

Development of a Web GIS Application to Aid Marathon Runners in the Race Selection and Planning  
Process

by

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## **Dedication**

To my patient and supportive husband, Greg, and my family and friends who provided endless encouragement and were by my side throughout the process.

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## List of Abbreviations

|      |                                          |
|------|------------------------------------------|
| API  | Application Programming Interface        |
| CSS  | Cascading Style Sheets                   |
| CSV  | Comma Separated Values                   |
| ESRI | Environmental Systems Research Institute |
| GIS  | Geographic information system            |
| GPX  | GPS Exchange Format                      |
| KML  | Key Mark-up Language                     |
| HTML | Hypertext Markup Language                |
| MOMS | Motivation of Marathoner's Scale         |
| UX   | User Experience                          |

## **Abstract**

Runners who strive to complete a marathon will need to make many sacrifices in their daily lives and train for months in order to accomplish such a physical and mental endeavor. Given this, having a successful race experience is pivotal. All the hard work could be compromised without the proper tools to help select and plan for the race itself. There are numerous resources that provide guidance for runners focusing on how to prepare physically for the distance, minimize injury and maximize performance. What is currently lacking are resources focusing on the individual needs of the runner and the logistical process of selecting and preparing for a race. The development of this Web GIS application used a geodatabase and Web GIS technology that allows a runner to personally select criteria to find a race that meets their needs, view races and elevation profiles on a map, select a 3D interactive view of the race courses to study the terrain, and view nearby lodging and dining options. Geospatial technology gives a runner a better understanding of the course and streamlines the travel process, reducing stress and increasing the likelihood of a successful and enjoyable race experience. After careful analysis of a runner's needs and the marathon selection process, and evaluating what techniques and methods should be used, a Web GIS application was developed to help facilitate the process for an enhanced race experience. In addition to providing a valuable tool for runners, this application provides a template for developers constructing a Web GIS application for any athletic or travel based event. Emerging technology will transform the Web GIS application into an even more powerful tool. Utilizing predictive analytics which incorporates data, statistical algorithms and machine learning techniques, patterns from the race course can be modelled and compared with local terrain to create similar courses for training purposes. It's invigorating to think of what effect the amalgamation of GIS technology into the athletic world will have on an athletes' experience.

## Chapter 1 Introduction

Beyond the physical and mental challenge of running a marathon, a runner faces the additional stress of selecting which marathon to run, what to expect from the race, and how to navigate the logistics of travel involved. Additionally, runners all have a unique purpose and goal so choosing a race that suits their individual needs is difficult. Runners tend to rely on websites, periodicals and other media to help guide them through the process, however prior to the Web GIS application developed for this thesis, resources primarily focused on the training aspect for a race.

For example, if you were to type into Google, “How to plan to run a marathon,” you would get the following return, shown in Figure 1:

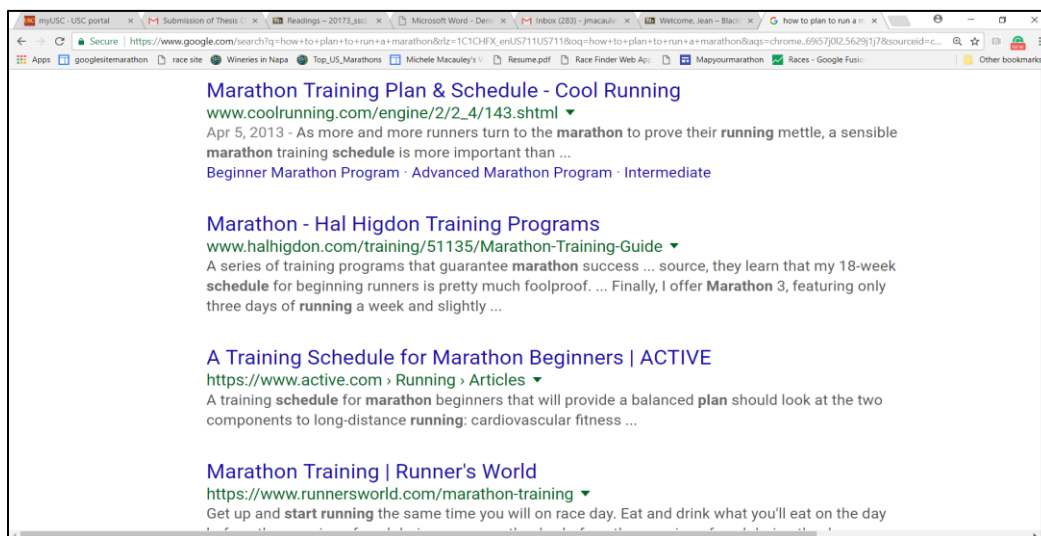


Figure 1 – Screenshot of Google search “How to plan to run a marathon” results

“Planning” in the athletic community clearly refers to the physical planning involved and not planning for the logistics of the race. Trying another technique, entering “Find and plan a marathon race” yields the following results, shown in Figure 2:

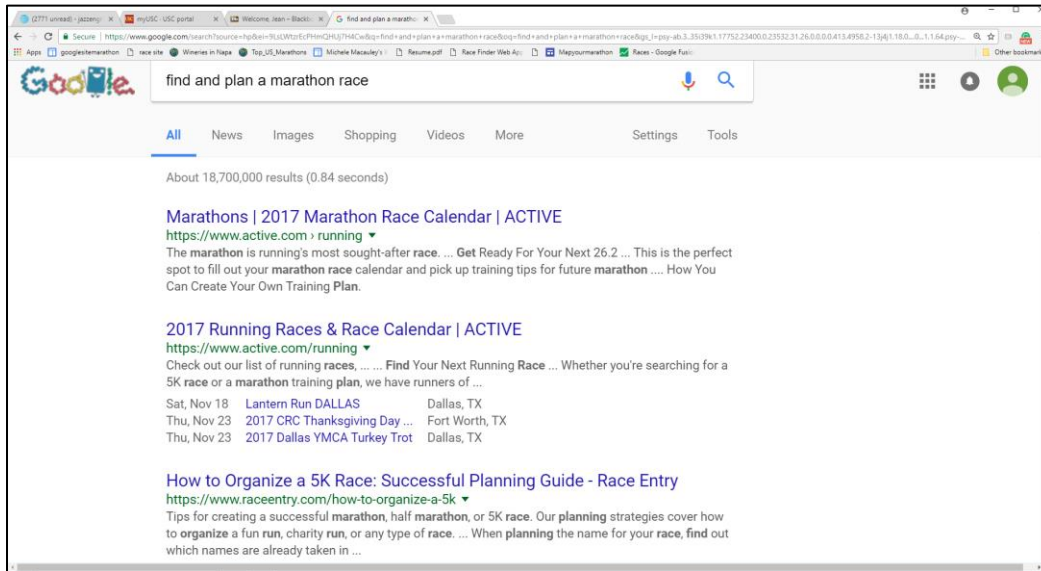


Figure 2 – Screenshot of Google search, “Find and plan a marathon race” results

These results are closer to offering a runner guidance in planning the logistics of a race by offering calendars of races, generally by date or geographical area, but they still do not offer the proper tools to adequately plan for the race experience.

