San Diego Wildfire Hazards Information Center Mashup

by

Ryan Mock

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List of Abbreviations

ABAG	Association of Bay Area Governments
AGOL	ArcGIS Online
API	Application Programming Interface
CAL FIRE	California Department of Forestry and Fire Protection
COP	Common Operating Picture
FHSZ	Fire Hazard Severity Zone
GIS	Geographic Information System
MIT	Massachusetts Institute of Technology
NICS	Next-Generation Incident Command System
NOAA	National Oceanic and Atmospheric Administration
QA/QC	Quality Assurance/Quality Control
RSS	Really Simple Syndication
SSI	Spatial Sciences Institute
USC	University of Southern California
USGS	United States Geologic Service
UX/UI	User Experience/User Interface
VGI	Volunteered geographic information
WUI	Wildland-Urban Interface

Abstract

The purpose of this thesis project is to empower San Diego County, California residents by educating them on the potential wildfire risk to their homes by providing local hazard and preparedness information through a publically accessible, web-based geospatial application. Wildfires are uncontrolled vegetation fires that directly threaten the homes, populations, and livelihoods of all Southern Californian residents. Exponential population growth in California has expanded home constructions into more rural geographies, which increase the frequency of wildfires in the region. The growth of the Wildland-Urban Interface (WUI), areas where new home construction meets vegetation fuel, has fed the frequency and scale of destruction incurred by manmade and spontaneous wildfire occurrences in San Diego County. Whether wildfires are caused by nature or influenced by people, the unpredictable nature of these hazards means they can easily spread to populated areas and present a reoccurring threat to San Diego County communities. The focus of this research is the development of a web map mashup that incorporates well-documented, published spatial data such as the wildfire hazard potential and fire hazard severity zones in the San Diego region into easily understood features on a publicly accessible web map. San Diego County homeowners may utilize the web map mashup to understand the relative risk of a wildfire to their home, the history of local wildfire burns, their proximity to emergency response resources, and real-time wildfire information. This study utilized Esri's ArcGIS desktop to prepare the data, ArcGIS Online to publish and host the data, and ArcGIS Web AppBuilder to produce a custom map template with analytical widgets and tools. Lastly, professional and public review of the web map mashup was solicited and incorporated into the final version of the web map application.

Chapter 1 Introduction

This thesis research involved the creation of an interactive web map mashup for the County of San Diego, California (CA) homeowners to provide them with spatial data and tools to understand historical wildfires, the wildfire hazard potential based on real-time news feeds, and firefighting and other emergency resources in proximity to their property (Figure 1-1).

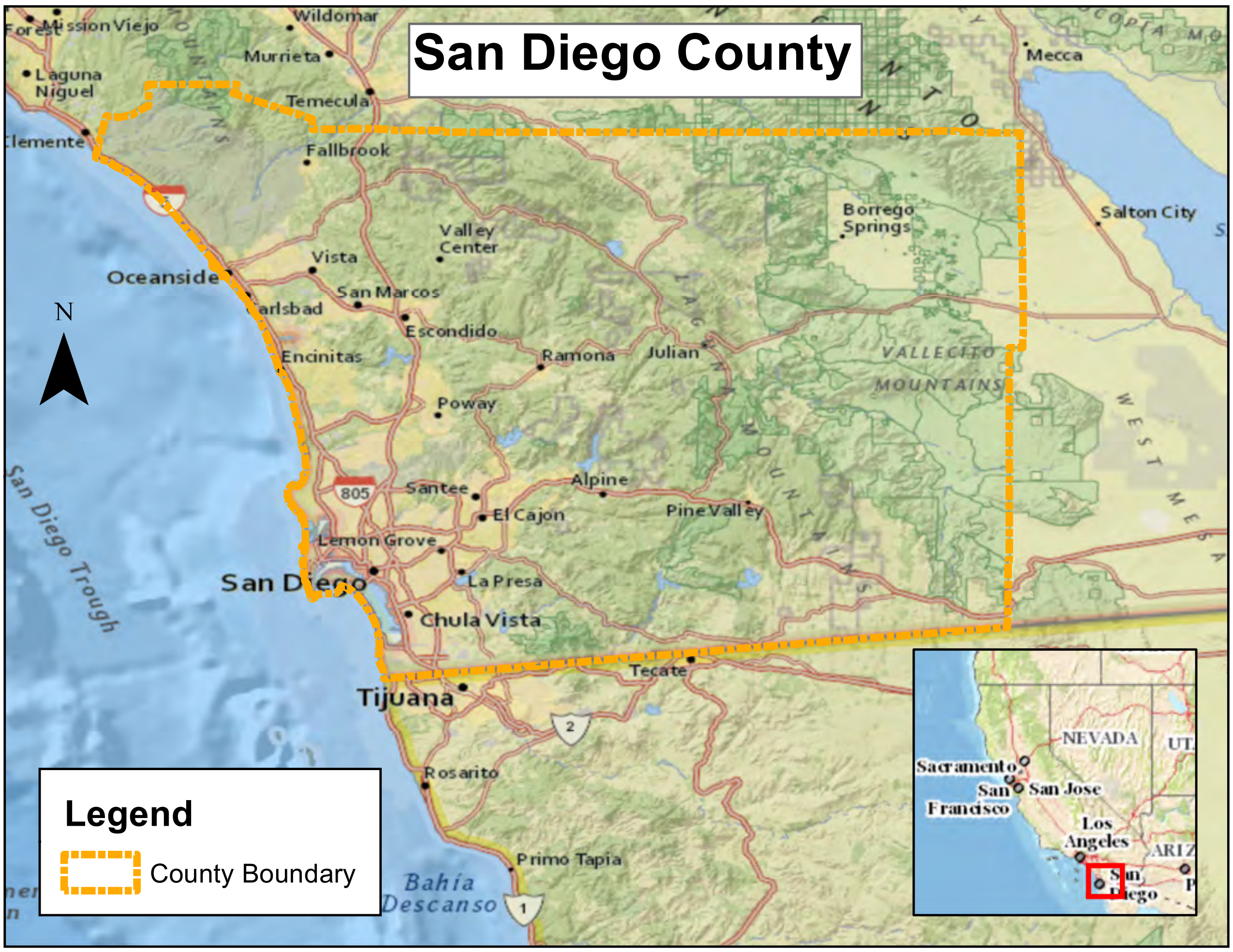

Figure 1-1: San Diego County Study Area

A web map mashup developed as part of this thesis project is herein defined as a browser-side GIS application programming interface (API) that integrates multiple geospatial data layers and datasets from multiple sources (Fu & Sun, 2011). Currently available web maps designed for the general public, like the San Diego County Emergency Management map, provide real-time updates of wildfire incidents with no historical data or analytical tools (San Diego County 2016). The San Diego Wildfire Hazard Map provides limited information on recent wildfires in the form of dated fire hazard severity zones. Contrastingly, first responder platforms like the Next-Generation Incident Command System (NICS) are geared more to professional emergency management personnel and therefore require professional expertise and training with a complicated GIS (Homeland Security 2015).

The overall goal of this thesis project is to develop a web map mashup that bridges the gap between the higher analytical capabilities of a GIS designed for emergency management professionals and an over-simplified web mapping platform geared specifically toward homeowners. The focus of the tools created as part of this research is on providing homeowners with a regional web map that offers a wealth of information concerning historical wildfire burns, first responder information, a potential wildfire hazard value, and live updates of emergency fire information via streaming news related to San Diego, California and the immediate vicinity.

1.1 Wildfires

The life and strength of a wildfire are most influenced by three factors: fuel, topography, and weather (Bennett et al. 2006). The chaparral vegetation of the San Diego Californian region consists primarily of dry brush and shrubs. This environment experiences a short rainy season, a dry and arid summer, and an annual fire season fueled by the Santa Ana winds in the fall. Topography, normally broken down into slope, aspect, and elevation, can create obstacles to cordoning off the spread of wildfire and even aid in the proliferation of surface fires. Weather can drive moisture to low levels of drought and create dangerous wind patterns like the annual

Santa Anna winds that have a dramatic effect on the annual South California fire season. By correlating local wildfire history to wildfire hazard potential values using the search tool and information pop-ups, the web map mashup shows homeowners how often wildfires have occurred in an area, as well as the likelihood that another wildfire will occur in the same area again.

1.2 Motivation

In 2015, the U.S. experienced over 100,000 wildfires that burned upwards of 9 million acres of land (National Geographic 2016). Wildfires are naturally occurring hazards linked to the ecology of the Southwest of the United States, much like seasonal weather patterns in the South Pacific or tornadoes in the Mid-Western United States. Wildfires are a fact of life that residents and homeowners in Southern California must learn to prepare for and cope with. As previously stated, this guided the goals of this thesis project, to provide non-GIS-savvy Southern California homeowners with an easily maneuverable web map that provides them with valuable information regarding the prevention, mitigation, and reaction options to wildfire threats in their area.

A major motivation behind this fire-related web map development project is to provide a unique set of map-based analytical tools in an easily digestible and comprehensible online platform. Access to spatial data that is normally used only by professionals or analysts is explained in a manner that can be disseminated to the masses. This thesis work includes research into filtering fire-hazard related spatial data on the backend to feed the web map, such that average San Diego citizens would have access to relevant wildfire emergency information. This project empowers San Diego County residents to gain awareness of wildfire hazards near their property or neighborhood.

1.3 Study Area

San Diego County was selected as the study area for this research because this coastal region in Southern California has experienced some of the most destructive wildfires in California's recent history. The 2003 Cedar Fire became the largest fire in California history by burning 280,278 acres, destroying 2,820 buildings, and claiming 15 fatalities (Monteagudo et al. 2013). Then in 2007, the Witch Creek fire burned 197,990 acres, destroyed 1,125 residential structures, and claimed 2 fatalities. Booming populations, arid summers, and dry brush portray the city of San Diego as a perfect example of wildland-urban interface (WUI) and a continual high-risk area for wildfires.

As seen in the overview window of Figure 1-1, San Diego is located in the Southwestern region of California. San Diego is an urban city situated on the coast of the Pacific Ocean that gives way to rural rolling hills and a low mountainous region in the east that separates the county from the low desert. Varying topography including finger canyons, mesas, and crests of elevation give the region a host of microclimates within the county. As of July 2015, San Diego County had an estimated population of 3,299,521 people and 133,957,180 households (US Census Bureau 2016). With a steady population growth of 1.5% in recent years, suburban sprawl and new home construction have begun to encroach upon chaparral habitats that historically experience naturally occurring fires without human interference.

1.4 Thesis Organization

The remainder of this thesis is divided into six chapters. Chapter 2 discusses background literature and related work on Southern California wildfires, the relationship between fire fuels, topography, and weather, and the shortfalls of existing wildfire hazard web maps available to the general public. Chapter 2 provides a discussion about the decision process for choosing GIS technology in use in this thesis work. Chapter 3 provides details on the requirements of the project and the design choices of the website. Chapter 4 follows the development of the web map application and website. Chapter 5 explores the results of the project and how the web map mashup works. Chapter 6 reviews progress made in obtaining feedback on the application through testing solicited from GIS professionals and San Diego residents. Chapter 7 explains the project conclusions, challenges, and recommended future work for the website.

Chapter 2 Literature Review

This thesis project incorporates wildfire risk hazard models and first responder information affecting wildfires into risk assessment tools visualized through a web map application. The first goal of the application development phase of this study was to incorporate wildfire risk hazard data from current scientific research of wildfire fuel and hazard models into the web map application. The second goal of this study was to supplement the application with near-real-time information about wildfires, for example streaming social media content and live news organizations feeds. The final challenge of this study was to develop a set of tools for the web map application that encourages the visualization of wildfire hazard data in a format easily used by homeowners with no prior GIS knowledge. The following review of the literature in the field of wildfire risk modeling provides examples of wildfire information and related online systems available to the general public, and web map applications available to wildfire emergency management professionals only. The goal of this review is to describe how all of this information was used to design a single, unique web map application intended for public use that supports fast search and discovery of historical wildfire as well as near-real time wildfire incidents.

2.1 Wildfire Information

By studying wildfires, researchers in the scientific community learn how to prevent, mitigate, and resolve these destructive forces more effectively. There is no catch-all wildfire model that can accurately predict the statistics and growth of a wildfire in every region of the world. "The potential of a wildfire to burn depends on a complex combination of environmental factors including vegetation, slope, aspect, weather, and elevation. The hazard rating (low, moderate, high and extreme) refers to the potential for damage from a wildfire, and is dependent on the combined effect of these environmental factors and how they affect fire behavior" (Bennett et al. 2006). Following the principles of fire science, an analyst can use historical data, regional fuels, topography, weather, fire simulations, and accepted fire behaviors to predict the probability of wildfires and assess the relative risk of a wildfire in each particular region.

2.2 Wildfire Models

In the context of this thesis, a wildfire model is defined as the availability of fuels, heat, and oxygen. This *triangle of fire* can further be explained by recent weather patterns, changes in climate and the way terrain can influence the burn of a wildfire. There are a number of commercial companies as well as government agencies that focus their efforts on wildfire preparedness, mitigation, and recovery. In this chapter, 3 existing wildfire models, and data management systems are focused on as example applications deemed to be similar or highly relevant to the research objectives of this thesis that are discussed.

For example, CoreLogic is a company that uses proprietary risk analysis models to provide insurance companies and commercial entities with wildfire risk assessments on buildings and properties in different regions (CoreLogic 2017). The 2015 CoreLogic Wildfire Risk Model evaluates the risk of wildfires according to fuel, terrain, and vegetation. Wildfire fuel refers to any combustible materials that contribute to the growth and extent of a wildfire. In terms of vegetation, ground litter and grasses are more likely to ignite a wildfire than moist, swampy fauna. The logic behind selecting these variables is to create stable models across broad swathes of regions that face minimal change by weather and climate conditions (Botts et al. 2015). Although the CoreLogic models and algorithms are proprietary, like most work in fire science, all wildfire models are fundamentally based on the same set of core scientific principles throughout the field of study.

