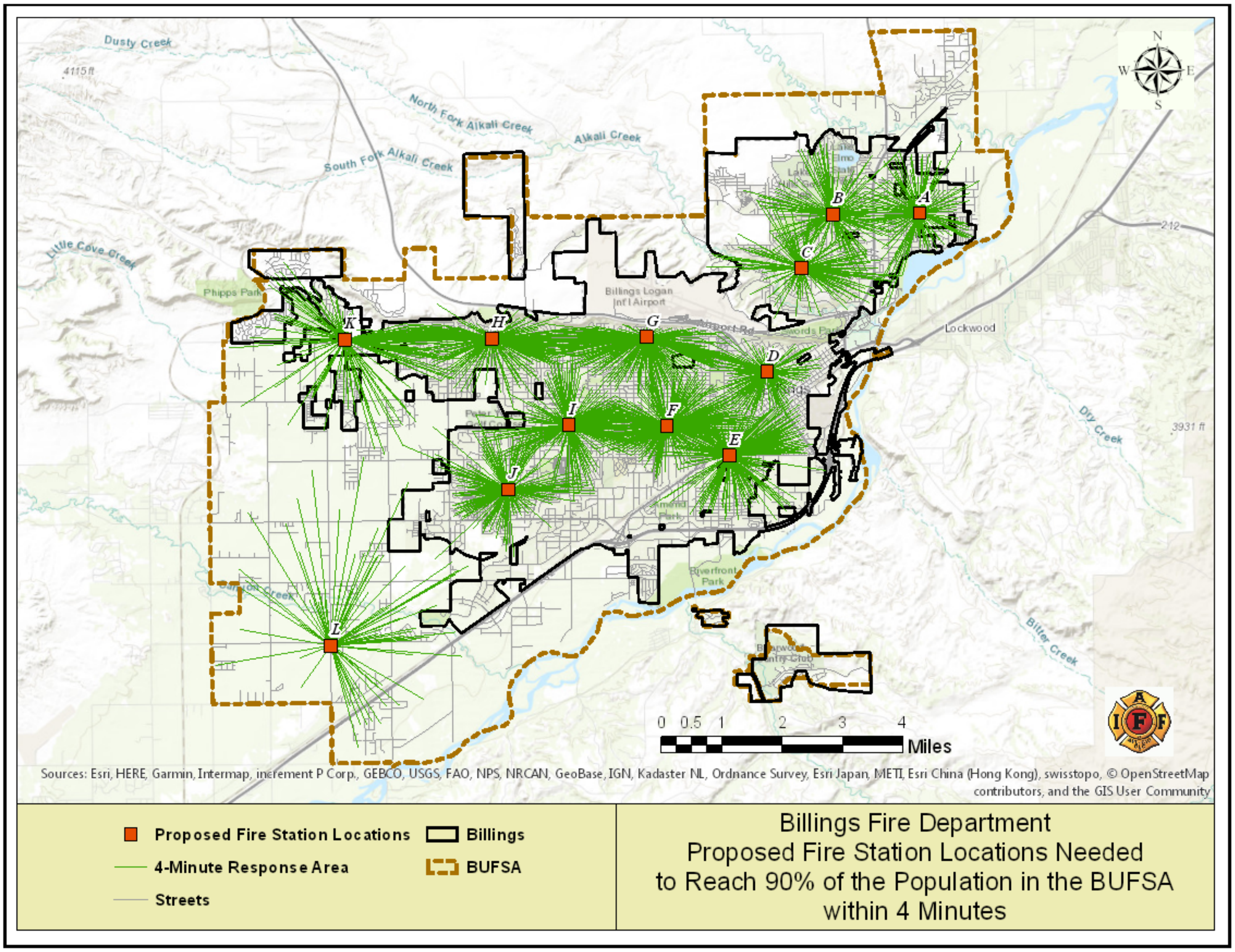
- The new stations to be added to the department are Proposed Station A, Proposed Station C, Proposed Station H, Proposed Station I, and Proposed Station L.