It is important to recognize that every marathon runner has a specific goal. For some it is a lifetime goal to complete a marathon so they may desire a large race with a lot of fan support or in a scenic location. For others, it may be trying to complete a personal challenge such as running one in all fifty states where the location is the primary factor. Some runners are trying to qualify for renowned races such as Boston or New York so a race that is relatively flat or downhill is best to achieve the fastest race possible. The time of year and temperature are key factors as well. Heat and extreme cold can negatively impact a runner’s performance. Marathon training coach and developer of Marathon Nation training program Patrick McCrann notes, “No 26.2 miles is the same, and not all races are created equal. Some are big, others are small. Some are epic tests, others are (literally) a walk in the park. Finding the right race that syncs with your

goals, abilities, and geographical location can go a long way towards ensuring you are able to run to your potential” (McCraan 2016). McCraan validates the benefit of a Web GIS application that offers runners tools to help find a race based on individual needs.

After an analysis of the marathon selection process and current technology available, how does the development of a Web GIS application aid in this process? This Web GIS application helps runners to find the right race by allowing them to view races on a map that includes pertinent race information, customize race selection based on personal criteria, view selected races on a map interactively including 3D visualization of routes, elevation profiles, projected temperature, street view, terrain and nearby lodging and dining options.

The objectives of this thesis are to document the motivation, methodology, and value of a Web GIS application designed for runners planning to run a marathon and offer a blueprint for other developers in creating a Web application using geospatial technology. The intention is to develop the application even further, using modern and future technology to incorporate such techniques as crowdsourcing, predictive analytics and machine learning to allow runners and other athletes to get the full benefit of available technology in their planning and training process.

## **1.1. Motivation**

Those who have never contemplated running a marathon often ask “Why would someone want to run a marathon?” Studying the motivation helped determine what elements were necessary to the success of the Web GIS application. As authors Chris Hammer and Leslie Podlog explain:

Perhaps no other athletic event has a greater tradition than the marathon. The modern marathon was first run in 1896, commemorating the legend of



Pheidippides, who in 490 B.C. ran from the Battle of Marathon to Athens, Greece to deliver a message of victory. In addition to being an incredible feat of stamina and determination, many people view completing a marathon as a testament to the human spirit, making the marathon a popular event for those wishing to experience the personal challenges and triumphs the marathon has to offer (Hammer and Podlog, 2016).

Hammer and Podlog provide insight to the behavior of runners who choose to run a marathon and their motivation in their book *Marathon Running: Physiology, Psychology, Nutrition and Training Aspects*. They examine the growing popularity of marathon races. Over the past 35 years, the median finishing time for a U.S. marathon slowed by 47 min (for males), the median age for male marathoners increased from 34 (1980) to 40 years (2014), and the number of marathon finishers grew from an estimated 143,000 (1980) to over 550,000. (Running USA in 2014 Running USA annual marathon report, 2015). Based on the appeal of marathons, Hammer and Podlog pose the question “why are so many individuals motivated to undertake such a grueling activity?” (Hammer and Podlog 2016).

Hammer and Podlog suggest that there is not one motivating factor but many and they are varying based on such traits as experience level, age, and gender. Their research included statistics developed by Masters et al. (1993) who created the Motivations of Marathoners Scale (MOMS), an instrument designed to assess individuals’ motives for undertaking marathon training.

### *1.1.1. Experience level*

Results of the MOMS indicated that experienced marathon runners (those who ran more than three marathons) were primarily driven by social reasons such as identity, recognition,

affiliation, competitive reasons and health concerns. First time marathoners were drawn to marathons for goal achievement, self-esteem, and health and weight concerns.

### *1.1.2. Age*

Results based on age indicated older runners were more motivated by general health, weight concerns, and a desire to seek a sense of life meaning or purpose and affiliation with other runners. Younger runners were more motivated by personal goal achievement such as best personal times.

### *1.1.3. Gender*

Results revealed women were more likely to be motivated by weight concern (i.e., to maintain/lose weight, to stay physically attractive), affiliation (i.e., to meet people, socialize, and share group identity), self-esteem (i.e., to improve confidence, to feel sense of achievement), life meaning (i.e., to make life more purposeful, to feel at peace with the world), and psychological coping (i.e., to improve mood and feel less anxious). Men's motivation were generally to improve speed, reach potential (i.e., "personal goal achievers"), and compete with others (i.e., "competitive achievers").

### *1.1.4. Additional traits and factors*

Family status also plays a role in motivation, however, the categories were numerous so the results are not discussed in this thesis. Additionally, cause-based marathon training (fundraising for a charity) often gives a runner an increased sense of connection to a cause (Hammer and Podlog 2016).

Evaluating and analyzing the motivation behind running a marathon assisted in the development of the Web GIS application. Research indicated runners have diverse needs and

goals based on varying traits. Since the motivation for running marathons differ, it follows that the choice of race and planning process vary as well.

It is a lack of resources that provided motivation for the development of the application itself. Although there are many applications designed to help runners searching for a marathon, no resources are readily available to a runner that allow them to find a race based on specific needs and goals, view races on a map in a three dimensional environment giving them a spatial perspective and view logistics on races for travel constraints all in one application. These considerations can make all the difference for a runner's experience and performance. Many websites exist listing marathon races, however, most resources allow a user to select a race by date or state with no other parameters. The results are given in list format, generally alphabetically or chronologically. A runner must then select a race website and read the full site to get the details he or she needs to properly make a decision about the race. The concept of developing a Web GIS application stemmed from my personal experience spending endless hours combing websites, buying race magazines, and asking fellow runners on social media trying to identify the appropriate race. It is inevitable that all runners must deal with the burden of determining which race to run and how to plan for the dynamics surrounding the race. *Running World* author Susan Paul offers the following example of a runner attempting to navigate the selection process:

Bill asks: I have been running pretty regularly for about nine months now and recently decided to train for a marathon. I thought I would do the New York City Marathon, only to find out that it is a lottery and I missed the entry date. I decided on another marathon and found out it was already full. I had no idea it would be

this difficult to pick a marathon. How do runners go about selecting a marathon?  
(Paul 2014).

Paul's response to this question is to do your homework and visit all the websites of races you think you would be interested in, check out dates and logistics of how and when to register. She lists factors to consider, defined in the following section, but does not actually provide tools to aid in this quest. Combing race websites, travel and logistic sites is time consuming and can be overwhelming. The Web GIS application designed for this thesis combines all the necessary tools for finding and planning a race in one application.