2.2.1 -Wildfire Risk Hazard Models

Different wildfires have their own characteristics and attributes. It is important to adjust weights and variables by region to account for the differences in wildfire behaviors (Adab 2011). In 2014, Gerdzheva reported a comparative study of wildfire risk assessment models in the southern Bulgarian district of Smolyan using historical wildfire records. Similar to the San Diego region, the district of Smolyan has a hilly geography and a Mediterranean climate. As seen in Table 2-1, Adab's (2011) model showed the best correlation with 75% of Smolyan historical fires categorized as high or very high-risk zones (Gerdzheva 2014). Table 2-1 provides a typical example of how a hazard rating or index can be created to develop a wildfire hazard model for a particular region. For example, a rating of hazard equal to 0 means a low model weight, while a higher rating of hazard implies the variable could increase the likelihood of a wildfire and is given more weight when the model is run. Adab (2011) 's model exemplifies why one fuel or hazard model for a particular region might have certain weighted values that accurately represent its inputs, but that does not necessarily mean that those same fuel and hazard inputs would be appropriate to use as-is in another region of the world that has a completely different profile of climate, geography or vegetation. Individual wildfire hazard models can be very subjective and require rigorous research to validate each numeric value and weighted input appropriately.

Risk model	Variables	Classes	Ratings of hazard*
Cáceres, 2011	Land cover	Rangeland(Scrub/ Shrubs), Forest Land ,Agricultural Land, Urban or Built-up Land , Barren Land and Water	0,1, 2, 3, 4
	Elevation	> 1501, 1001 – 1500, 501 – 1000, < 500	0,1,2,3
	Slope	> 35 % , 35 – 25 %, 25 – 10 % , 10 – 5 % , < 5 %	0, 1, 2, 3, 4
	Aspect	South, Southwest, Southeast, East , North , Northeast , Northwest	0, 0, 1, 1, 2, 2, 2
	Roads	<50, 50 – 100m, 100 – 200m, 200 – 300m , 300 – 400m, > 400m	0, 1, 2, 3,4, 5
	Settlements	<500m, 500 – 1000m, 1000 – 2000m , 2000 – 3000m, > 3000m	0, 1, 2, 3, 4
Ozelkan, 2009	NDVI	Few or no vegetation, Very dry, Dry, Moist, Fresh-like, Fresh	1, 10, 8, 6, 4, 2
	Slope	64-89, 45-64, 36-45, 29-36, 23-29, 17-23, 11-17, 3-11, 0-3	10, 9, 8, 7, 6, 5, 4, 3, 2
	Aspect	South, Southwest, Southeast, Flat, West, East, Northwest, Northeast, North	10, 9, 8, 7,6, 5, 4, 3, 2
	Roads	0 – 308, 308 – 616, 616 – 925, 925 – 1233, 1233 – 1541, 1541 – 1850	10, 8, 6, 4, 2, 1
	Elevation	1790 – 2300, 1425 – 1790, 1069 – 1425, 730 – 1069, 425 – 730, 24 – 425	10, 8, 6, 4, 2, 1
Adab,, 2011	NDMI	>0.36,0.26-0.36,0.16-0.26,0-0.16,<0	1,2,3,4,5
	Elevation	>2000,1000-2000, ,500-1000 , 200-500, <200	1,2,3,4,5
	Slope	<5%, 10-5%, 25-10%, 35-25%, >35%	1,2,3,4,5
	Aspect	North, East, West, South	2,3,4,5
	Roads	>400 , 300-400, 200-300, 100-200, <100 m	1,2,3,4,5
	Settlements	>2000 , 1500-2000, 1000-1500, 500-1000, <500m	1,2,3,4,5

Table 2-1: Wildfire Models (adapted from Gerdzheva 2014)

This study provided an example of how wildfire hazards can be ranked that contributed to the development of the web map mashup developed in this project. This study explained how broad and generic wildfire hazard models do not provide enough value for a public product. Instead, an accurate wildfire hazard model must incorporate a variety of values and fire simulation data to produce a comprehensive wildfire hazard risk assessment.

2.2.2 - LANDFIRE Models

Any wildfire model is only as good as the input data and values assigned to the variables that comprise the formula. In terms of consistent wildfire models documented in the literature, most national-level agencies and wildland fire management decision support software applications were based on LANDFIRE datasets (LANDFIRE 2017). LANDFIRE is a wildfire management program, developed by the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior that produces consistent national-level, landscape-scale geospatial products to support fire and fuels management planning, analysis, and budgeting to evaluate fire management alternatives (Firelab 2017). California Department of Forestry and Fire Protection's (CAL FIRE) Fire Hazard Severity Zone (FHSZ) is a geospatial wildfire model based on LANDFIRE data and assigns a hazard score based on the factors that influence fire likelihood and fire behavior (Fire 2017). The hazard score is defined as medium, high, very high, or not at risk, and provides an indication of a wildfire occurring in the next 30 to 50 years. The Wildfire Hazard Potential (WHP) web map is another example of a geospatial wildfire model developed by the USDA Forest Service Fire Modeling Institute that incorporates LANDFIRE data with additional simulation models to produce a wildfire hazard model that has been updated even more recently than the Fire Hazard Severity Zone model (Firelab 2017). By consistently incorporating up-to-date, accurate wildfire hazard geospatial data into a web mapping application, the end user gains a better insight into the dangers of a wildfire incident occurring near or at their residence. The WHP application is designed to address the concerns of homeowners and the propensity of a wildfire occurrence near their property, also a goal of this thesis research. As such, the WHP provided an example starting point on which to build a more comprehensive system in this thesis study which also conveys additional wildfire hazard information, historical wildfire facts and proximity to currently available emergency services directly to the end user.

2.3 Wildfire Web Map Applications

Most emergency management web maps encountered in the literature to date are in fact GIS-based tools that are designed to disseminate historical, real-time, and analytical data on natural and man-made hazards such as wildfires. The potential consumer of emergency management web maps could range anywhere from a private citizen wanting to check the path of a wildfire to a trained professional organizing evacuation routes. Each audience brings their own proficiency in scientific and technological background, and expectations about what tasks and information an emergency management web map can and should perform and provide, respectively.

2.3.1 Professional Wildfire Management Web Maps

Professional emergency management web maps combine a litany of technologies to give the GIS user tremendous amounts of information. For example, the Next-Generation Incident Command System (NICS) is a cooperative inter-agency web map developed by Massachusetts Institute of Technology (MIT) Lincoln Laboratory in conjunction with CAL FIRE and the Department of Homeland Security (Homeland Security 2015). The NICS Common Operational Picture (COP) incorporates real-time feeds, GIS data, video, airborne images, and updates from mobile personnel on the fly. The NICS has been field tested in the Southern California region since 2010 and has been utilized in over 300 wildfire and other hazard incidents in more than 250 organizations (Homeland Security 2015). As seen in Figure 2-1, the NICS command system contains many types of data, including volunteered geographic information (VGI) collected in the field in real-time and historical hazard databases. The only challenge to using this powerful emergency management tool is that each individual user must be trained on how to operate it, and it is not available to the general public. The emergency management professionals that use NICS require several hours of training on how to use the web map tools, contribute new geospatial and non-spatial data, share information contained in the map with first responders in the field, and operate the web map tools effectively to fulfill a given goal. There is a clear disparity between rudimentary web maps developed for the general public and professionally managed GIS platforms like NICS. This thesis project is intended to bridge this gap between proprietary or private wildfire risk management systems web maps and publically available wildfire information web map applications by providing public users with an intuitive and easily negotiable web map application that provides customer-tailored analytics about wildfire risk and hazards.

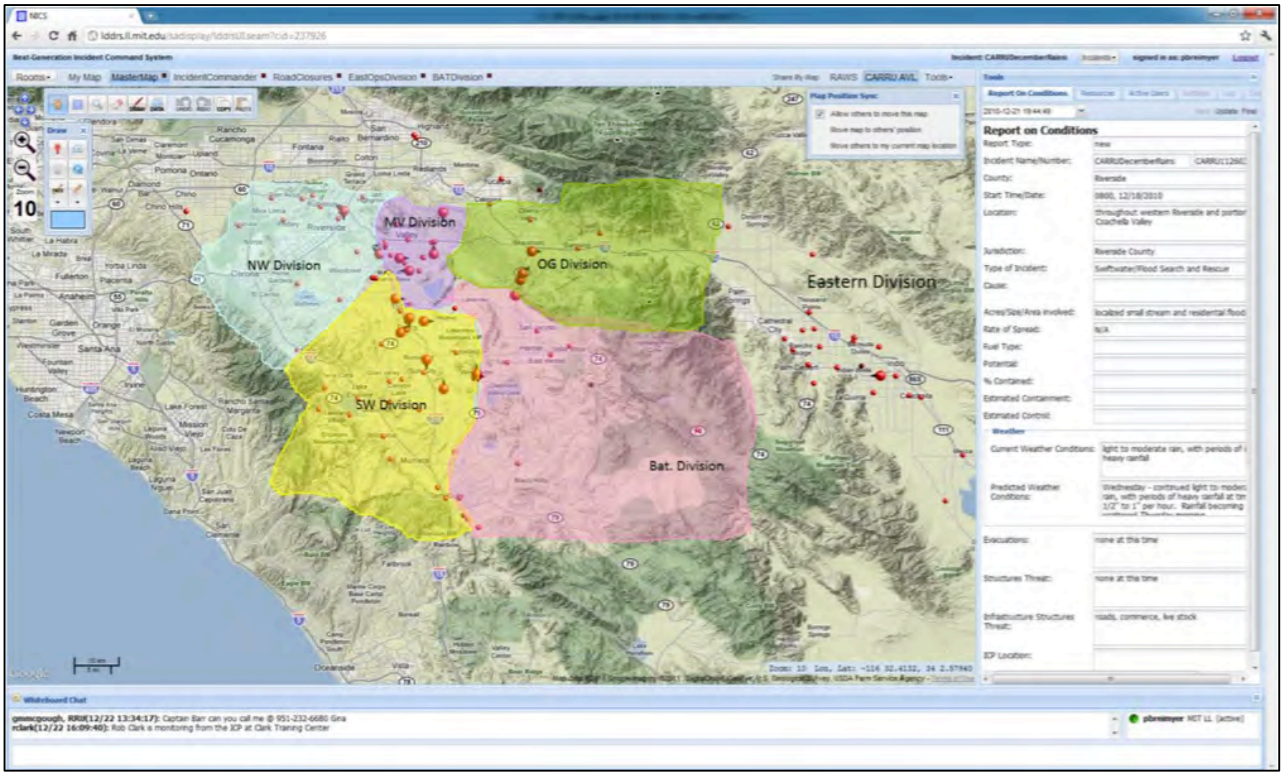

Figure 2-1: Next-Generation Incident Command System (Breimyer 2011)

2.3.2 Public Wildfire Hazard Web Maps

Based on recent literature review and internet search results, in general public web maps developed by the United States (US) government to date focused on wildfire hazards offer simplistic data visualization, few data analysis options, and offer limited map navigation functionality, such as panning and zooming in and out of the map, as seen in the Ready San Diego hazards map (Ready San Diego 2017). Since most consumers of these basic information programs presumably have little to no GIS experience, it is important not to overwhelm the user and to keep functionality simple and straightforward. Organizations like the Association of Bay Area Governments (ABAG) host a series of simple web maps that promote sustainability and recovery from the effects of earthquakes, wildfires, and other natural hazards (Association of Bay Area Governments 2014). For example, the ABAG web map includes CALFIRE datasets about wildfire history, potential burn areas identified by WUI data, and emergency services in the different communities of the San Francisco Bay area (Figure 2-2). While the ABAG web map publishes historical datasets concerning hazards, the city of San Diego publishes its own series of web maps focusing on real-time events and historical fire perimeters.

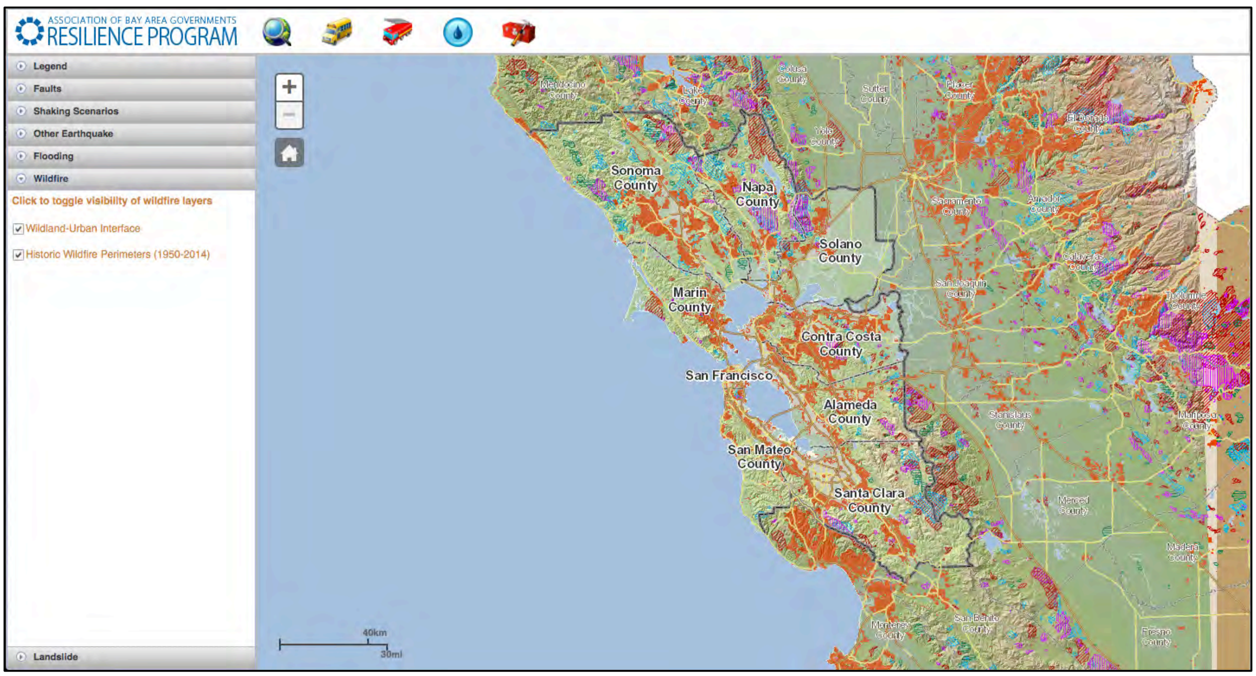

Figure 2-2: ABAG wildfire web map (Association of Bay Area Governments 2014)

2.3.3 San Diego Web Maps

Ready San Diego is a government entity run by the County of San Diego Office of Emergency Services that works to educate and empower residents to prepare and respond to natural disasters and hazards (San Diego County 2017). Coupled with the county-wide emergency notification system, Alert San Diego, Ready San Diego provides residents real-time information about local emergency relief efforts via landlines, emails, and wireless alerts. As seen in Figure 2-3, Ready San Diego provides local residents with a basic wildfire hazard map that is populated by CAL FIRE's Fire Hazard Severity Zone data. Severity zones are areas defined by CAL FIRE as those expected to experience a wildfire hazard, versus not at risk, and provide an indication of a wildfire occurring in the next 30 to 50 years (California Department of Forestry and Fire Protection 2007). The major shortcoming of this web map application is that it fails to provide any critical analysis of wildfire risk or any pertinent information based on the proximity of a given hazard to the end user. This thesis project expands on what the city of San Diego has already created by giving homeowners additional information including proximity to emergency services, real-time wildfire news, historic wildfire information, and the relative wildfire risk.