Proposed Stations	Approximate Address	Proposed Apparatus	Proposed Staffing
Station 1	2305 8th Ave. N.	Engine 1 Truck 1 Battalion Chief	4 Firefighters 4 Firefighters 1 Battalion Chief
Station 6	1601 St. Andrews Dr.	Engine 6 Brush 6	4 Firefighters Special Request
Station 7	1501 54th St. W.	Engine 7 Engine 77 Brush 7 Truck 77	4 Firefighters Reserve Special Request Reserve
Proposed Station E (From Station 2)	Broadwater Ave. & 24th St. W. -108.521445, 45.76984	Engine 2 Rescue 2	4 Firefighters Cross-staffed
Proposed Station G (From Station 3)	Rimrock Rd. & 13th St. W. -108.549362, 45.798565	Engine 3 Squad 3	4 Firefighters Reserve
Proposed Station F (From Station 4)	Broadwater Ave. & 11th St. W. -108.542672, 45.777086	Engine 4 MAC 4-Mobile Air Van Squad 4	4 Firefighters Special Request Reserve
Proposed Station J (From Station 5)	Monad Rd. & S. 32nd St. W. -108.579359, 45.76228	Engine 5 Engine 55 Brush 5 Tender 5 Hazmat	4 Firefighters Reserve Special Request Special Request Special Request
Proposed Station A	Wicks Ln. & Hawthorn Ln. -108.455177, 45.82741.	Engine	4 Firefighters

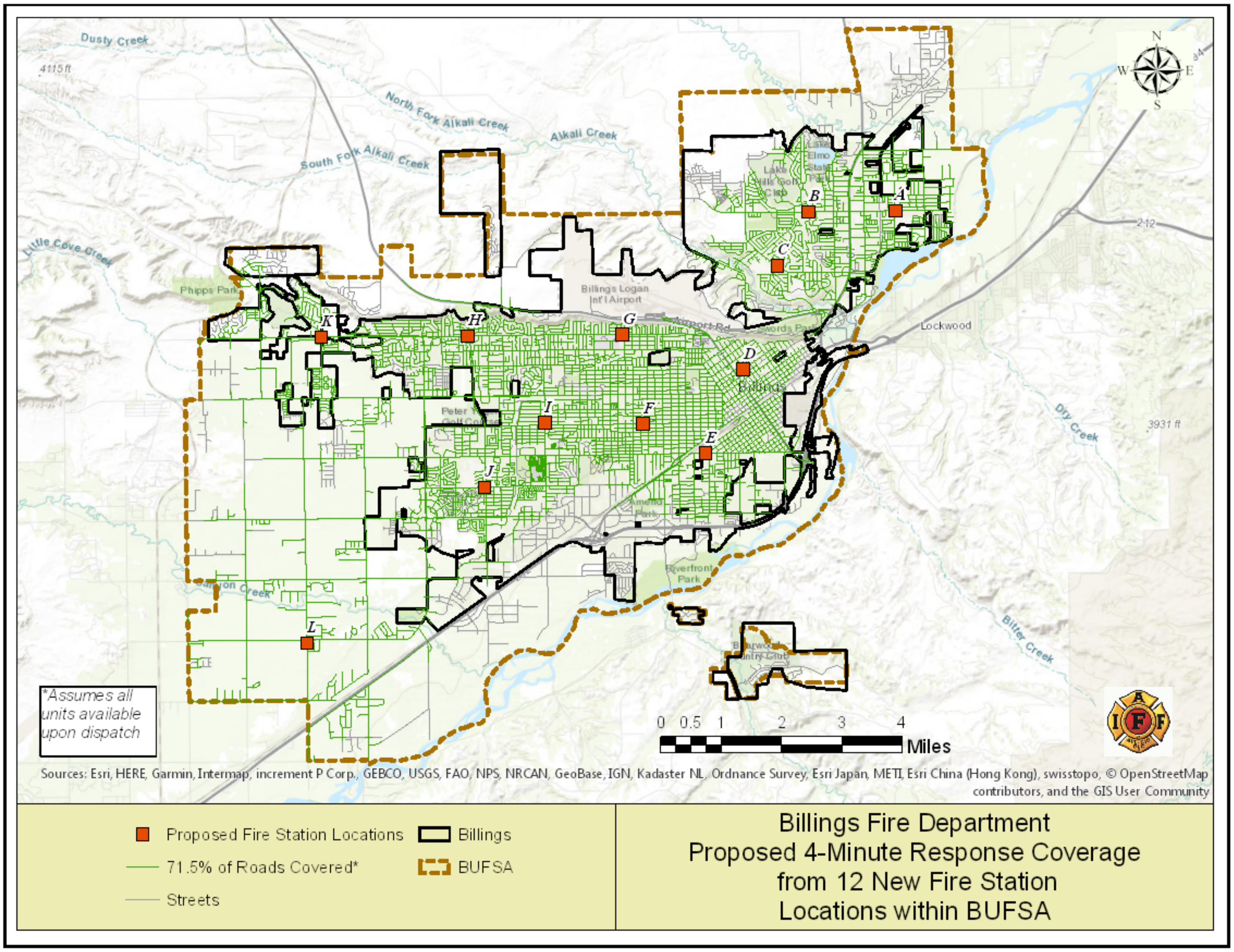
Table 11: Recommended Existing and New Stations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. The above table displays the combined current and proposed new fire stations and the existing and proposed minimum apparatus and staffing. New stations would be need in the area of Broadwater Ave. & 24th St. W., Rimrock Rd & 13th St. W., Broadwater Ave. & 11th St. W., Monad Rd. & S. 32nd St. W., Wicks Ln. & Hawthorn Ln, Govenors Blvd. & Araonson Ave, Rimrock Rd. & Zimmerman Ave, 24th St. W. & Wyoming Ave., and S. 56th St. W., & Neibaurer Rd.