## **1.2. Benefits of Web GIS application**

Examples of factors to consider when selecting a race are location, terrain, temperature and elevation. Considering these attributes reflect geospatial concerns, a spatial analysis or perspective using GIS is a logical approach. Allowing a runner to interactively view races on a map that show the specific courses, location, terrain and average temperature for the time of the race allows a runner to better prepare for the race. American Olympian Jeff Galloway recommends running different portions of the actual course during the training process to better understand what to expect on race day (Galloway 2016). Running the course itself is ideal, but not always realistic if the race is not in close proximity to the runner's home. A virtual approach to the course offers similar benefits allowing the runner to view the terrain from a street view or bird's eye view and mentally prepare for the course. Illustrations below demonstrate how the Web GIS application helps runner understand the dynamics of the course. Imagine running the Pikes Peak Marathon without preparing properly for this type of course. Figures 3 through 5 are screen shots created from the Web GIS application developed for this thesis illustrating the 3D image of a course (Figures 3 and 4) and allowing the user to navigate through the race, and view

the elevation profile (Figure 5). The elevation profile is dynamic with a slider at the bottom to view the elevation at any point along the course.



Figure 3 – Web GIS application displaying 3D View of Big Sur Marathon Course

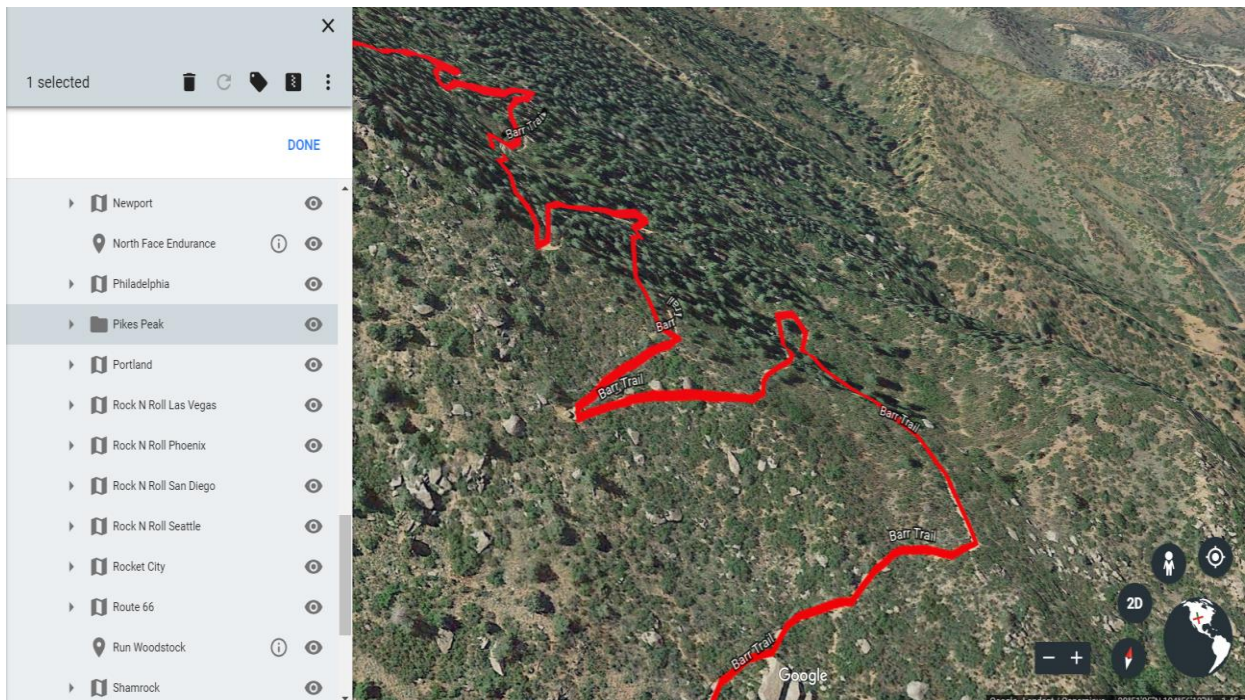


Figure 4 – Web GIS application displaying 3D View of Pikes Peak Marathon Course



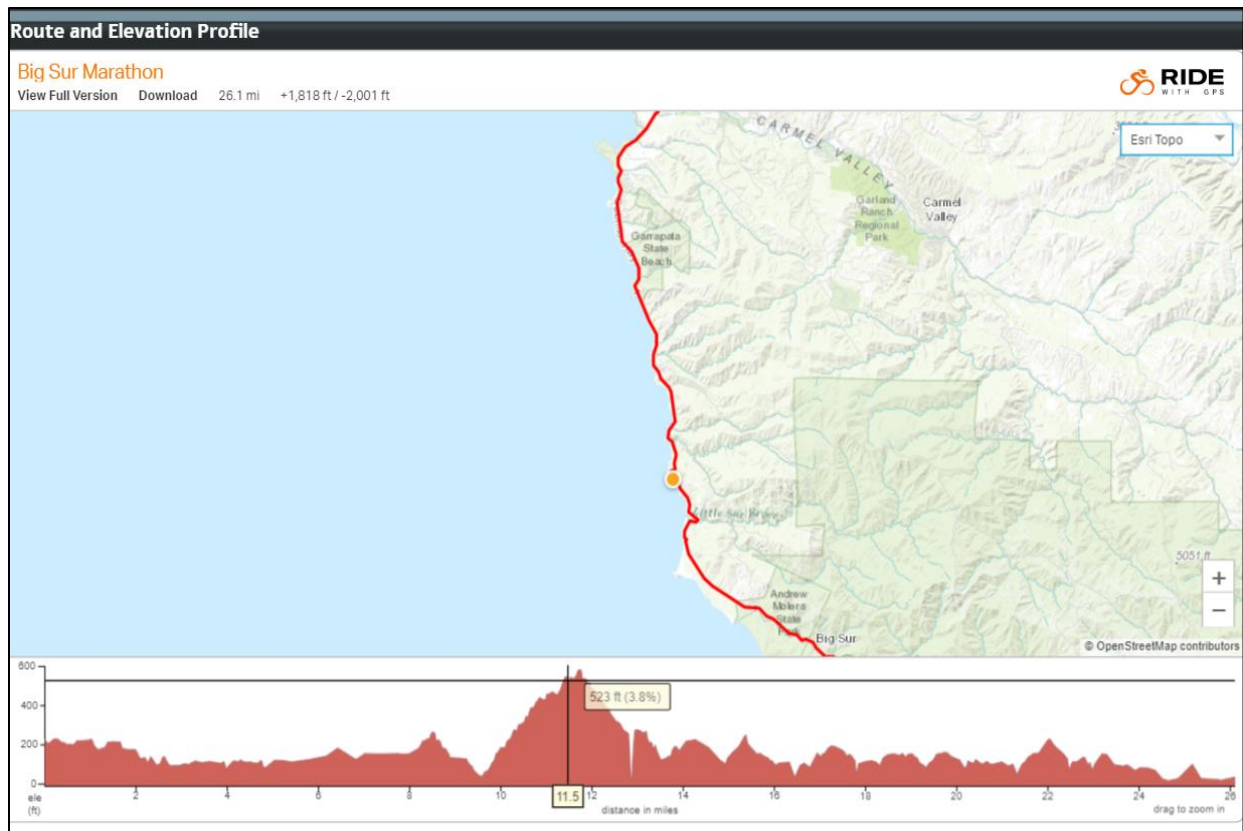


Figure 5 – Web GIS application displaying Elevation Profile of Big Sur Marathon

The Web GIS application developed for this thesis utilizes spatial technology to resolve the challenge for runners in selecting, planning and preparing for a marathon. Further benefits to the Web GIS application allow a runner the ability to look for nearby lodging and dining options (Figure 6), and projected weather on race day (see Figure 7) minimizing other stressful components of a race. Finally, using a geodatabase containing attributes specific to a runner’s needs, a runner can search for a race based on his or her personal criteria (see Figure 8). Selecting an appropriate race for a runner based on personal needs enhances the race experience and the potential for improved runner’s performance.

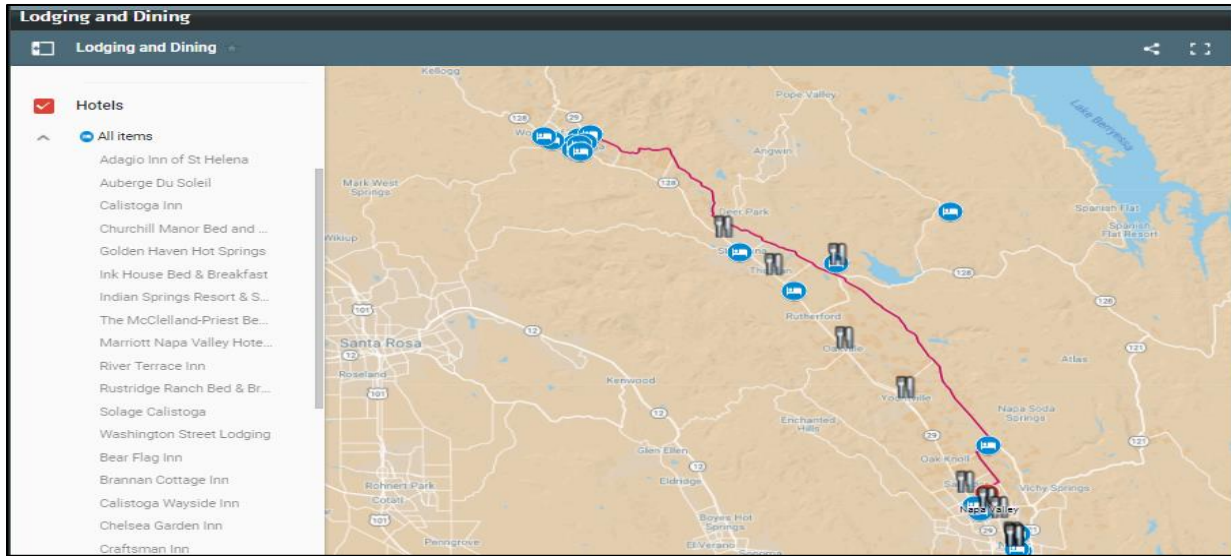


Figure 6 – Web GIS application displaying Lodging and Dining options near Napa Marathon

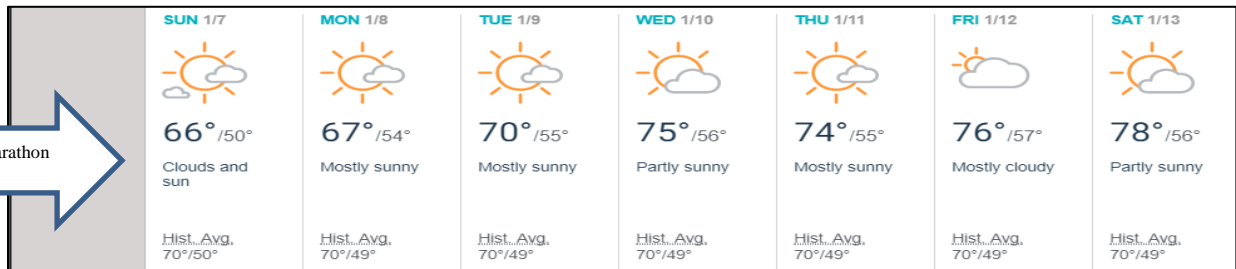


Figure 7 – Web GIS application displaying projected weather and historical averages

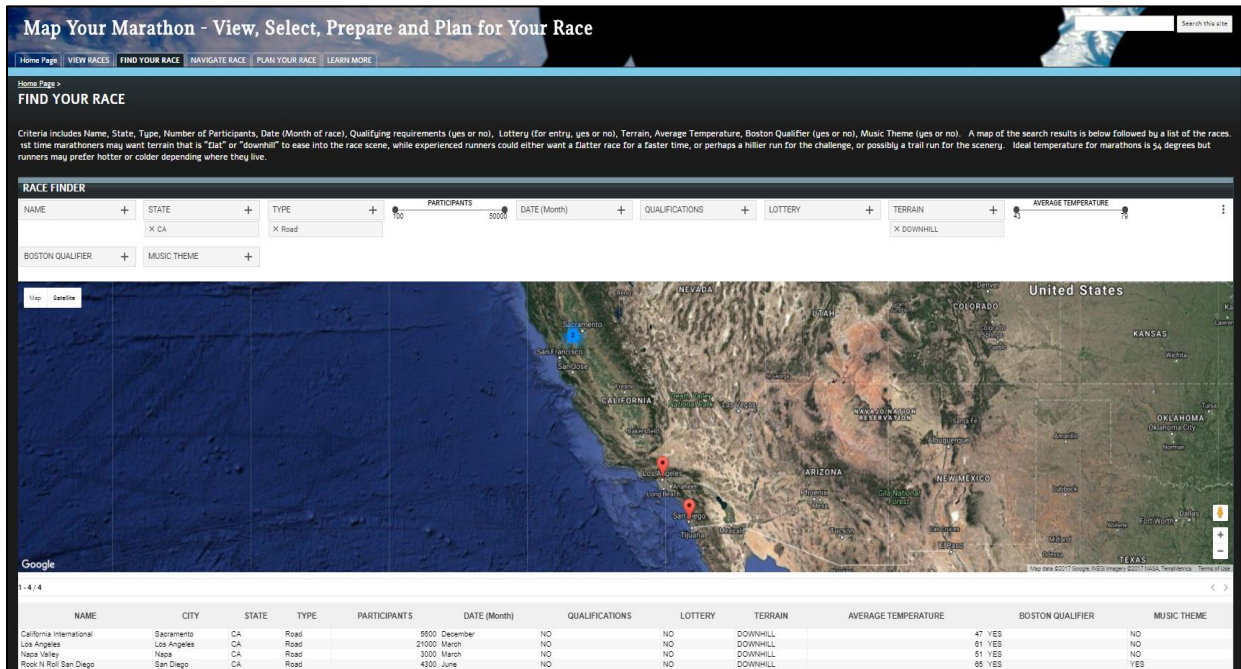


Figure 8– Web GIS application displaying results of query for downhill road races in California