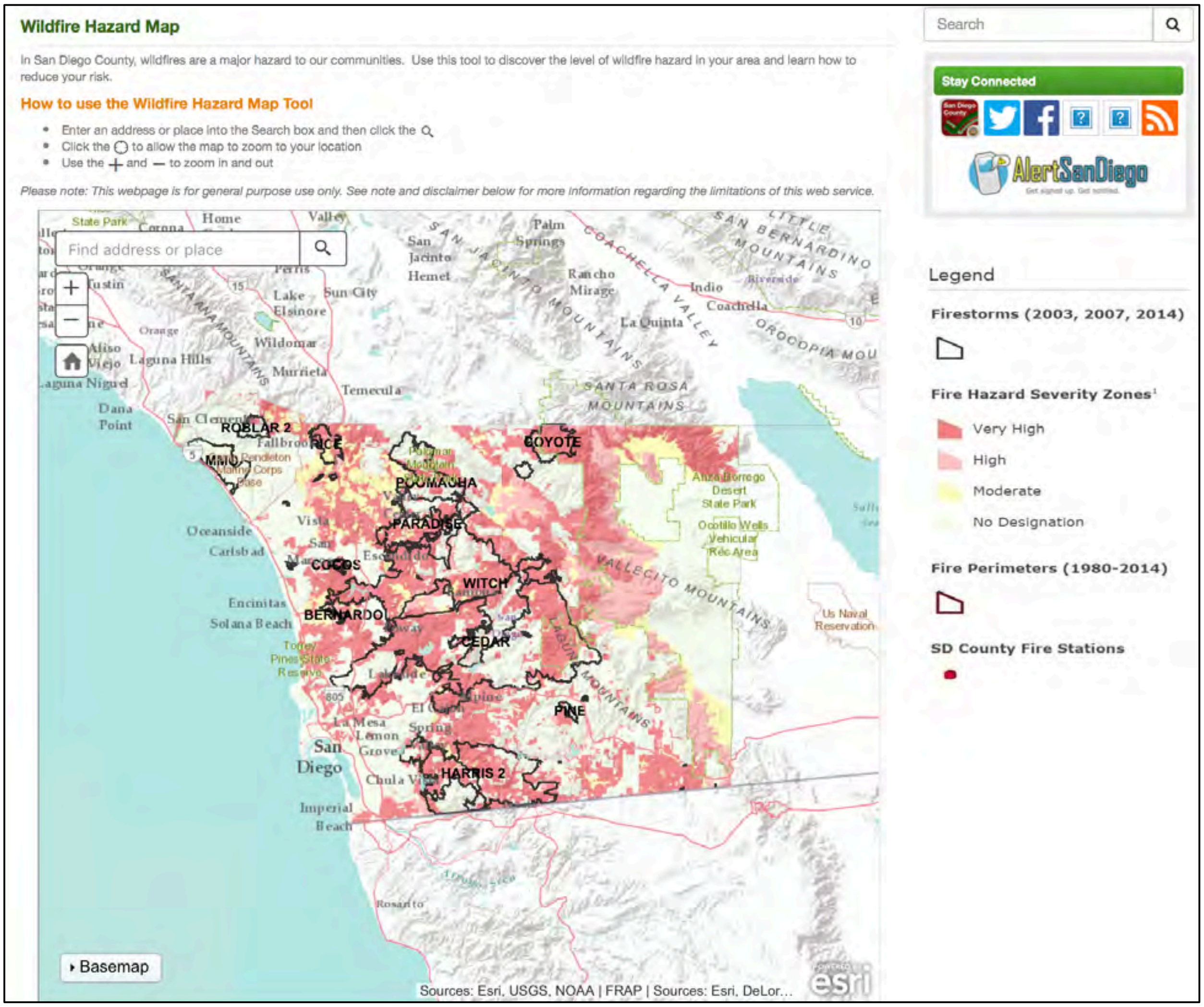

Figure 2-3: Ready San Diego Wildfire Hazard Map (Ready San Diego 2017)

2.4 – Summary of existing wildfire web map applications

Through researching different emergency maps and resources available to the public, the variation in the way that wildfire information is disseminated was found to be daunting. By selectively choosing relevant wildfire information for a web map mashup, this project simplifies the way local San Diego residents can access current, important wildfire information. In the context of this study, a mashup is defined as a browser-side GIS API that integrates multiple geospatial data layers and datasets from multiple sources (Fu & Sun, 2011). This web map application, or mashup, was designed to build upon examples of existing, successful, similar applications, to be a more effective tool for conveying wildfire hazard information pertinent to local home and business owners. At present, while a wildfire is raging nearby, a resident must search numerous websites containing up-to-date information on the status of the hazard in terms of proximity and potential risk. Improvements incorporated into this project web map over the examples discussed above include near-real-time access to news, and social media resources focused on fires, historical wildfire data and local emergency services that provide a simplified means for determining risk, tracking current wildfires, potential evacuation information, all in a one-stop-shop web map application.

Chapter 3 Requirements

In the age of information, maintaining current and accurate information is paramount to success. It is important for this information to be conveyed simply and directly so as not to overwhelm the audience. Roth (2015) explains that the concepts of aesthetics, emotion, and style are as important to cartographic interaction as they are to cartographic representation. By keeping the design of the website tight and concise, this thesis effort was able to focus on goals and a limited number of requirements. By following the adage of less is more, and making the focus of the project both visually appealing and inviting to the end-user, the successful construction of a functional web map mashup was achieved.

3.1 – Application Goals

As previously stated, the goal of this application is to provide the end-user with the means to perform quick and meaningful research about the history and risks of a wildfire hazard occurring on or near their property and be able to find available resources and information to mitigate a wildfire event. This ultimate goal was achieved by mashing a web map application with other tools like news and social media feeds, to produce a well-rounded common operating picture (COP) of wildfire events in San Diego County for local residents.

3.2 – User Requirements

The end users for this website are local San Diego residents. All end-users will be able to use and operate any function on the website for free without any registration or login process. By allowing everyone unrestricted access, the information visualized on the website can be shared in an easily consumed format. Normally all of this information would have to be found on different Internet websites, in different formats, and in different degrees of availability to the end-users. With a simple Internet connection, the user can access the website via a desktop computer, tablet, or even mobile phone (with limited functionality). No login or enrollment is required, the end-user only needs to visit the website and dive in.

3.3 – Functional Requirements

The web map mashup is reliant on a lot of sources and hosts working in symphony to achieve functionality. Since the web map and website components exist on the Internet, Internet connectivity is key for the website to function. The web map pulls the published data using Esri’s ArcGIS Online (AGOL), which is hosted through an educational site license agreement with the University of Southern California (USC). Although the data and map services are publically shared on AGOL, if the terms of the agreement are shifted, the web map application may experience data loading errors and not function properly. The code for the website is hosted on University servers and is reliant on student enrollment to continue to be hosted by USC. There are a lot of moving parts from different web map and news services that ultimately play in symphony to achieve a straightforward user experience on the thesis project website.

3.4 – Design Principles

User satisfaction and participation is instrumental in a website succeeding and gaining a greater user base. Marsh (2013) explains that visitors make judgments about a new website in the first 3-5 seconds or in the blink of an eye. It was important for the website to be developed to be visually pleasing and simplistic in the way web map tools are presented to the user so as not confuse or overwhelm the user with GIS jargon. The tools are implemented in an intuitive way with limited instruction and users will be able to understand how to operate the GIS tools easily, and not have to be given explicit step-by-step instructions on how to interpret the results. The goal is to simplify complex GIS operations to a point where non-GIS users can easily digest self-produced, analytical results relevant to their homes and safety in the event of a nearby wildfire.

By creating an environment of simplicity and limiting map tool options, the attention of the user is diverted to a small set of very powerful tools that can assess the relative wildfire risk to their home.

Esri's proprietary Web AppBuilder v2.4 was chosen to build the web map application. By using the USC Spatial Sciences Institute's AGOL educational credits, the web map application can expose a wealth of GIS tools and templates to the general public that are normally reserved for internal Enterprise or organizational account users.

Since the Ready San Diego Wildfire Hazard Map included CAL FIRE's FHSZ data, the author thought it appropriate to include the data as a selectable layer as well. The U.S. Forest Service's wildfire hazard potential data was included because it was based on a more complex wildfire hazard model that included LANDFIRE data, fire simulation data, previous fire occurrence data, multiple classifications, and multiple iterations published on a fairly consistent basis from 2007 to 2014. To round the scope of map data included in the web map was SanGIS's first responder information and historical wildfire burns. SanGIS provides San Diego Countywide data to the general public as a public service.

In order for data to be accessible to the general public through a web map, the permissions on the data published using AGOL must be shared publically, which allows all users who visit the website to use the web map application without having to log in or build an Esri account. The web map application was embedded into the website seamlessly using Hyper Text Markup Language 5 (HTML5), Cascading Style Sheets (CSS), and JavaScript (JS) code. Alongside the web map application, an accordion style drop-down tool was included in the web page to provide real-time news feeds and related wildfire information. The simple layout of the accordion confines the streaming feeds and information in a small part of the webpage, while allowing the user to access each type of information individually with the simple click on a heading.

Chapter 4 Application Development

An interesting aspect of GIS is that it transforms geographic data into cartographic visualizations to serve a purpose. As a shortfall in the currently available dissemination of wildfire information to the San Diego County general public was identified, this project focus shifted towards wildfire and emergency management. Figure 4-1 illustrates the steps taken to develop the web map application and auxiliary tools that comprise the website.

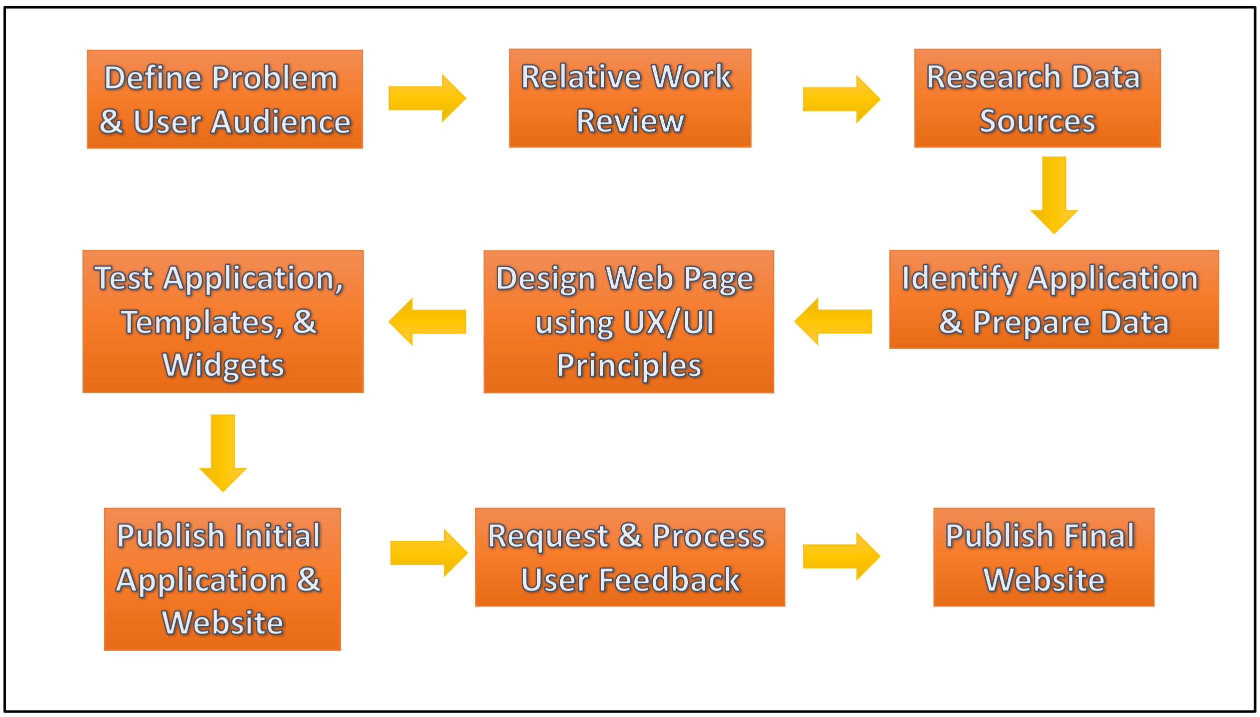

Figure 4-1: Application Development Flowchart

4.1 – Define Problem

Growing up as native San Diegan, the author wanted to build a GIS product that could serve or inspire his community positively. As the author submitted his package for enrollment to USC in late spring of 2014, a string of wildfires struck San Diego burning approximately 26,000 acres, causing nearly $60 million in damage, and killing at least one person. The author knew personally the fear of having to evacuate under threat of shifting wildfires or seeing the anguish of community members being displaced by fire damage. This experience inspired this effort to build a GIS solution to empower San Diego residents with cartographic information about wildfires and to help them learn how to mitigate the risks of a wildfire event affecting their home.

4.2 – Relative Work Review

The original idea for this project was to create a relative wildfire risk model defined by weighted values. This proved inefficient because of the expertise involved in scientifically assigning appropriate values to each criterion in the model. Since the results varied every time the model was executed, a proven, published scientific model with legitimate results was chosen instead. Using the Ready San Diego Wildfire Hazard Map (Ready San Diego 2017) as a starting point, this thesis project improves upon the limited functionality of the Ready San Diego web map by empowering the user with more analytical tools, more wildfire-related data to explore, and additional real-time information feeds.

4.3 – Research Data

The data used for this project was collected from municipal, state and federal agencies for study on a regional scale, as provided in Table 4-1. In regards to the accuracy of each dataset used, more current and detailed information about each dataset can be found on each individual data source website (CAL FIRE 2012; Fire, Fuel, and Smoke Science Program 2016; SanGIS 2015).