Proposed Stations Continued	Approximate Address Continued	Proposed Apparatus Continued	Proposed Staffing Continued
Proposed Station C	Governors Blvd. & Aronson Ave. 108.495941, 45.814645	Engine	4 Firefighters
Proposed Station H	Rimrock Rd. & Zimmerman Ave. -108.602422, 45.798624	Engine	4 Firefighters
Proposed Station I	24th St. W. & Wyoming Ave. -108.576353, 45.777631	Engine	4 Firefighters
Proposed Station L	S. 56th St. W. & Neibauer Rd. -108.65871, 45.725366	Engine	4 Firefighters

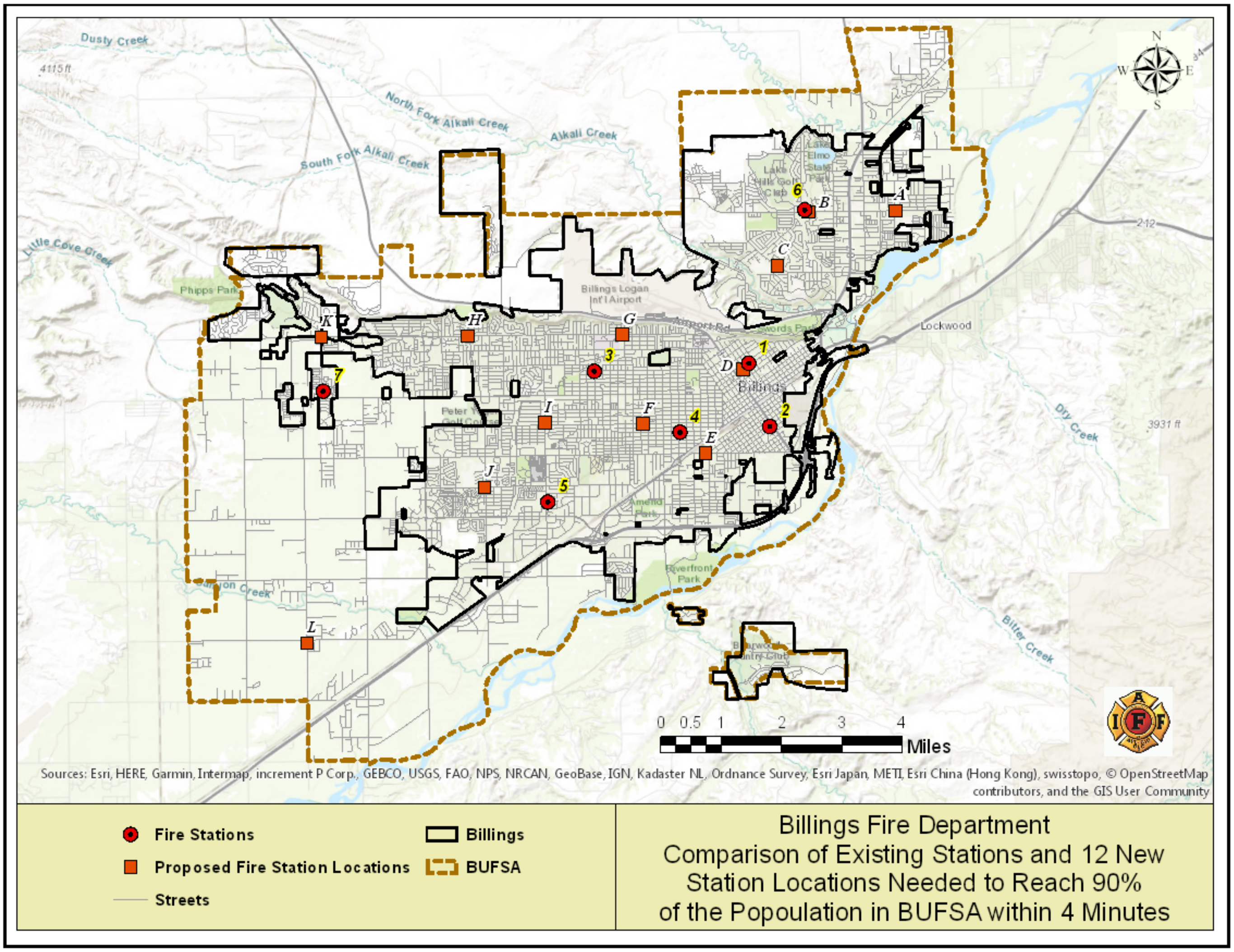
Table 11 Continued: Recommended Existing and New Stations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. The above table displays the combined current and proposed new fire stations and the existing and proposed minimum apparatus and staffing. New stations would be need in the area of Broadwater Ave. & 24th St. W., Rimrock Rd & 13th St. W., Broadwater Ave. & 11th St. W., Monad Rd. & S. 32nd St. W., Wicks Ln. & Hawthorn Ln, Govenors Blvd. & Araonson Ave, Rimrock Rd. & Zimmerman Ave, 24th St. W. & Wyoming Ave., and S. 56th St. W., & Neibaurer Rd.