## **Chapter 2 Related Work**

The goal of this thesis was to document the development of an application utilizing GIS (Geographic Information System) technology that will aid runners by visualizing races and other relevant spatial components geographically, and allow runners to select a race based on specific criteria. Constructing a Web GIS application cannot be accomplished without evaluating current GIS technology, researching comparable applications and analyzing the value of the Web GIS application. In developing a Web GIS application, one must ask first and foremost, what is the end goal of the project? What is one trying to accomplish, solve, fix? This Web GIS application aids in minimizing the stressful aspects in planning for a marathon.

In order to create a Web GIS application for marathon race selection and planning, research was subdivided to facilitate a template for the process. Subdivisions of the research process include: Value of Web GIS application, Identifying Top Races in the United States and Identifying Scope, Determining Criteria for Query Function, Development of Geodatabase and Web GIS application.

### **2.1. Value of Web GIS application**

Determining the value of a Web GIS application begins with finding out if similar applications already exist and asking the following questions: If other applications do exist, what functionality is missing that should be implemented in the Web GIS application, what elements of other applications are runners using to assist them and how are these techniques constructed, and when evaluating what components are beneficial to a runner, what resources are currently available and what tools are lacking aided in the development of the Web GIS application for this thesis?



Author and marathon training coach Patrick McCrann offers four main factors when considering a race: timing, terrain, conditions and logistics. All of these elements can be offered spatially in a web GIS map. McCrann illustrates the challenge a runner faces in selecting a marathon and offers suggestions on navigating the process. He lists common goals for runners participating in a marathon. Goals include completing a marathon for the first time, qualifying for the Boston Marathon, and finding an appealing destination to run a marathon. These goals further corroborate the advantages of a web GIS map that gives a user ability to personally select criteria (McCrann 2016).

The challenges of selecting the right marathon are substantiated by Susan Paul. She states:

This year I'm going to run my first marathon, and I'm not worried about the training. No, I have bigger concerns than logging miles. My challenge is choosing a race. The options are staggering. There are thousands of marathons around the world. There are trail races, ocean side races, races in the heat and at Christmas too. With so many choices it is tempting to stay close to home and play it safe, but I like a little adventure and I love to travel, so part of me wants to go somewhere new (Paul 2014).

Paul explains the many options runners face, making it difficult to decide on a specific race. The Web GIS application developed for this thesis addresses Paul's concerns offering tools to help in the selection process. Identifying individual needs of runners are discussed in the section 2.3. (Determining the Criteria for Query Function).

There are at least two sites that provide assistance for runners, giving general information about races, mainly listed alphabetically, by state or by date. Findmy marathon.com was the first

site used for comparative purposes. This website has the most comprehensive list of marathons. It contains data on all the marathons used in this study. Since the inception of the Web GIS application for this project over a year ago, FindmyMarathon.com has produced one functionality of its site that is similar to the Web GIS application developed for the thesis. It appears to even use a similar platform. Previously, FindmyMarathon.com allowed a user to filter races but only allowed three attributes; month, state and Boston qualifier. At first glance, it appears that is still the case, however, if you select one of the options (location, state or keyword) it displays a map allowing filter capabilities. Selecting either of the three options brings up a window with several filter options. Nowhere in the site is it explained that the search by location, state or keyword brings up many other filter options. Figure 9 illustrates the filter page and Figure 10 illustrates what is displayed regardless of which of the three options are selected.

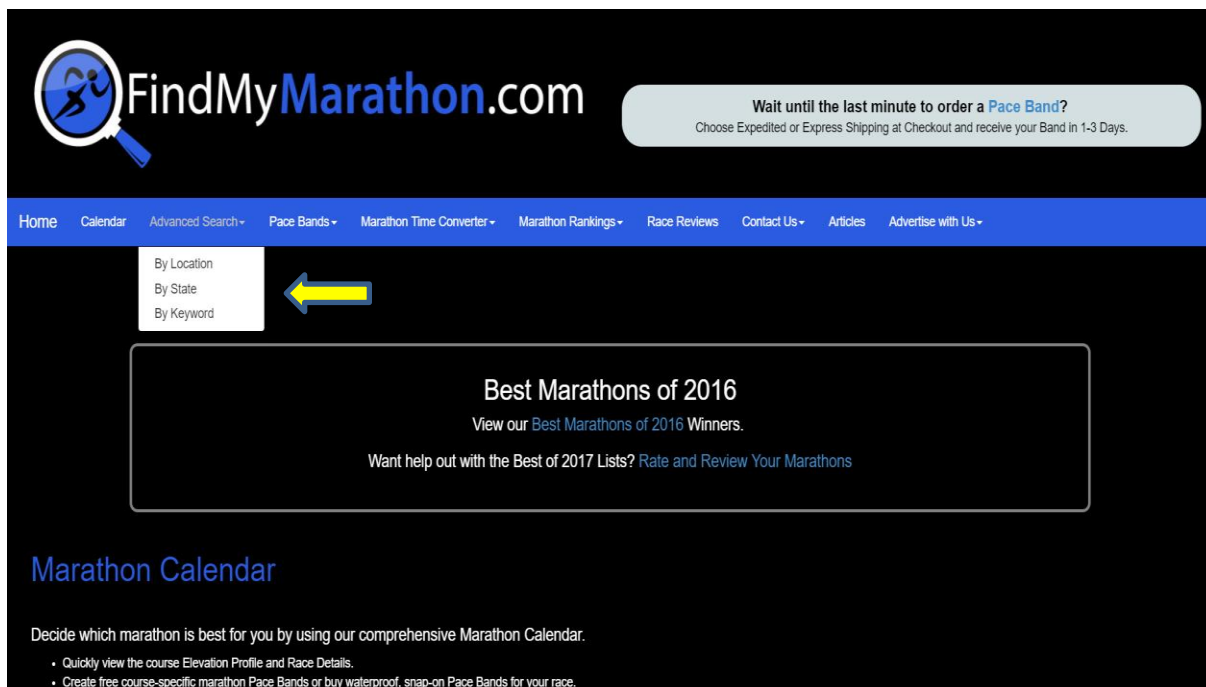


Figure 9 – FindMyMarathon website drop down menu showing query options

California
RESET

**Race Month & Day**

Select Race Month(s)

January  May  September

February  June  October

March  July  November

April  August  December

Select Race Day(s)

Saturday  Sunday  Other

**Course**

Course Profile

Downhill  Rolling Hills

Pancake Flat  Hilly

Mostly Flat  Very Hilly

Course Surface

Road  Trail

Mostly Road  Mostly Trail

Is the Course Certified?