Name	Type	Source	Date of Publication	Description
Fire Hazard Severity Zones	Vector	CAL FIRE	November 6, 2007	Likelihood of a wildfire burn
Wildfire Hazard Potential (2014)	Raster	USFS	May 23, 2014	Potential for a wildfire igniting
Law Enforcement Facilities	Vector	SanGIS	August 26, 2016	Police stations
Fire Stations	Vector	SanGIS	October 10, 2016	Fire stations
Hospitals	Vector	SanGIS	August 2012	Medical clinics and hospitals
County Border	Vector	SanGIS	August 2016	San Diego County Border
Historical Wildfires	Vector	SanGIS	September 10, 2016	Historical wildfire perimeter burns and statistics

Table 4-1: GIS Data Included in the Thesis Project Web Map

The Ready San Diego wildfire hazard map developers chose to include CAL FIRE's fire hazard severity zone data in their web map (see Figure 4-2). Although the data was scientifically derived, the methods and data used to ascertain the severity zone values proved to be outdated, with the most recent publication being in November 2007. The fire hazard severity zones were classified into three categories of risk and based on the physical conditions that create the likelihood of a wildfire ignition in that area (Ready San Diego 2017). The FHSZ data for California city counties was available at a scale of 1:150,000 for download (CAL FIRE 2012).

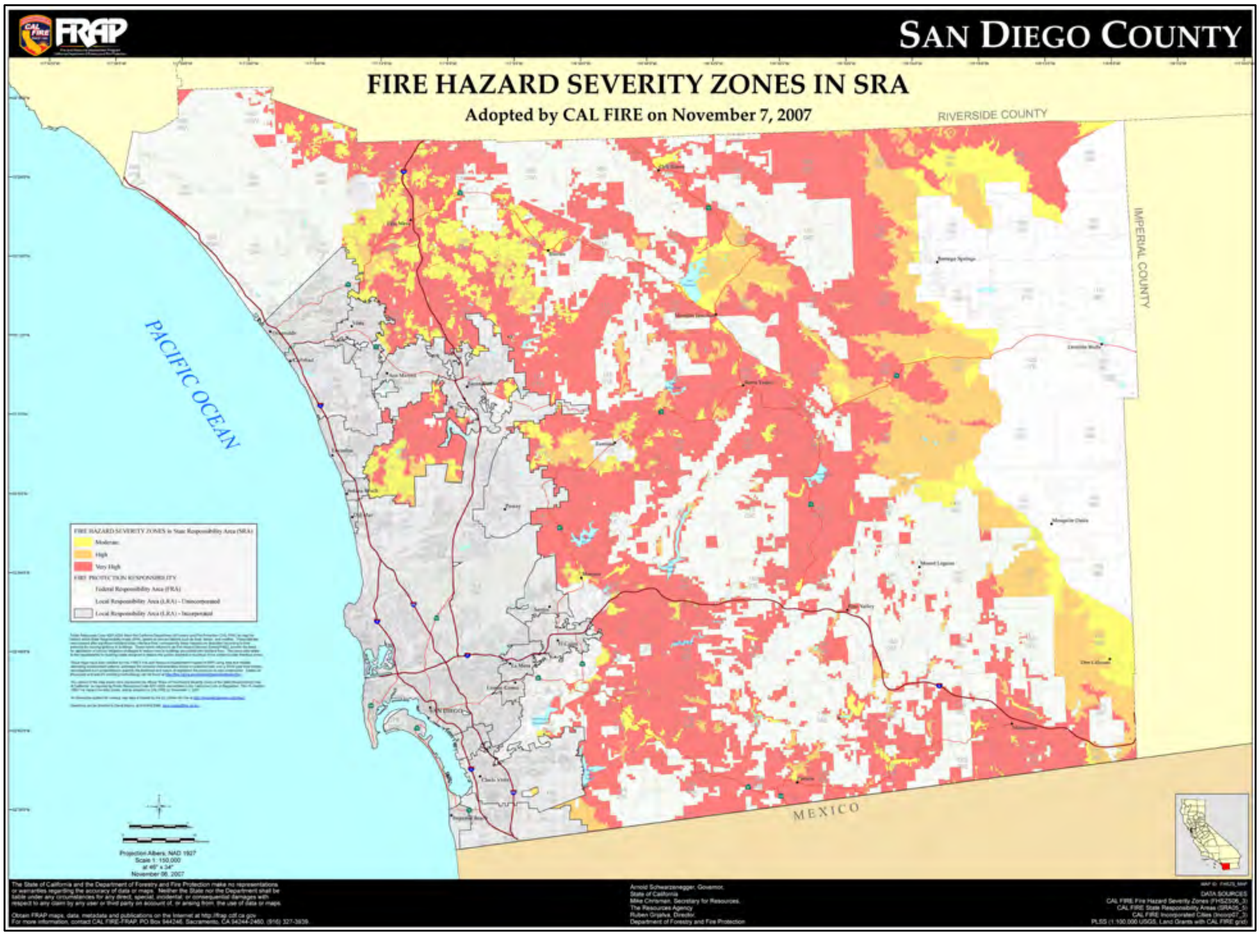

Figure 4-2: CAL FIRE Fire Hazard Severity Zones in San Diego County (CAL FIRE 2012)

Although CAL FIRE's zone data was included in the web map as a selectable layer, ultimately the wildfire hazard potential data was chosen as the default layer for the web map. The wildfire hazard potential map version 2014 was developed by the USDA Forest Service, Fire Modeling Institute "to depict the relative potential for wildfire that would be difficult for suppression resources to contain" (Fire, Fuel and Smoke Science Program 2016). As seen in Figure 4-3, the wildfire hazard potential model is a combination of LANDFIRE data and fire simulations. The input values for the wildfire hazard potential model include fire occurrence point data, LANDFIRE data about vegetation and wildfire fuels, fire simulation probability data, and are categorized by wildfire behavior within the model. The classified raster graphic is broken down into seven values based on the relative risk of a wildfire occurring (Figure 4-4) from very low to very high. The index of the WHP map data shows the conterminous United States at a spatial resolution of 270 meters per pixel cell (Fire, Fuel and Smoke Science Program 2016).

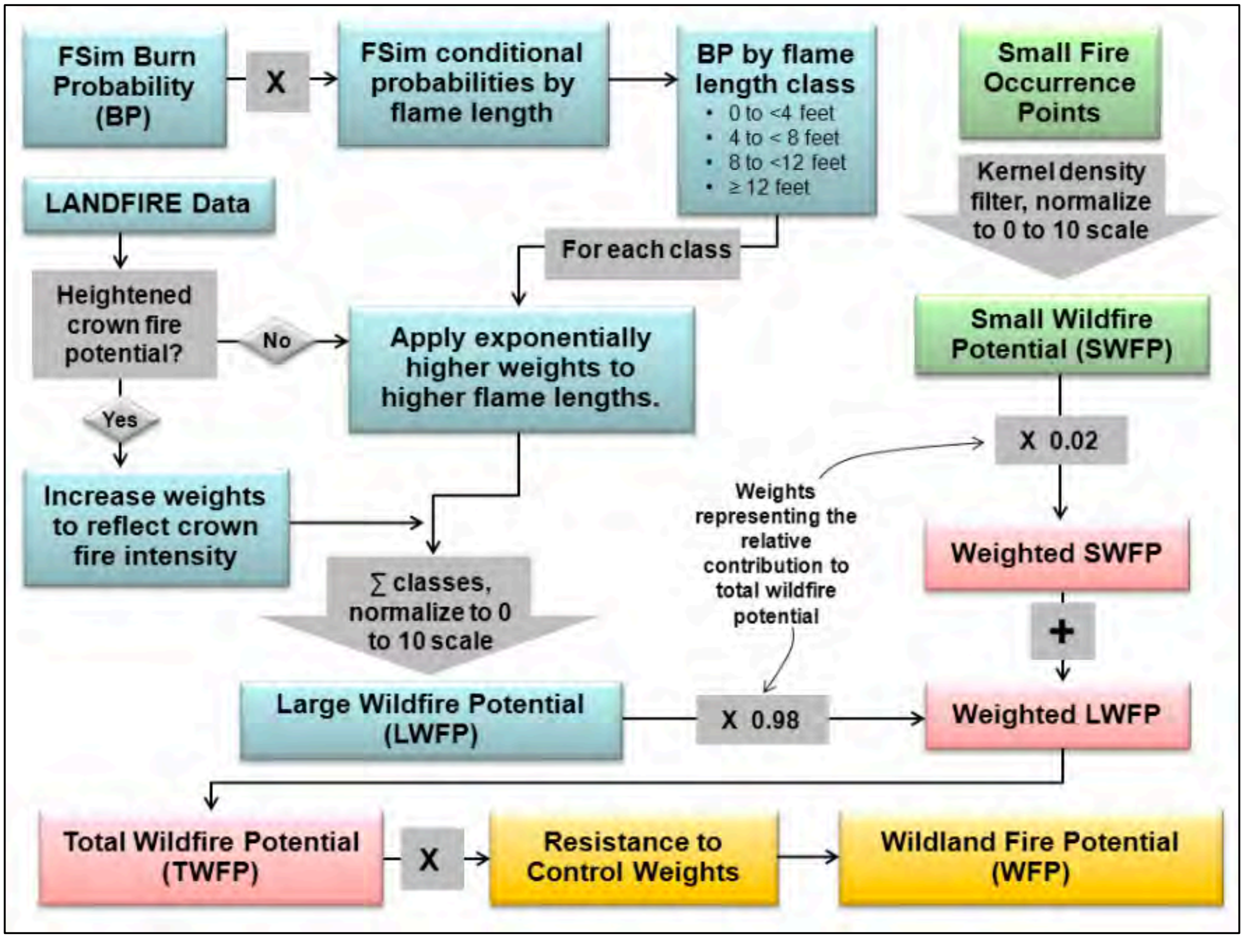

Figure 4-3: Wildfire Hazard Potential model (Dillon 2013)

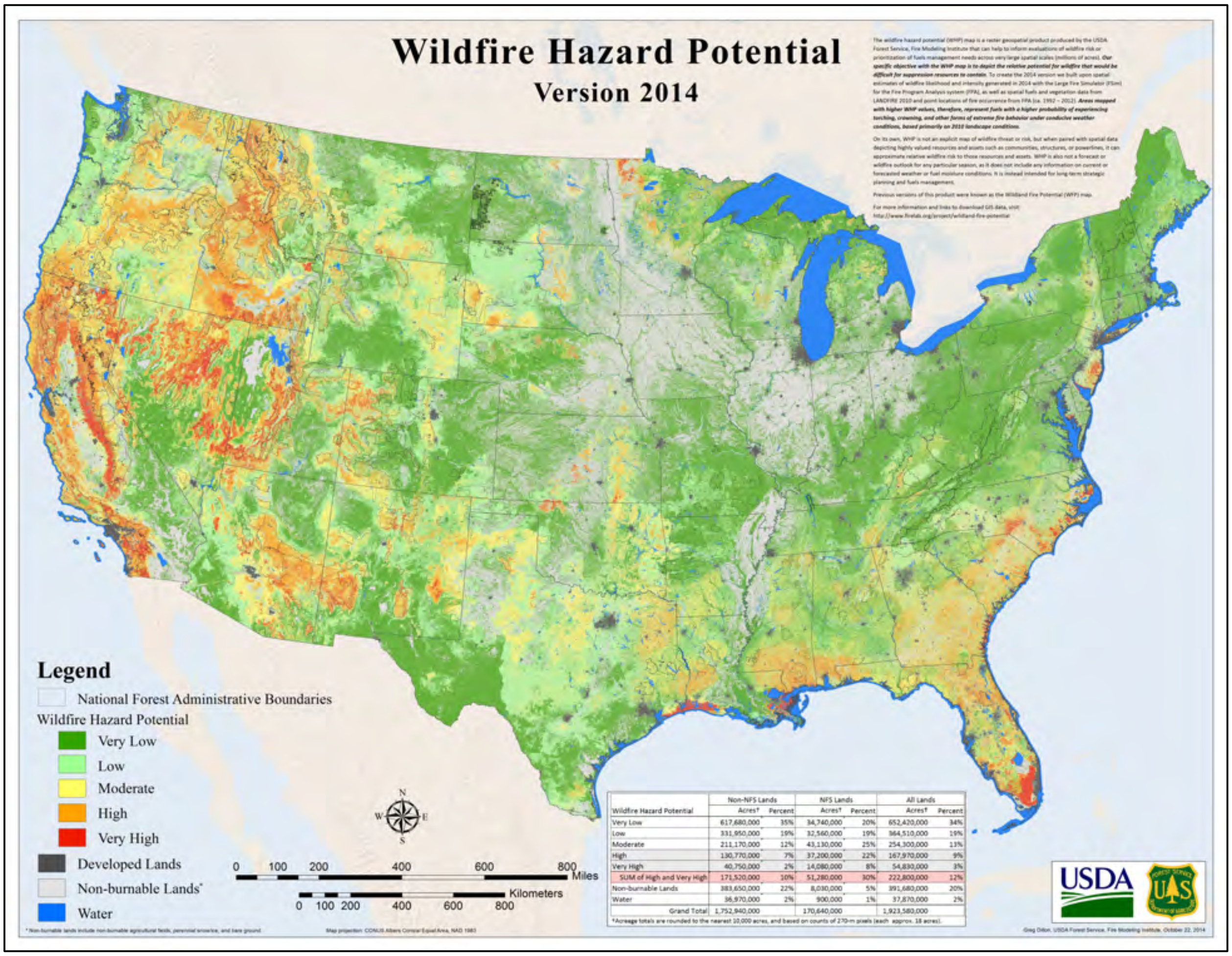

Figure 4-4: Wildfire Hazard Potential Map (Fire, Fuel, and Smoke Science Program 2016)

The police, fire, hospital, county border, and historical wildfire layers were sourced from the San Diego Geographic Information Source (SanGIS). SanGIS is an organization run by the city and county of San Diego and maintains a spatial data warehouse for the San Diego region. Once all the appropriate data was gathered, it was important to identify how to visualize the data on the web map.

4.4 – Identify Application & Prepare Data

Initially, the goal of the project was to create an application that could ingest multiple datasets, geolocate an address, and deliver an information pop-up with customized results and analysis. The Information Lookup map template developed by ArcGIS Solutions (Esri 2017) accomplished some of these tasks but was limited in functionality since it was a custom coded map template. Although the template provided a very clean, cookie-cutter solution for the website, it failed to deliver solutions such as including additional web map analytical tool options, did not offer ways to customize the information pop-ups, and ultimately proved to be a bad fit as the web map template. I then decided to build the web map data layers or feature classes by publishing them as web and feature services through AGOL, and then loading the web map into Web AppBuilder in order to take advantage of all the analytical tools and web map templates to create a customized web mapping application that could be readily embedded in a website.