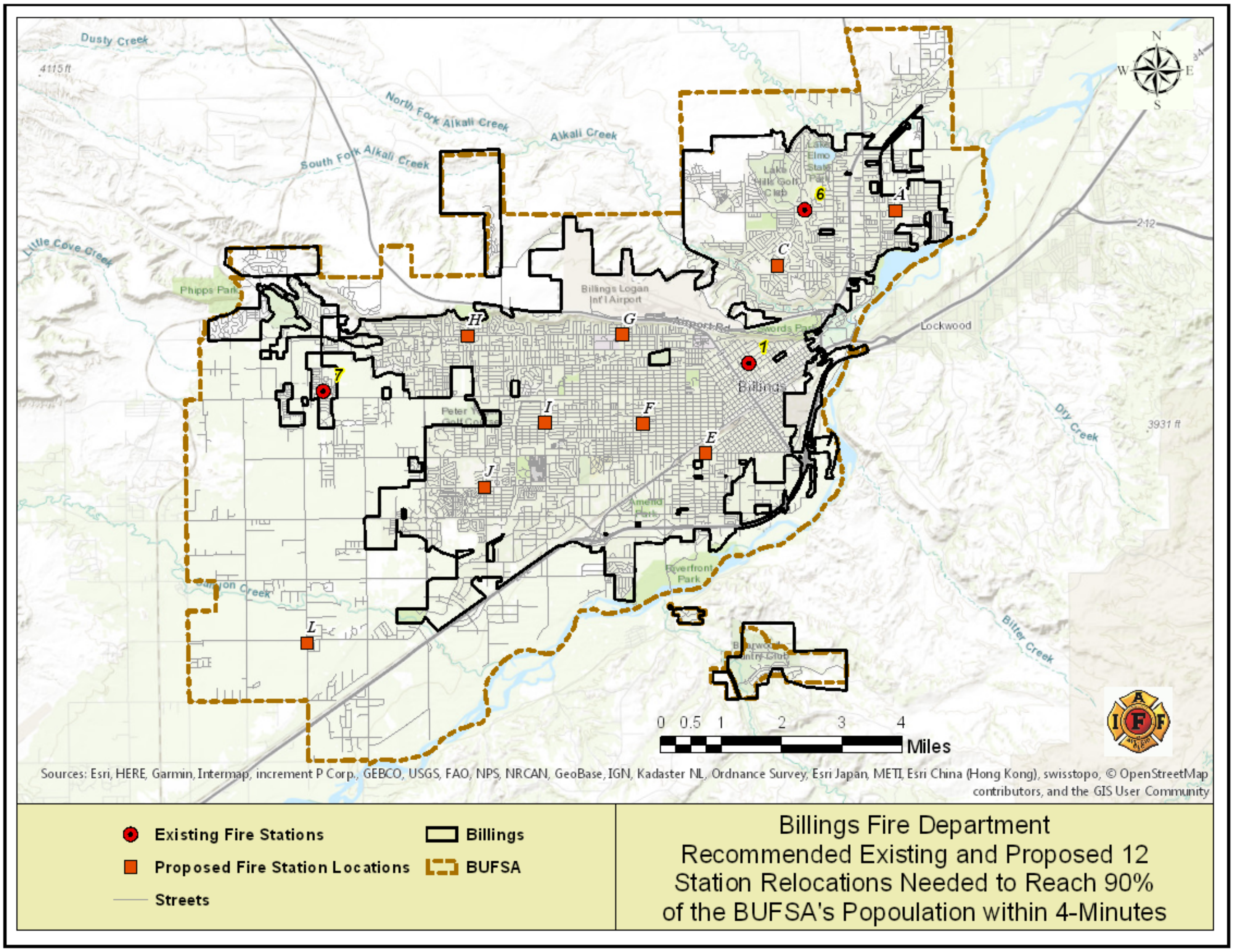
Map 16: Proposed Fire Station Locations Needed to Reach 90% of the Population in the BUFSA within 4 Minutes. Map 16 depicts the results of the location-allocation analysis, which determined where fire stations would be needed in order to reach the 90% of the population in the BUFSA within a 4-minute travel time. If the Billings Fire Department could relocate all fire stations, 12 stations would be needed to reach 90% of the population within the BUFSA within 4 minutes.



Map 17: Proposed 4-Minute Response Coverage from 12 New Fire Station Locations within the BUFSA. Map 17 identifies those roads where companies would be able to reach within 4 minutes of travel from 12 proposed new fire station locations in the BUFSA and where a minimum of 4 firefighters would be able to assemble on scene. Units would be capable of responding on 71.5% of roads within the response jurisdiction within 4 minutes, which is a 39.7% increase in road coverage above current conditions.