Yes  No

Course Type

Loop  Out & Back

Mostly Loop  Mostly Out & Back

Multi-Loop  Multi-Out & Back

Point to Point

**Miscellaneous**

Average Race Day Temperature

0 To max Degrees F

Field Size

1 TO max Runners

Early Entry Fee

min TO max

Only Races with PR Scores

Map Satellite

Google

**We found 3 results.**

| Race Name                                   | City       | State | 2016 Date  | 2017 Date  | Avg Temp  | Finishers | PR Score | Course Score | Compare                 |
|---------------------------------------------|------------|-------|------------|------------|-----------|-----------|----------|--------------|-------------------------|
| <a href="#">Cal-Neva Marathon</a>           | Tahoe City | CA    | 10/08/2016 | 10/14/2017 | 47F / 8C  | 75        |          |              | <a href="#">Compare</a> |
| <a href="#">Ventura Marathon</a>            | Ventura    | CA    | 09/11/2016 | 10/22/2017 | 67F / 19C | 736       | 101.38   | 102.33       | <a href="#">Compare</a> |
| <a href="#">Bizz Johnson Trail Marathon</a> | Susanville | CA    | 10/09/2016 | 10/08/2017 | 50F / 10C | 79        | 95.71    | 95.71        | <a href="#">Compare</a> |

Figure 10 – FindMyMarathon website filter options

While this site does offer filter capabilities similar to the Web GIS application, it is not user friendly and has some limitations. The lack of navigation instructions to get to the filters page is significant. The filter by State freezes and the field size is limiting. Furthermore, the visual display of search results is the only geospatial view of the races in the website. It does not allow you to select races on the map and other search functions display results in a list format. Comparing Findmymarathon.com to the Web GIS application for the thesis, the Web GIS application excels by offering several geospatial functions to aid runners. Allowing the user to view races on a map, select the race based on personal needs, view elevation profile, zoom in,

observe the route on the map, convert it to 3D view to explore the terrain, and view nearby lodging and dining options all give a runner a perspective not allowed without a GIS based app. Capabilities and examples of the thesis' Web GIS application are illustrated in the Methods section.

Another site, Marathonguide.com provides runners an extensive list of marathon races. The most useful part of this site is the users input rating of the races. Additionally, the application attempts to offer an interactive web map of races but it is in beta mode and has not worked since its inception over a year ago. The site's efforts to create a geospatial view of races demonstrate that a web GIS does offer value to runners and also validates the need for a more extensive and comprehensive web GIS app. Figure 11 shows Marathon Guide's beta mode web map while, in contrast, Figure 12 displays the web map of races designed for the Web GIS application for this thesis.

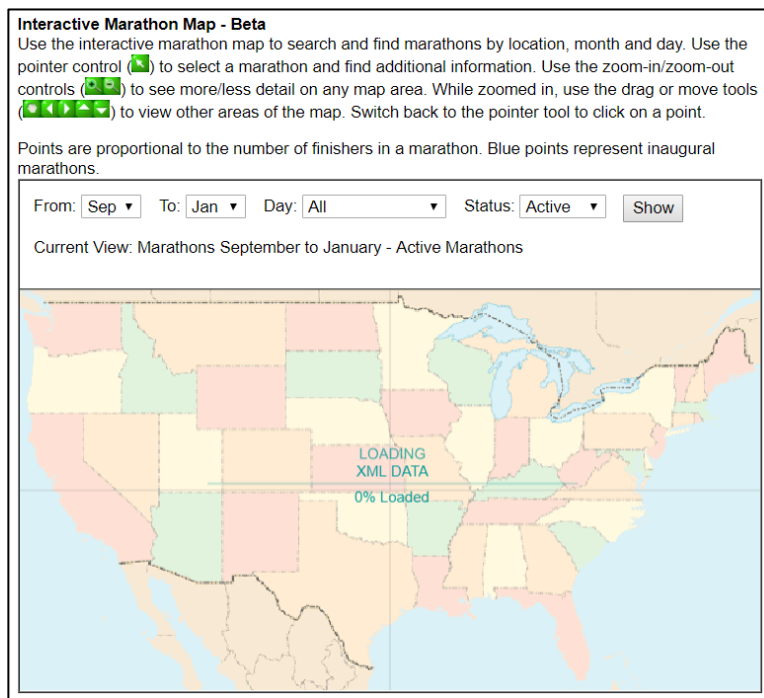


Figure 11 – MarathonGuide website beta interactive map

Although Marathonguide.com offers runners a wealth of information about races, it does not offer a geospatial perspective or allow a runner to select races from the map to obtain information about the race. The Web GIS application developed for this project allows a user to view races on a map and select a race to scroll through race information on the left side of the screen.

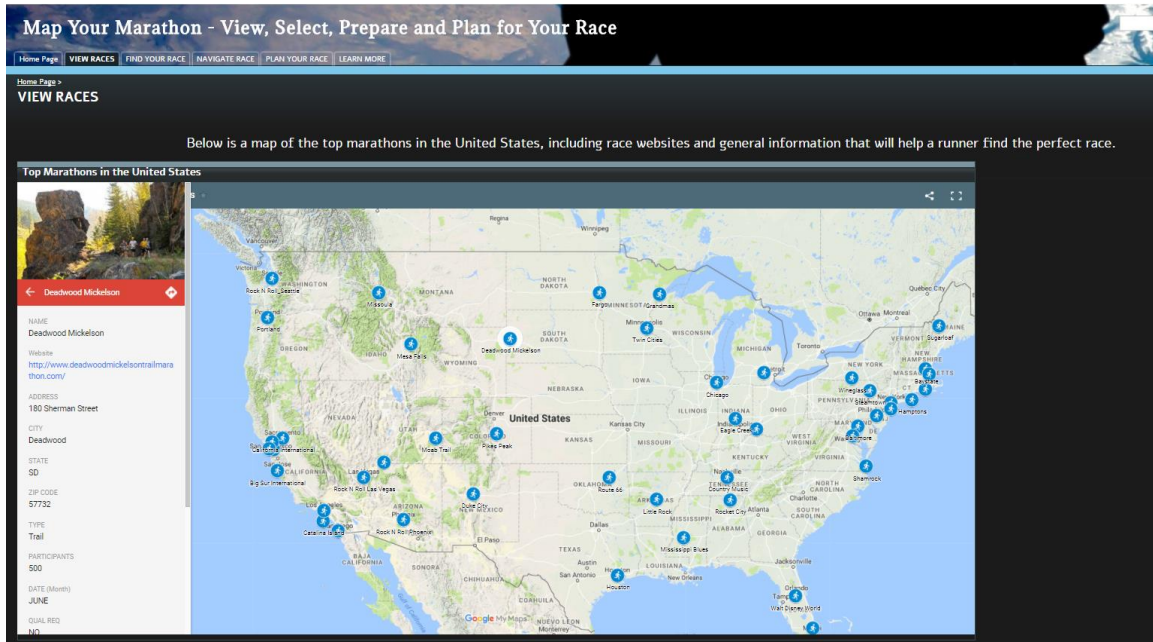


Figure 12- Web GIS application displaying view race page with Deadwood Mickelson Marathon Selected