Most of the web map data sets were ready to publish to the AGOL account after downloading them from their original sources. The only exception was the wildfire hazard potential layer file which was a raster file. AGOL only allows users to publish vector data, so the wildfire hazard potential file had to be prepared for publication using ArcGIS Desktop version 10.4 prior to uploading it to AGOL. This was accomplished by using the raster to polygon tool, to convert the raster file to a vector shapefile. Since the original WHP raster was converted from raster cells to polygons, there were small edge changes that can be noticed at a large scale extent. Once all the feature layers were prepared for publication, the shapefiles were compressed into zip files, and the feature layers were uploaded to the My Content section of AGOL, and then finally added to a single web map.

4.5 – Web Page Design

WebStorm 10 software was utilized to write the code for the website because it is compatible with the Macintosh operating system and could accommodate HTML5, CSS, and JS code languages (JetBrains 2017). The open-source file transfer protocol (FTP) client Fetch version 5.3 was used because it is compatible with the Macintosh operating system and has a user-friendly graphic user interface (GUI) for developers. Once the HTML5 code was written on WebStorm, Fetch would be used to connect the developer computer to the University servers, and create a means to publish the code using a University approved student account.

To conform to industry standards, the open-source website design template Bootstrap was used in this project (Bootstrap 2017). Bootstrap is a front-end web development framework using HTML, CSS, and JavaScript. Bootstrap was used to organize the style of the website and ensure a consistent template is loaded across different browser types users might employ. Using Bootstrap and User Experience/User Interface (UX/UI) design principles, the design layout of the website included a heading, the web map application, an accordion sidebar, and some fine print information on the footer of the website. An interactive GIS project should promote a positive UX/UI to succeed. Roth (2012) defines "cartographic interaction as the two-way dialogue between a user and a map mediated by a computing device." With the goal of the project to be a website that "emphasizes the achievement of user goals to ensure a satisfying and valuable experience with the digital interface" (Roth 2012). In short, this project pushes the user to drive the experience of the website, rather than the author or the website to drive the user experience of the website.

All the non-GIS widgets and tools needed to be organized in a way that was easily selectable and did not overwhelm the user with too much information. Through research in open-source code, Srdjan Pajdic's *Sexy Accordion* tool was used to fill this need (Pajdic 2017). As seen in Figure 4-5 or Appendix A, the accordion tool nests listed information into a vertical tab bar that expands and contracts when each heading is selected. The real-time wildfire news feeds included in the accordion tabs tool included a scrolling news feed related to wildfire events in Southern California and a Twitter news feed including content providers like CAL FIRE and the San Diego Fire Department. Once all the news feeds, information lists and the weather widget were embedded into the accordion tool; the website code was adjusted so that all the tools would fit within the margins and the text within each tool matched with the design of the website.

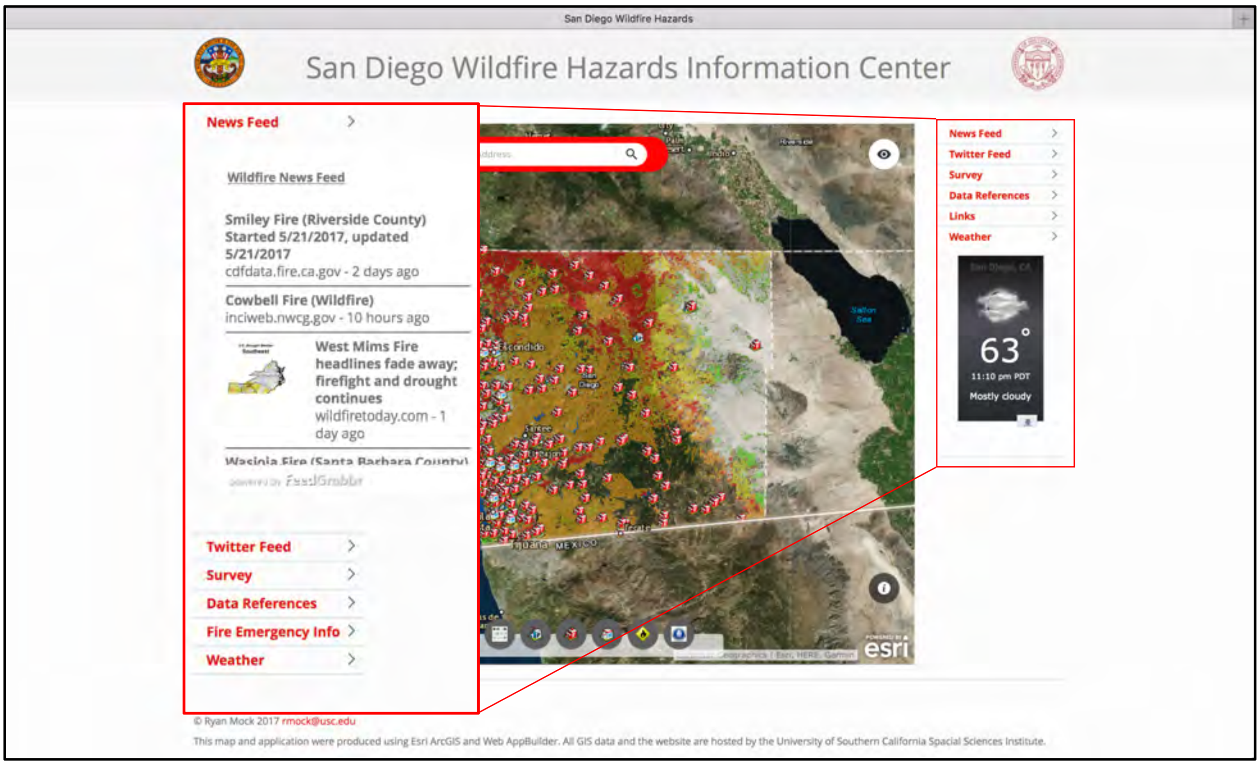

Figure 4-5: Accordion Tool

4.6 – Testing

The next phase of this project involved testing all of the widgets and tools within the web map and to ensure that all the tools in the accordion functioned properly. The information pop-ups for the data layers needed to be configured to display the appropriate information when clicked on. The tools nested within the accordion initially conflicted, so the code had to be debugged in WebStorm 10 and meticulously overhauled to ensure that the tabs worked properly and that all of the wildfire-related news and other related information was displayed correctly on the website.

4.7 – Publish Initial Website

Once all the initial webpage coding conflicts were debugged and resolved, the first draft of the website was ready to be published to the web address on the USC server. Information technology colleagues outside of USC reviewed the code and website for any bugs or errors that may have been overlooked during development. Once the third party quality assurance consultants expressed their satisfaction, messages containing invitations were sent to potential users to solicit feedback on the website user experience.

4.8 – Conduct User Feedback

It was important to include third party oversight and quality control of the website. A wide gamut of users with GIS experience were invited to test the website and provide feedback, including GIS professionals, San Diego residents, and laymen GIS users. Users could respond via a simple, multiple choice feedback survey using Google forms (Google 2017). The survey was free to operate, easily embedded into the code of the website, and preserved the anonymity of the users submitting feedback. Google Forms gathered the results from seven multiple choice questions, compiled into statistical pie and bar charts. In addition to the multiple choice questions, users were asked in a short answer question what their overall impressions of the website were and how the website could be improved for future iterations. The entire user feedback form can be found in Appendix B.

4.9 – Publish Final Webpage

After receiving feedback from the targeted end-users, user feedback was used to guide minor aesthetic changes on-the-fly, and to develop future plans to implement more significant changes to the website beyond this thesis project. After the update, the final working version of the website was published online.

Chapter 5 Results

The resulting thesis project mashes together the power of a GIS web map with the near-real-time wildfire information into a functional website at: http://www-scf.usc.edu/~rmock/index.html. The web map mashup developed using Web AppBuilder gave the user access to additional data, news feeds, and other map-based tools that are not available in the environment of a basic web map. The finished website is a unique balance of cartographic visualization and the accompaniment of streaming information feeds.

5.1 – Website Components

Once the website loads to the browser, the user is presented with a splash screen (Figure 5-1). The splash screen provides the user with a breakdown of all buttons, widgets, and tools located on the web map application and accordion sidebar. Just below the web map application is a link that allows users to maximize the web map into a full-screen mode and examine the data of the web map in much finer detail.

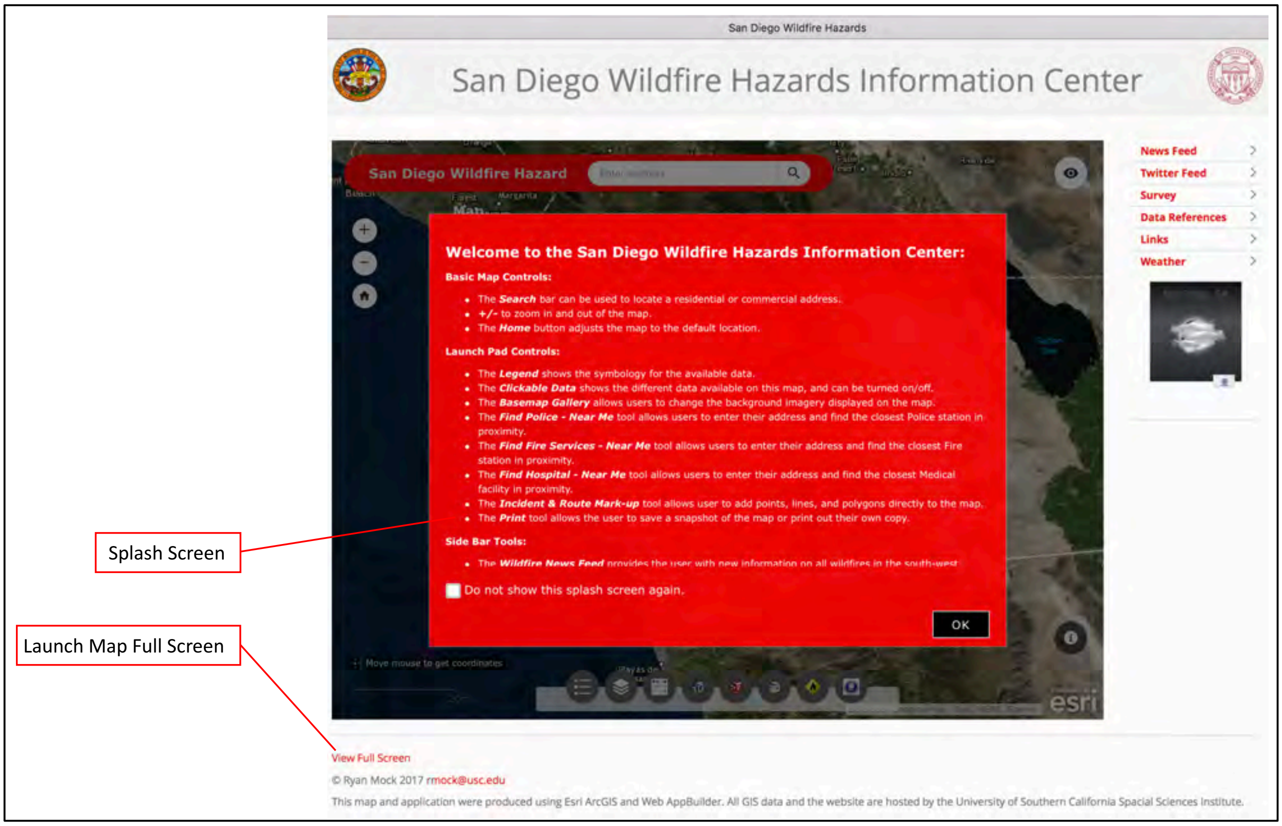

Figure 5-1: Website with Splash Screen Diagram (http://www-scf.usc.edu/~rmock/index.html)

Once the user closes the default splash screen, all the details and tools of the web map can be seen (Figure 5-2). Prominently positioned on the top of the web map is the address search bar, which is an Esri address geolocator running behind the scenes. The address search bar allows homeowners to search for their property by address, then the web map will zoom into the requested location. Underneath the address search bar are the zoom buttons that lets the user zoom in (+) and out (-) of the web map. The home button returns the map to the original default map extent.