Map 18: Comparison of Existing Stations and 12 New Station Locations Needed to Reach 90% of the Population in the BUFSA within 4 Minutes. Map 18 depicts the locations of existing fire stations in relation to the locations of 12 new fire stations, as determined by the location-allocation analysis.



Map 19: Recommended Existing and Proposed 12 Station Locations Needed to Reach 90% of the BUFSA's Population within 4 Minutes. Map 19 depicts the recommended relocations of existing and proposed fire stations needed to reach 90% of the BUFSA's population within 10 minutes.

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Conclusion

In conclusion, regardless of the type of response, the Billings Fire Department does not currently meet staffing and performance objectives as outlined in industry standards to provide for safe, efficient, and effective response to fires and rescue situations. Population growth has led to the fire department currently being unable to meet industry standard performance objectives. The Billings Fire Department should consider adding fire stations and staffed apparatus to the current configuration to ensure an apparatus can be on the scene of an incident within a 4-minute travel time.

Deficiencies in staffing and apparatus utilization contribute to delays in fire suppression, rescue, and response. These deficiencies should be remedied to improve response and enhance service to the citizens. At a minimum, 3 additional fire stations are needed and 2 current stations may be relocated within the City. At most 5 additional stations are needed and 4 current stations may be relocated. Whatever scenario the Department and City may wish to pursue, results indicate additional resources are needed in the Billings Fire Department. The proposals identified were only based off two parameters. They were reaching 90% population and current stations located within half a mile of proposed stations. The results show trends, but further analysis is needed to define the exact number and locations of stations needed by the Department. Most importantly the Department should work with the City to define available land for stations. Additional parameters may also be defined to should also be considered by the City and Department. Some examples are building or maintain stations near the highest concentration of historical incidents, building or maintaining fire stations within a certain distance of high hazard sites or within a certain distance of major roads, and building future stations where growth and development will occur.

It is essential that departmental resources are able to meet demand. The department's existing workload and 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 of Billings. It also increases the risk of considerable property loss for housing units and businesses in many areas of the city.

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

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

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

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

Appendix A

Performance Standards

NFPA 1710 is the consensus standard for career firefighter deployment, including requirements for fire department arrival time, staffing levels, and fireground responsibilities.[75]

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

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

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

- 5.2.3.1 & 5.2.3.1.1
    - Fire companies, whose primary functions are to pump and deliver water and perform basic firefighting at fires, including search and rescue… shall be staffed with a minimum of four on-duty members.
- 5.2.1.2
    - In jurisdictions with a high number of incidents or geographical restrictions, as identified by AHJ, these companies shall be staffed with a minimum of five on-duty members.

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

[75] NFPA 1710, 2016

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

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

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

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

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

- 5.2.4.1.1
    - The initial full alarm assignment to a structure fire in a typical 2000 ft^2 … two-story single-family dwelling without basement and with no exposures shall provide for the following

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

- 5.2.4.2.1
    - The initial full alarm assignment to a structure fire in a typical open-air strip shopping center ranging from 13,000 ft^2 to 196,000 ft^2 (1203 m^2 to 18,209 m^2) in size

- 5.2.4.3.1
    - The initial full alarm assignment to a structure fire in a typical 1200 ft^2 (111 m^2) apartment within a three-story, garden-style apartment building shall provide for the following:

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

- 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)
IRIC/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 a Floor Below Involved Floor	2 Firefighters
Firefighter Rehabilitation	2 Firefighters (1 must be ALS)
Vertical Ventilation Crew	1 Officer 3 Firefighters
External Base Operations	1 Officer
2 EMS ALS Transport Units	4 Firefighters
Required Minimum Personnel for Full Alarm	**36 Firefighters 1 Incident Commander 6 Officers**

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

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

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

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