## 2.2. Identifying Top Races in the United States

Selecting appropriate races to use for the purpose of the project is essential in reflecting what is important to the marathon runner. Researching articles and periodicals listing top races help understand what factors actually define a “top race.” Concurrently, this research corroborates that fifty races give runners a solid base for selection. This thesis enables future additions allowing a developer or user to add races to further enhance the benefit of the application. The scope of this study includes the United States. This area of study is specific

enough to acquire the necessary data but large enough to give runners reasonable options for a destination race.

Analyzing several “Best of” articles reveal many of the same races are considered the “Best” by authors and runner’s polls. For example, the Boston Marathon is the world’s oldest annual marathon and has stringent qualifying requirements in order to participate. These, and other factors make Boston one of the most prestigious races for runners, often on their “bucket list.” The Big Sur Marathon tops many lists for its incredible scenery along the course. The Chicago Marathon is famous for its energy and great crowd support. These races and others that were consistently on the top of the lists were easy choices. Choosing the additional races were slightly more challenging. Trail races were especially difficult to locate because the “Best of” for trail runs were often not exactly 26.2 miles (the distance for an actual marathon) but distances based on the trails themselves. Paul Cuno-Booth, author of *Trail Runner* magazine offers a list of 21 trail races he believes are top races which aided in the search for top trail races in the United States.

For the remaining races, marathons were selected that were unique either in geography or theme. Examples of unique marathons include Walt Disney World, a race that navigates through the park, or Rock and Roll Las Vegas that occurs at night on the strip.

Florida Sports Magazine contained an article, “A Guide to Some of the Best Marathons in North America,” by Jason Effmann that offers a comprehensive list of marathons Effman believes are the “best” in North America. Although this list and others used for the purpose of this project are subjective, creating a list based on cumulative opinions of authors who are well entrenched in the running community help legitimize the compilation of races.

Findmymarathon.com's article "The Best Marathons of 2016" include a list of marathons based its criteria on reviews from the site, social media, running community comments and other reviews. The article has added value in that it obtained its data directly from the running community.

Additional marathons were selected from Erin Kelly's article, "The 17 Best Marathons for Beginners" in Greatist.com since it is often new runners that struggle more than others with finding a race (Kelly 2015). While seasoned marathon runners will benefit from the Web GIS application in many ways, first time marathon runners are faced with a potentially more stressful experience without the aid of the Web GIS application since the overall process is foreign to them.

Jordan Rane offers input on the top seven races in the United States based on the overall experience and travel destination in CNN's online article. Travel and experience are essential components when selecting a race. Lodging as close to the race as possible has dual benefits. Races often start very early so the closer to the race, the longer the runner can rest beforehand. Following the race, runners suffer exhaustion and often pain so the closer their accommodations can be, the better. Logistics of travel can be stressful, and a desirable destination can add to a more positive, enriching experience. This article aids in the selection of races for the web GIS app and also illustrates the benefit of a geospatial application that shows lodging and dining options within close proximity to the race (Rane 2015).

The website Topeventsusa.com offers a list of the 20 top marathons in the USA. In addition to the list, this article adds value because it explains what components of each race qualified it to be a top race (2017). Key components are evaluated in the following section, Determining Criteria for Query Function.

Although determining what qualifies as “top races” is subjective, soliciting data from reputable resources helped define what runners were looking for and thus what races to incorporate into the database for the Web GIS application. Observing the myriad of races qualified as top races by experts, differing greatly from large, boisterous road races to small trail races authenticate the need to assist runners in selecting the appropriate race to meet their goals. The races selected for the purpose of this app, based on the above research, give the user a wide variety of options to best meet their needs.

### **2.3. Determining Criteria for Query Function**

Once the top races were established, an examination of runner’s top criteria for selecting a race was conducted. These criteria were defined based on following research. Common determinants (underlined in below references to show commonality) include size of race, “fastest” (corresponds with flat or downhill course), Boston qualifier, terrain, travel involved, weather, the course, race type and logistics. Along with the components incorporated into the query function, the Web GIS application displays nearby lodging and dining locations and offers a Google Earth view option, allowing a runner an interactive, 3D view of the race course. Combining the query function, hotel and dining layer, and 3D map option a runner is best equipped to find the most appropriate race.

Findmy marathon.com provides a list of best marathons and bases its criteria on reviews from the site, social media, running community comments and other reviews. This site has added value in that it obtained its data directly from the running community giving it added validity. In addition, the races were categorized by best marathons of 2016, best mid-sized marathons of 2016, fastest marathons, best marathons to qualify for Boston, most scenic, best



new marathon and best organized. This break down helped determine criteria and search capabilities for the user.

Kyla Jones describes the experience of the first time marathon runner in *Competitor Running Magazine* offering further criteria important to runners. “Your first marathon is a special event. You may run many and each one will be a unique experience. But there is nothing as special as your first 26.2. So how do you pick a marathon? There are thousands all over the world, and they each have their own appeal. While researching, consider these questions when choosing your first marathon” (Jones 2017). Jones uses the following considerations to choose a marathon. How far are you willing to travel? What is the terrain like? Do you want to qualify for Boston? Do you want to run with friends?

“It’s hard to overstate the importance of choosing the right race” says online author Matt Frazier. Frazier discusses six key factors when selecting a marathon in order to make the experience as memorable as it should be in his article, “Want to Run Your First Marathon in 2011? 6 Factors to Keep in Mind When Choosing Your Race.” The factors, he explains, include time frame, location, weather conditions, course, size, and the “wow” factor, substantiating the need for a web GIS map that gives a user ability to personally select criteria (Frazier 2011).

Susan Paul discusses the overwhelming process in choosing a marathon and offers advice on how to evaluate and prioritize when selecting a race. Paul’s list of considerations further emphasize the advantage of filter abilities in a web app. She lists cost, date, personal goal, terrain, and race type as factors. These components reaffirm the value of a site that allows a user to customize a race search (Paul 2014).