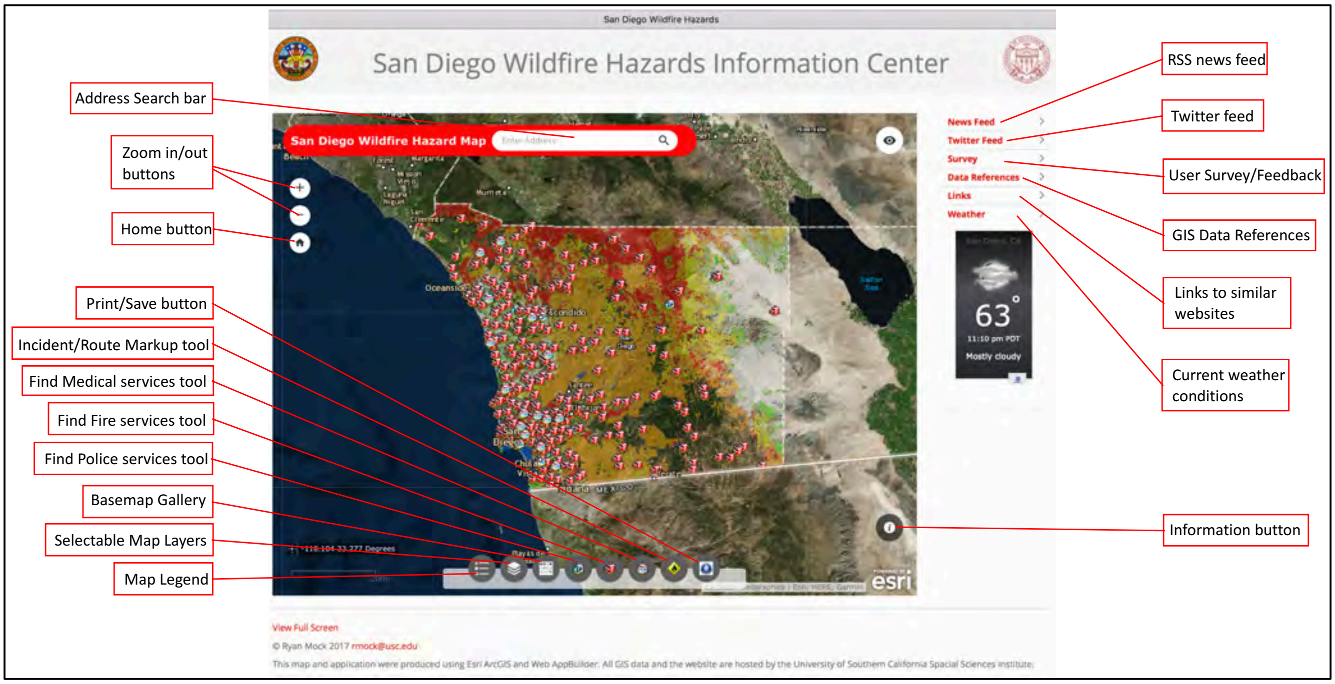

Figure 5-2: Website Diagram and Tools Display

Located on the bottom of the web map are the launch pad controls which host all the web map tools and widgets. Starting from left to right, the first button is the Map Legend. The map legend provides the user with symbology and labels for the data represented in the web map. Next is the selectable map layer list, or clickable data button, which allows the user to toggle all available data layers in the web map. The basemap gallery button gives the user the option to change the background imagery visualized on the web map. The next three tools are variations of the same widget, the Near Me widget. The Near Me widget allows users to find a certain feature within a buffer distance of a defined address, and view detailed information and directions to the feature via a pop-up (Esri 2017). The Find Police, Find Fire Services and Find Hospital buttons use the Near Me functionality to locate the nearest selected first responder services and provide the user with an information popup with pertinent information. The next widget is the Incident & Route Mark-Up Tool, which is based on the Draw widget. The Draw widget allows users to create a point, line, or polygon graphics that display directly onto the web map. In addition to the drawn features, the Draw widget creates an operational layer specific to the user, that can be toggled on and off (Esri 2017). The purpose of the Incident & Route Mark-Up Tool is to provide the user with the means to add events, routes, and incidences to their web map that wouldn't already be populated on the map. For instance, if the user is notified of a road closure or newly created emergency evacuation route, they could mark the road closure with a red X and highlight the new evacuation route in green. The final tool on the launch pad is the Print tool. The print tool allows the user to print or save a copy of their web map for personal use. Directly to the right of the launch pad controls is the Project Information button that explains the purpose and goals of the San Diego Wildfire Hazards Information Center.

Located to the right of the web map application are the sidebar tools. All the tools and information lists are compacted into a selectable, accordion style information list. From top to bottom, the first tool is a Really Simple Syndication (RSS) news feed widget developed by FeedGrabbr (FeedGrabbr 2017). The streaming news feed widget hosts 3 near-real-time news feeds about wildfires incidences in Southwestern California. Each news article can be selected and opened in a new browser tab. The next tool is a streaming Twitter feed list that provides information about wildfires in San Diego County and wildfire preparation (Twitter 2017). The Wildfire Emergency Twitter list hosts feeds from CAL FIRE San Diego, San Diego County, Ready San Diego, and the San Diego Fire Department. Below the Twitter feed is the thesis project user survey and feedback form hosted by Google Forms (Google 2017). The Google Forms survey does require the user to login to their Google account prior to submittal but does not share any of the user's personal information and preserving user anonymity in the responses. The Data References tab provides links to the sources of all the original data included in the web map. The Fire Emergency Info tab is a list of organizations that could provide users with increased value in planning and mitigating wildfire events. The last tab is an open-source weather widget hosted by AccuWeather that visualizes current weather conditions (AccuWeather 2017). Users can change the default weather location by clicking on the weather graphic and changing the location in the new browser tab. All the widgets and tools chosen in this web map mashup reflect a desire to incorporate open-source software as much as possible and work together to provide the end-user a central hub of wildfire related information.

5.2 – End User Scenario

In order to illustrate the value of the San Diego Wildfire Hazard Information Center, the following is an end-user scenario with a problem and solution. A full video link to this user scenario can be found at http://www.screencast.com/t/ySafKPH9TADm.

Problem:

A local camping club is planning a hike to Cowles Mountain regional park in eastern San Diego, CA. It is early October, the climate is dry, and winds have picked up, so the National Weather Service has declared a Red Flag warning for the weekend in San Diego County. In order to be safe, Cal the event planner would like to determine the likelihood of a wildfire occurring on the trail, the last time a wildfire burned in the area, and find the closest hospital to the trail in case a camper gets hurt while hiking.

Solution:

Cal's first step is to open his Internet browser and type in the address to the website: http://www-scf.usc.edu/~rmock/index.html. Once the website loads, Cal will enter the name or address of the location (i.e. Cowles Mountain) in the address search bar to find his location. Since the WHP layer is set to default, Cal just has to open the legend widget to learn the park has a Very High potential for a wildfire. Concerned by this information, Cal clicks on the Clickable Data button to learn more about the park. Cal toggles off the WHP layer, and toggles on the historic wildfire layer to find out information about the most recent wildfire in proximity to the park. Cal spots a wildfire polygon just to the north, clicks on the polygon, and ascertains that the 2003 Cedar fire burned nearly 288,369 acres. In case of an emergency, Cal wants to know how far he will need to travel to find medical support. Cal enters the name of the park in the Find Hospital – Near Me tool and is shown an information popup with nearby medical facilities. Cal clicks on the nearest result, which provides information for Grossmont Hospital which is only 3.1 miles away. Concerned that the area is at a very high risk of a wildfire, and the local vegetation hasn't experienced a burn since 2003, Cal ultimately decides to avoid the high risk and postpone the hike until the weather cools off.

The preceding scenario shows how a user can easily use the web map and accompanying tools to find information about any location or address within San Diego County. The incorporation of historical wildfire data, wildfire potential, simplistic web map tools and visual cartography allow San Diego residents to produce an educated analysis to a problem. By making GIS tools easy to understand and maneuver, and providing accompanying information to these tools, any user with little to no GIS experience can successfully traverse this website.

Chapter 6 Application Evaluation

Application evaluations are vital for tracking the user experience, information comprehension, and whether any measurable value was gained by the user. The goal of the feedback portion of this study was to gauge the user experience through simple questions and a short answer critique of the web map. Like a focus group or Yelp review, positive and negative feedback from the target audience are important because it shows what succeeded and what needed improvement.

6.1 – User Sample Population

Over the course of 4 days, invitations were sent out to potential users to test the functions of the website and provide feedback via the Google Forms survey. User invitations were sent to Facebook, LinkedIn, student groups, and a military veteran GIS organization. Although feedback was received from only 10 users via the survey and 2 users provided notes via email, the website logged approximately 205 visits over 4 days.

6.2 – User Survey and Feedback

The user survey is broken down into 7 multiple choice questions and 1 short answer question (see Appendix B). The survey questions ask users a wide range of questions including demographics, familiarity with GIS, to rate the value of the website, and finally what they would like to see improved or added to the website.

Questions 1 and 2 (Figures 6-1 and 6-2) summarize the residency status of users and the type of home they reside in. 80% of users lived in San Diego County, while the remaining users reside outside of the county. Half of the users surveyed are homeowners, while the other half are renters. Question 3 broke down the demographics of the user population, with 20% being GIS professionals, 70% having experience using GPS or web maps prior, and 10% having little to no exposure to any kind of GIS or web map.

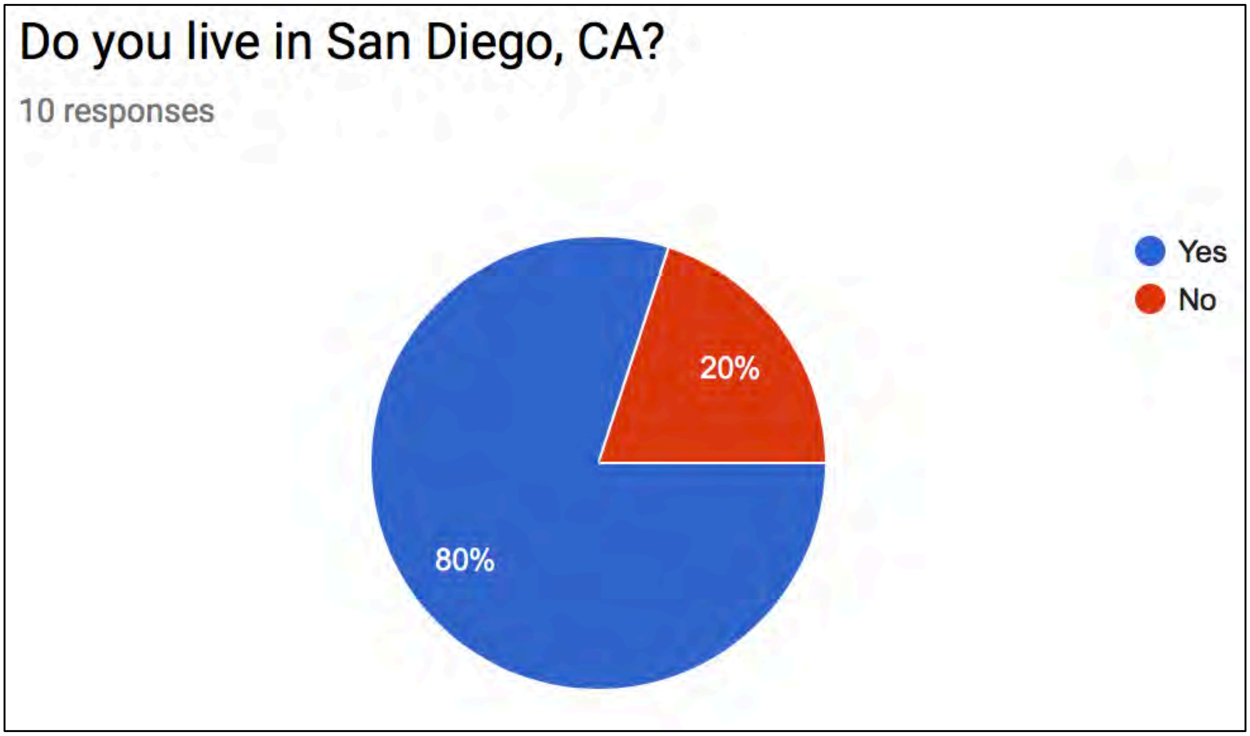

Figure 6-1: Survey Question #1

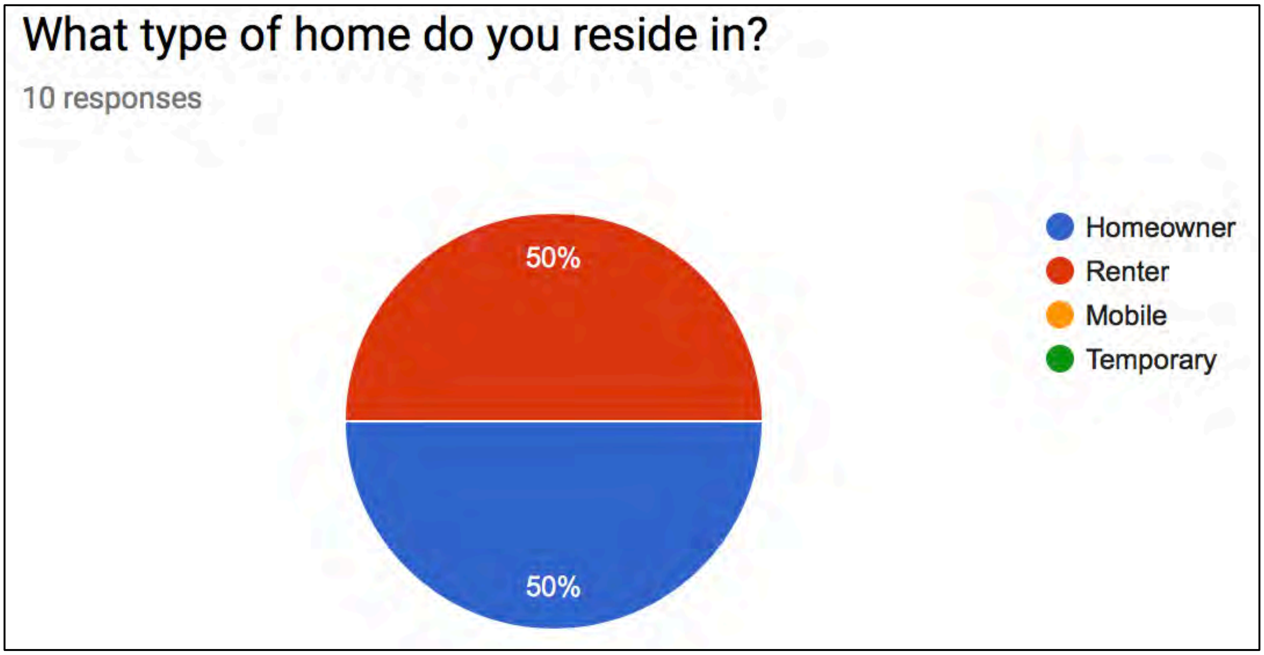

Figure 6-2: Survey Question #2

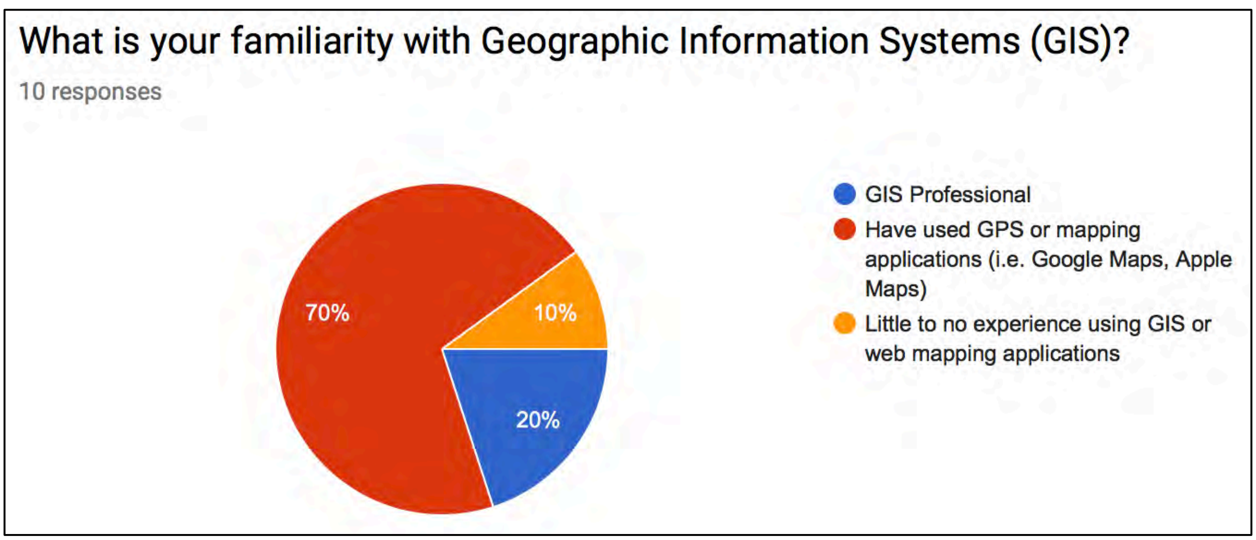

Figure 6-3: Survey Question #3

Questions 4, 5, 6, and 7 (Figures 6-4, 6-5, 6-6, 6-7) explain that approximately 90% of users found the data easy to comprehend, the analysis tools easy to operate, and enjoyed a positive user experience. 10% of the users had a slightly negative experience, showing that some small improvements may be needed to help non-savvy users maneuver the website.

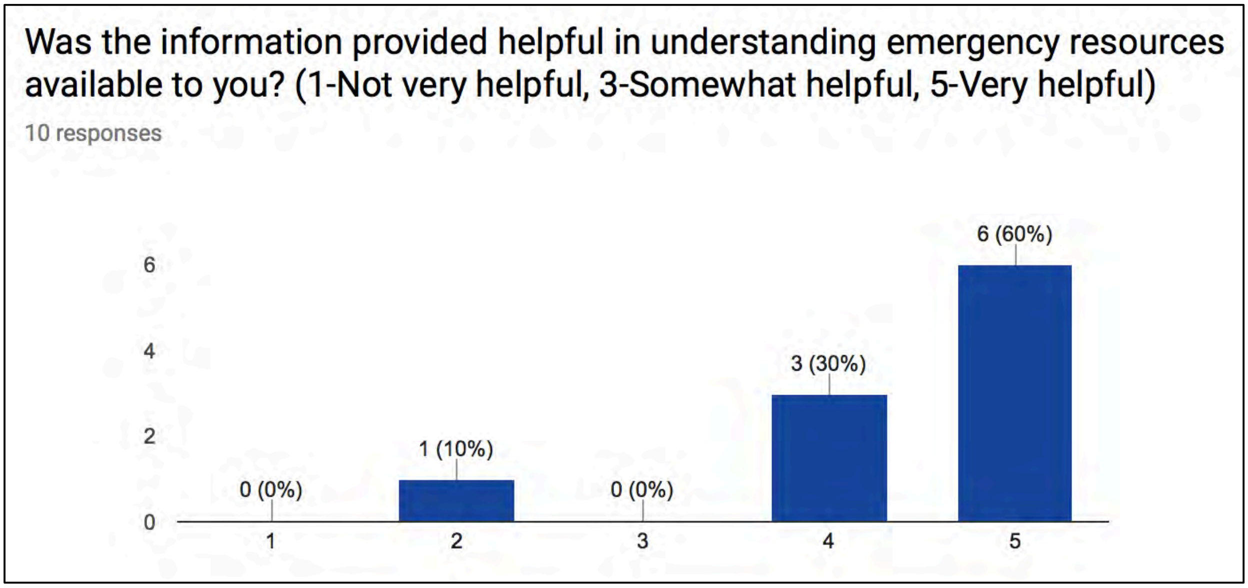

Figure 6-4: Survey Question #4

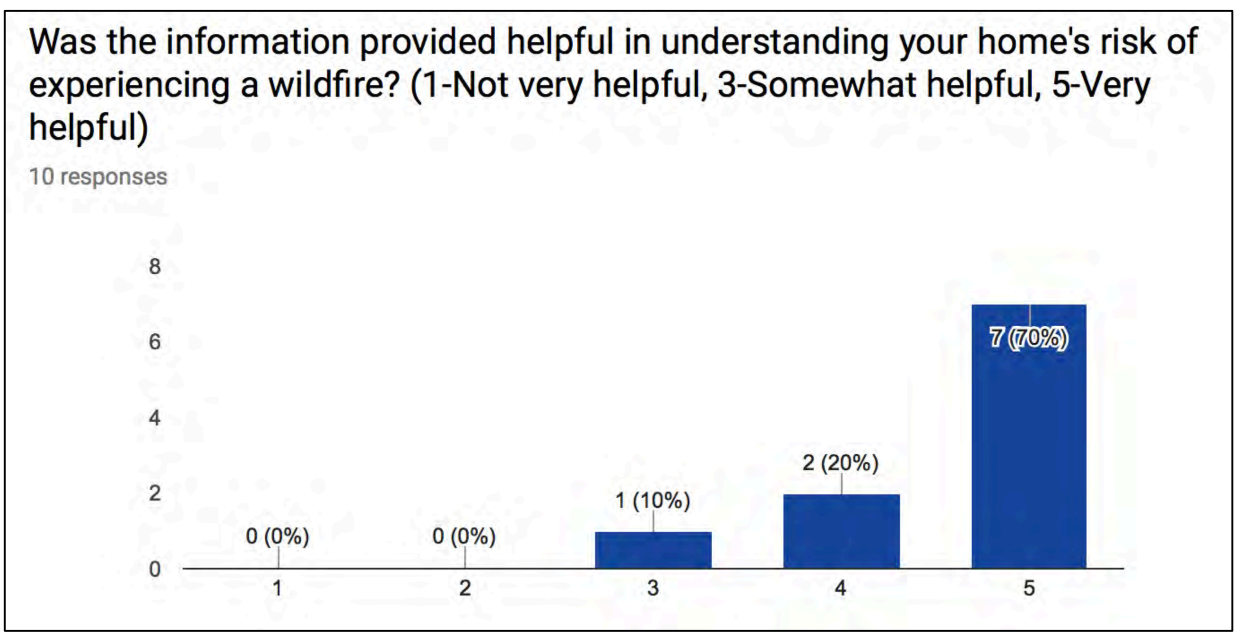

Figure 6-5: Survey Question #5

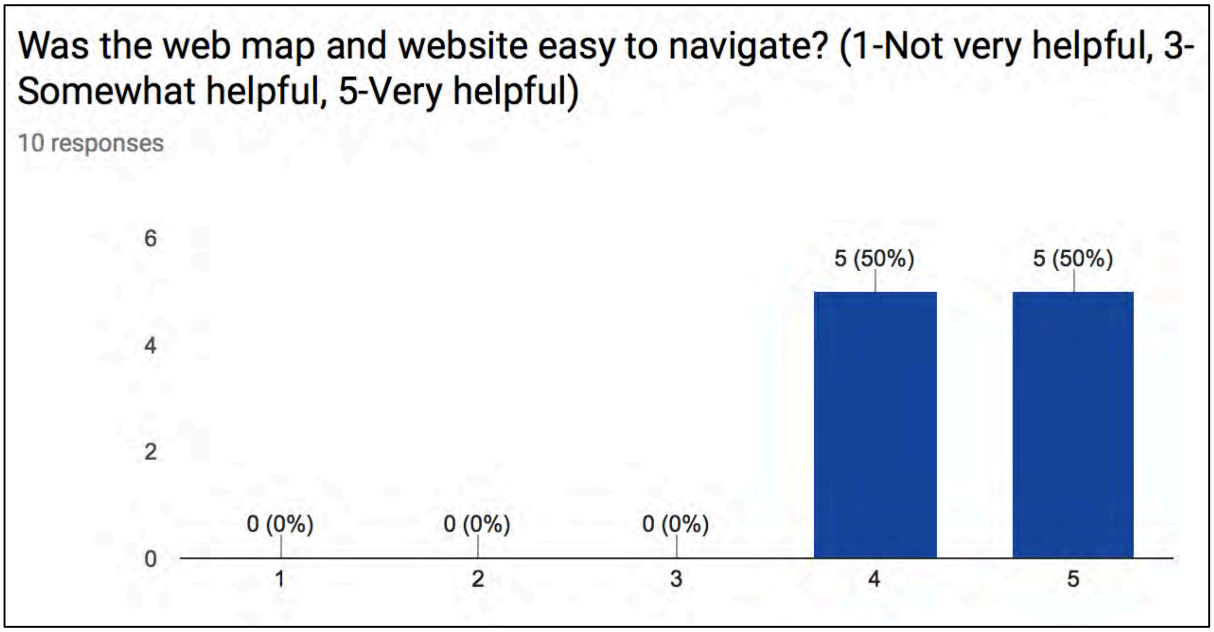

Figure 6-6: Survey Question #6

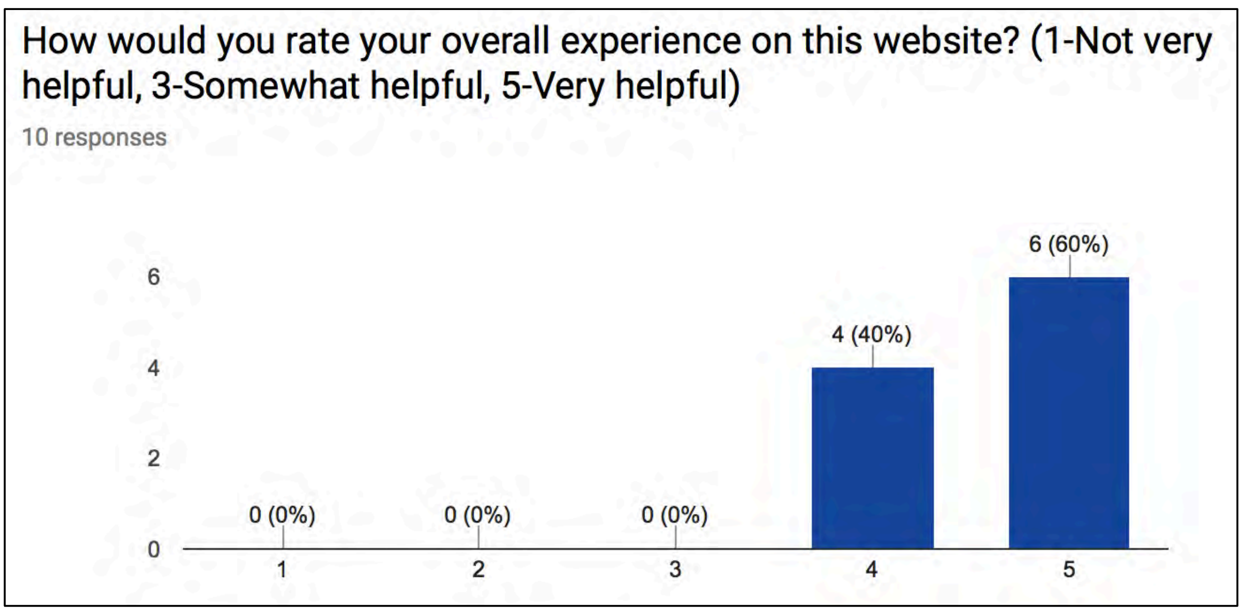

Figure 6-7: Survey Question #7

Most of the short answer critiques from Question 8 (Figure 6-8) found that users were mostly positive and provided useful advice for future iterations of the web map application and website development. Although the sample population was not scientifically random, the feedback obtained provided helpful insights into the failings and successes of the project from mostly non-bias users, as well as some indication of the career profiles of those who responded to the survey.

How do you feel this website could be improved?

8 responses

Great site!

Scroll bars in the sidebar drop downs

Some thoughts from a former Topite: (1) maybe it'd make sense to put the key roads (I-5, etc) on top of the fire data. This may help orientate people, especially if they are trying to figure out quickly where the fire station is ("is that the one on X street or Y avenue?"). Or maybe have that data appear when they zoom to a certain scale. (2) I feel like some people may be nervous to add their own vector data to the website. They may assume that whatever data they add is automatically ingested without any quality control. For fear of being inaccurate, I can imagine them just foregoing that option altogether. Maybe put quick note saying that it'll be reviewed. They may be more likely to use this feature. (3) It's a little hard to differentiate between hospitals and police stations. (4) Maybe above the map itself say 1 sentence like "This map is designed to help you..." just so they know what it is meant to be used for when they get to the page. --- overall great site. Can imagine it's very useful. Well done.

Looks good.

That the survey didn't jump to the bottom every time you select an answer. Lorna

Real time evacuation locations on map? Twitter/News works great. Overall awesome.

Legend should show on the side at all times outside of the map area

Honestly, it's really on point. maybe have the small collapsable legend display automatically so people aren't having to navigate for it. Apart from that, great tool to have.

Figure 6-8: User responses on Survey Question #8

6.3 – Application Evaluation & Improvements

The project received very useful feedback from the Google Forms survey (Figure 6-8) and some additional comments sent through email. Many of the suggestions received consisted of small changes in language to the splash screen, minor corrections, typographic errors, and aesthetic choices such as color scheme. The splash screen instructions were changed multiple times to specify the functions of the tools, and to minimize text instructions for the end-user. Aesthetic changes were made to the text and images in the accordion tool widgets to better conform to the overall design of the entire website. The RSS news feed widget was adjusted to limit the number of feeds that are viewed, and condense the feeds to align with the other widgets in the accordion tabs.

The most profound critique received was an idea to include a layer that displays possible evacuation areas and routes to these areas in the event of an emergency. Future work will include incorporation of this idea by including a selectable layer that displays an evacuation areas layer such as schools, stadiums, and parks. Future project cooperation with emergency management authorities would allow for the inclusion of more accurate and real-time data feeds to the web map.

Chapter 7 Conclusions

This chapter summarizes the completed application, the challenges experienced in the development process, project limitations, possible future work on the project, and the final conclusions.

7.1 – Summary Description of Application

This web map application provides users with a one-stop-shop location for wildfire data, wildfire news, and related content specifically for San Diego County, California. The website provides San Diego County homeowners with the visual and spatial tools to understand the relative risk of a wildfire damaging their home, the history of local wildfire burns, their proximity to emergency response resources, and real-time wildfire news feeds and related information. This web map mashup gives end-users the necessary tools to develop their own analyses and conclusions. By developing all the tools and data on the back-end, end-users can easily maneuver the front-end website with little to no instruction.

7.2 – Challenges

The author’s professional GIS background is comprised of producing military or commercial maps on paper. It was easy to describe this experience of tackling the world of web GIS as extremely challenging. The first challenge was deciding whether to pursue a custom web map template or build a web map from scratch using Web AppBuilder. After wrestling with the pros and cons of both paths, the out-of-the-box functionality of Web AppBuilder was clearly the best option. Web map templates customized by others often have very narrow capabilities in terms of functionality and ease of further customization, and usually, require extensive recoding to include additional robust tools. Whereas Web AppBuilder provides developers a wealth of widgets and tools that can be immediately deployed with simple modifications in the settings.

The main challenge that plagued this project's efforts was the amount of web page scripting code (HTML, CSS, and JavaScript) that needed to be reworked, audited, and debugged. Although most of the coded solutions were developed by third parties, the original code written by the authors' needed to be adapted to the aesthetics of this particular project goals. If a CSS or JavaScript issue could not be resolved, further assistance was sought from Github, coding forums, or expertise from professional colleagues in the web design world. For instance, the accordion tabs on the sidebar were initially designed to just contain lists of text. The expanding accordion tabs had to be re-engineered to include a variety of widgets, tools, and lists. Much of the third party tools created conflicted with the Bootstrap framework or original accordion code. These code conflicts resulted in weeks of testing and debugging to find an equilibrium to all the moving parts embedded in the website.

7.3 – Project Limitations

The author sought to develop a web mapping application using primarily out-of-the-box solutions provided by Web AppBuilder. Although the functionality of the tools was effective for finding solutions to basic coding problems, it did not provide intensive solutions to more complex issues. It would be more helpful if Esri provided developers with a more robust catalog of tools and widgets in Web AppBuilder, much like the tool extensions and open-source solutions that are available in ArcGIS desktop. The limited amount and functionality of tools or widgets provided by Web AppBuilder created a proverbial ceiling that capped user choices to conduct more complex analyses that currently can be accomplished using in a Desktop GIS application development environment.

7.4 – Future Work

Although this project resulted in a useful web map mashup website, there is always room for improvement. For instance, all of the webpage (not web map) tools used in this project were open-source or free. With a nominal budget, the functionality and reliability of some of the components in the website could be improved. For instance, the RSS news feed by FeedGrabbr limits developers using the free version to three news sources minimizes functionality of the widget, and only offers a basic feed template to choose from. Likewise, the AccuWeather widget used was a free version of the company's weather widget that is clunky and could be replaced with a more elaborate or proprietary weather data widget.

Future versions of the website need to incorporate a healthy collaboration with other developers to refine the code, adjust aesthetics, and market the product to the end-user effectively. Although through the project efforts all of this work was able to be accomplished independently, a positive collaboration between motivated developers can produce greater results than the efforts of just one person. Just by talking out ideas and including Quality Assurance/Quality Control (QA/QC) in the development process, the quality of work being produced is enriched, and the developers become more motivated to accomplish new goals.

7.5 – Alternative Solutions

Open-source alternatives to Esri's suite of GIS software and online data hosting include the Google Map API for basic mapping functions, the Leaflet API for interactive mapping needs, or the OpenStreetMap API for a more collaborative type Volunteered Geographic Information (VGI) solution. Each of the preceding mapping API solutions provides smaller organizations with a free or low-cost solution to produce web maps for organizational websites. These alternative solutions allow for data to be hosted on cloud computing platforms such as Amazon or IBM or on servers owned by the organizations doing the application development or their clients, so server host costs could be reduced compared to the cost of AGOL licensing.

If a future organization does decide to employ an AGOL solution, the project manager will need keep in mind that a basic AGOL user plan will cost $500 a year based on prices at the time of this writing, and incur additional credit costs from hosting original datasets on AGOL and enabling higher level functions in WebApp Builder tools, such as directional routing for users (Esri 2017). An ArcGIS desktop license would be helpful in preparing data for online publishing, which has a basic license cost of approximately $1500.

7.6 – Final Conclusions

The final iteration of the website hosts a litany of visual tools and widgets that solved the initial problem of how to educate San Diego residents about local wildfires. The execution of the development process was arduous but ultimately fulfilling as the author learned a great deal about resolving coding conflicts within the web map application and website code. Although discouraging to find examples of one's unique ideas already in development by others along the way, the author chose to incorporate these ideas into the thesis project and build upon them.

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Appendix A – Website Code

```
<!doctype html>
<!--[if lt IE 7]>      <html class="no-js lt-ie9 lt-ie8 lt-ie7"
lang=""> <![endif]-->
<!--[if IE 7]>         <html class="no-js lt-ie9 lt-ie8"
lang=""> <![endif]-->
<!--[if IE 8]>         <html class="no-js lt-ie9" lang="">
<![endif]-->
<!--[if gt IE 8]><!-->
<html class="no-js" lang="">
<!--<![endif]-->

<head>
  <meta charset="utf-8">
  <meta http-equiv="X-UA-Compatible" content="IE=edge,chrome=1">
  <title>San Diego Wildfire Hazards</title>
  <meta name="description" content="Ryan Mock - Final Project">
  <meta name="viewport" content="width=device-width, initial-
scale=1">
  <link rel="apple-touch-icon" sizes="57x57" href="apple-touch-
icon-57x57.png">
  <link rel="apple-touch-icon" sizes="60x60" href="apple-touch-
icon-60x60.png">
  <link rel="apple-touch-icon" sizes="72x72" href="apple-touch-
icon-72x72.png">
  <link rel="apple-touch-icon" sizes="76x76" href="apple-touch-
icon-76x76.png">
  <link rel="apple-touch-icon" sizes="114x114" href="apple-
touch-icon-114x114.png">
  <link rel="apple-touch-icon" sizes="120x120" href="apple-
touch-icon-120x120.png">
  <link rel="apple-touch-icon" sizes="144x144" href="apple-
touch-icon-144x144.png">
  <link rel="apple-touch-icon" sizes="152x152" href="apple-
touch-icon-152x152.png">
  <link rel="apple-touch-icon" sizes="180x180" href="apple-
touch-icon-180x180.png">
  <link rel="icon" type="image/png" href="favicon-32x32.png"
sizes="32x32">
  <link rel="icon" type="image/png" href="android-chrome-
192x192.png" sizes="192x192">
  <link rel="icon" type="image/png" href="favicon-96x96.png"
sizes="96x96">
  <link rel="icon" type="image/png" href="favicon-16x16.png"
```

```
sizes="16x16">
  <link rel="manifest" href="manifest.json">
  <link rel="mask-icon" href="safari-pinned-tab.svg"
color="#5bbad5">
  <meta name="msapplication-TileColor" content="#da532c">
  <meta name="msapplication-TileImage" content="mstile-
144x144.png">
  <meta name="theme-color" content="#ffffff">
  <link rel="stylesheet" href="css/bootstrap.min.css">
  <link rel="stylesheet" href="css/main.css">

  <!-- ACCORDION CODE CSS -->
  <style type="text/css">

  .accordion {
    max-width: 560px;
    padding-left: 0;
  }

  .accordion > li {
    border-bottom: 1px solid #d9e5e8;
    position: relative;
    list-style-type: none;
  }

  .accordion > li > p {
    display: none;
    padding: 10px 25px 30px;
    color: #6b97a4;
  }

  .accordion > li > a {
    width: 100%;
    display: block;
    cursor: pointer;
    font-weight: 600;
    line-height: 2;
    font-size: 13px;
    text-indent: 15px;
    user-select: none;
  }

  .accordion > li > a:after {
    width: 8px;
    height: 8px;
    border-right: 1px solid #4a6e78;
```

```
    border-bottom: 1px solid #4a6e78;
    position: absolute;
    right: 10px;
    content: " ";
    top: 8px;
    transform: rotate(-45deg);
    -webkit-transition: all 0.2s ease-in-out;
    -moz-transition: all 0.2s ease-in-out;
    transition: all 0.2s ease-in-out;
  }

  .accordion p {
    font-size: 13px;
    line-height: 2;
    padding: 10px;
  }

  a.active:after {
    transform: rotate(45deg);
    -webkit-transition: all 0.2s ease-in-out;
    -moz-transition: all 0.2s ease-in-out;
    transition: all 0.2s ease-in-out;
  }

  .fg_font_times, .fg_font_times span, .fg_font_times p {
      font-family: "Open Sans","Helvetica
Neue",Helvetica,Arial,sans-serif !important;
      color: #777 !important;
    }
    .fg_wid_header span {
      font-size: 12px !important;
      text-decoration: underline;
    }
  </style>
  <!-- END ACCORDION CODE CSS -->

  <script src="js/vendor/modernizr-2.8.3-respond-
1.4.2.min.js"></script>
  <script
src="http://cdnjs.cloudflare.com/ajax/libs/jquery/2.1.3/jquery.m
in.js"></script>
</head>

<body>
  <div class="jumbotron" style="padding: 10px 0;">
    <div class="container">
```

```
      <div class="row">
        <div class="col-md-1">
          <img class="img-responsive" src="img/seal.png" />
        </div>
        <div class="col-md-10">
          <h1 class="text-center" style="margin-top:
0;"><small>San Diego Wildfire Hazards Information
Center</small></h1>
        </div>
        <div class="col-md-1">
          <img class="img-responsive" src="img/USC2.png" />
        </div>
      </div>
    </div>
  </div>

  <div class="container">
    <!-- ACCORDION 2 COLUMN -->
    <div class="row">
      <div class="col-md-10">
        <div class="embed-responsive embed-responsive-4by3">
          <iframe frameborder="0" scrolling="no"
marginheight="0" marginwidth="0" title="San Diego Wildfires"
src="http://uscssi.maps.arcgis.com/apps/webappviewer/index.html?
id=c062df2665d54e41a902afdbc6de971b"></iframe>
        </div>
      </div>
      <div class="col-md-2">
        <ul class="accordion">
          <li>
            <a href="#">News Feed</a>
            <p class="feedgrabbr_widget"
id="fgid_b61560005197adef11725b9a4"></p>
            <script> if (typeof(fg_widgets)==="undefined")
fg_widgets = new
Array();fg_widgets.push("fgid_b61560005197adef11725b9a4");</scri
pt>
            <script
src="http://www.feedgrabbr.com/widget/fgwidget.js"></script>
          </li>
          <li>
            <a href="#">Twitter Feed</a>
            <p><a class="twitter-timeline" data-lang="en" data-
link-color="#E95F28"
href="https://twitter.com/MockGreatness/lists/wildfireemergency"
>A Twitter List by MockGreatness</a> <script async
```

```
src="//platform.twitter.com/widgets.js" charset="utf-
8"></script></p>
          </li>
          <li>
            <a href="#">Survey</a>
            <p><iframe
src="https://docs.google.com/a/usc.edu/forms/d/e/1FAIpQLSfqj3_QD
fyOg4cXD1hA0n7bwNr6RE0b2rV0uQJ_4aZj_3AiNg/viewform?embedded=true
" width="300" height="300" frameborder="0" marginheight="0"
marginwidth="0">Loading...</iframe></p>
          </li>
          <li>
              <a href="#">Data References</a>
            <p>
              <a href="https://firelab.org/project/wildfire-
hazard-potential">Wildfire Hazard Potential (USFS)</a><br/>
              <a
href="http://www.fire.ca.gov/fire_prevention/fire_prevention_wil
dland_zones">Wildfire Severity Zone (CALFIRE)</a><br/>
              <a href="http://www.sangis.org">1st Responder
Information (SanGIS)</a>
            </p>
          </li>
          <li>
            <a href="#">Fire Emergency Info</a>
            <p>
              <a href="http://www.readysandiego.org">Ready San
Diego</a><br/>
              <a
href="http://wildlandfire.maps.arcgis.com/apps/PublicInformation
/index.html?appid=0c12ac1e89c24075a2be145f4db6caf5">WildlandFire
.com</a>
            </p>
           </li>

            <li>
            <a href="#">Weather</a>
            <p>
               <p id="awcc1448937122275" class="aw-widget-
current"  data-locationkey="" data-unit="f" data-language="en-
us" data-useip="true" data-uid="awcc1448937122275"></p>
<script type="text/javascript"
src="http://oap.accuweather.com/launch.js"></script>
         </p>
          </li>
```

```
        </ul>
      </div>
    </div>
    <!-- END ACCORDION 2 COLUMN -->
    <hr>
    <footer>
      <a href="http://www.accuweather.com/en/us/san-diego-
ca/92101/weather-forecast/347628" class="aw-widget-legal"></a>
      <p><a
href="http://uscssi.maps.arcgis.com/apps/webappviewer/index.html
?id=c062df2665d54e41a902afdbc6de971b" alt="Full Size Application
at ArcGIS.com" target="_blank">View Full Screen</a></p>
      <p>&copy; Ryan Mock 2017 <a
href="mailto:rmock@usc.edu">rmock@usc.edu</a></p>
      <p>This map and application were produced using Esri
ArcGIS and Web AppBuilder.  All GIS data and the website are
hosted by the University of Southern California Spatial Sciences
Institute.</p>
    </footer>
  </div>
</body>

<!-- ACCORDION CODE JS -->
<script type="text/javascript">
//$(document.load(function() {
  (function($) {

    $('.accordion a').click(function(j) {
        var dropDown = $(this).closest('li').find('p');


$(this).closest('.accordion').find('p').not(dropDown).slideUp();

        if ($(this).hasClass('active')) {
            $(this).removeClass('active');
        } else {

$(this).closest('.accordion').find('a.active').removeClass('acti
ve');
            $(this).addClass('active');
        }

        dropDown.stop(false, true).slideToggle();

        j.preventDefault();
    });
```

```
  })(jQuery);
//}))
</script>
<!-- END ACCORDON CODE JS -->


</html>
```

Appendix B – User Survey

User Survey

I appreciate your feedback!

1. Do you live in San Diego, CA?

Yes
No

2. What type of home do you reside in?

Homeowner
Renter
Mobile
Temporary

3. What is your familiarity with Geographic Information Systems (GIS)?

GIS Professional
Have used GPS or mapping applications (i.e. Google Maps, Apple Maps)
Little to no experience using GIS or web mapping applications

4. Was the information provided helpful in understanding emergency resources available to you? (1-Not very helpful, 3-Somewhat helpful, 5-Very helpful)

1
2
3
4
5

5. Was the information provided helpful in understanding your home's risk of experiencing a wildfire? (1-Not very helpful, 3-Somewhat helpful, 5-Very helpful)

1
2
3
4
5

6. Was the web map and website easy to navigate? (1-Not very helpful, 3-Somewhat helpful, 5-Very helpful)
1
2
3
4
5

7. How would you rate your overall experience on this website? (1-Not very helpful, 3-Somewhat helpful, 5-Very helpful)
1
2
3
4
5

8. How do you feel this website could be improved?
________________.