Finally, JP Slater offers tips on how to select the appropriate marathon in Runtastic.com, “Whether it is your first marathon or you are a seasoned road warrior, there is a lot of thought

that should go into picking which marathon is best for you! Choosing a good course, on the right day, the right terrain, with optimal weather, etc. ... all these things play into how you will perform come race day” (Slater 2016).

Although these related works may seem redundant, the commonality of geospatial elements among multiple sources reinforce the value of a resource that incorporates these traits as attributes in the Web GIS application database.

## **2.4. Development of Web GIS application**

Arguably, the most significant research in the development of a Web GIS application is in the construction of the app itself. Vast technology is available to the developer so researching, analyzing, and evaluating the many techniques and tools must occur in order to be successful in the development of the app.

Brenden Blee’s thesis, *Creating a Geodatabase and Web-GIS Map to Visualize Drone Legislation in the State of Maryland*, gives insight into the documentation of developing a geodatabase and web-GIS map. Blee’s thesis defines the need for visualizing no-fly zones for drones and documents the implementation and design of a geodatabase and Web GIS application. This thesis relates closely to the development of a Web GIS application for marathon races because data was primarily gathered from a geodatabase created by the developer, documented and used for the development of a Web GIS application (Blee 2016).

Evaluating multiple frameworks is crucial when developing a Web GIS application in order to provide a solid platform in which to build from. Google App Engine is a resource that describes the concepts of developing a web application using the Google App Engine, a platform that uses Google infrastructure. This book provides a guide and has instructional value for the development of a race finder web application (Ciurana 2009). This resource aided in the

comparison of web-GIS technologies and deciding on Google's infrastructure in the development of this application.

Visualization techniques enhance the overall appearance and usability of a web app. Richard Donahue's dissertation on web cartography illustrates the challenges of combining web design with cartography. He explains the importance of understanding available technologies in order to produce a viable web map. Donahue further directs his research into the optimum methods for both teaching and learning web cartography. The significance of this paper lies in the educational aspect. Because of the extensive technological skills required for the development of a geodatabase and web GIS app, this dissertation offers sound, cohesive direction for learning and understanding such technology assisting in producing a viable, visually appealing Web GIS application (Donahue 2014). Donahue's instruction enhanced the overall appearance of the Web GIS application.

Analysis of web GIS technology involved utilizing ESRI's Web GIS Story tool as an option for the framework. Observing Mallory Graves' use of this tool in her thesis demonstrates one method of Web GIS application development. Graves uses ESRI's Web GIS Story tool to engage the community in the cleanup efforts for the Del Amo and Montrose Superfund sites located in Los Angeles that have suffered groundwater contamination. The Web GIS Story Map incorporates geospatial visualization into a web application using limited programming skills (Graves 2015). Graves' thesis provided valuable insight to the challenges and benefits of the Web GIS Story Map. Web GIS Story map was compared and contrasted with other platforms. Ultimately, Google Sites platform was chosen based on its visual appeal and adaptability. Although the Web GIS Story map was not used for the Web GIS application for this thesis,

comparing technologies is key in the selection process and understanding Graves' development process was beneficial.

Authors Li, Groves, Morgenstern and Wai collaborated on the research and analysis of geospatial tools that would help the navigation process for trail runners. Their research paper explores geovisualization techniques used to improve the experience for the athletic community aided in the learning process of navigational tools and satellite imagery. The authors use animations/flyovers and allow for social interaction between the runners, and use quality satellite imagery, all tools that enhance a runner's experience (Li, Groves, Morgenstern, Wai 2017.) Such techniques were not only incorporated but were instrumental in the development of this thesis' Web GIS application.

The race routes on the web-GIS map are a significant component of the application. Graduate student, Anisha Santhatam created an Android application to allow users to dynamically create trail maps for bicycle and running trails. Santhatam's thesis correlates to the development of a Web GIS application for marathon races since they both relate to the development of trails or routes and both theses document the process of a Web GIS application development and implementation.

Deciding which API to use is difficult with so many mapping API's available. A careful study of the top mapping API's was necessary to select the most appropriate application for this project. Janet Wagner compares the top 10 mapping API's, defining the varying capabilities of each in her article in *Programmable Web*. This evaluation has an obvious benefit to a developer creating a Web GIS application. These API's offer such functionality as interactive and static maps, animated maps, geocoding, travel and transit directions, elevation data, traffic flow and more. Particularly, elevation data, geocoding and interactive maps are relevant and were

incorporated in the Web GIS application. Wagner used the following criteria in her comparison: popularity, potential, documentation, ease of use and functionality (Wagner 2015).

Once the appropriate framework is selected, it is essential to thoroughly dissect and understand the components involved. Elements include user context, license, software pattern, hosting requirement and learning curve (Siddharth 2009). Understanding these elements aided in minimizing risk of proprietary and security issues.

A consideration for future addition to this Web GIS application is crowdsourcing, offering a more dynamic and interactive experience for the user. Nathanael Wold's thesis "Participatory Web GIS Design – A Sustainable Recreation Decision Support System for Missoula County" explores incorporating local representatives' knowledge of appropriate recreation behaviors and areas into a Web GIS application utilizing ArcGIS Online to enhance sustainable recreation (Wold 2017). The evaluation of this crowdsourcing type application offers the developer of a Web GIS application the ability to see if this is a viable option for the future development of the project. Input from the community adds a solid component to the application.

### **Chapter 3 Methods and Data**

This thesis provides the tools necessary for a runner to select a marathon race from among the top fifty races in the United States using web-based GIS technology. This chapter documents the methodology and data sources used, divided into the following subsections: (1) Intended users and scope; (2) Geodatabase creation; (3) Web platform construction; (4) GIS Map development; (5) UX Design; (6) Testing environment and survey; (7) User requirements, Data and Technology.

### **3.1. Intended Users**

The intention of this thesis is to assist all runners who have decided to take on the challenge of participating in a marathon within the United States. Benefits aid both first time marathoners, unsure how to navigate the process to seasoned runners with specific goals in mind. The Web GIS application provides multiple benefits to help runners of all levels select and prepare and plan for a race. Whether it is a runner who is new to the marathon experience, trying to figure out where to run and how to plan for the travel involved, or an avid marathoner looking for the best race for a fast time and would like to understand and study the course, this Web GIS application is beneficial for all levels of experience.

This website was created to serve the needs of the running community in their quest to locate a marathon based on desired criteria. The study area includes the top fifty races in the United States. While there would be tremendous benefit in expanding this site to include marathons worldwide it was necessary to limit the area for initial implementation purposes. Thousands of marathons exist even within the United States so selecting the races for the purpose of this site was significant to its success. After extensive research, fifty marathons were selected as qualifying for top fifty. The articles researched in making this determination are noted in the related work section. The scope of this thesis, fifty races, was selected to offer the users enough well-documented top races to give the runners a diverse selection but specific enough to allow the developer the ability to construct an application that will offer users optimum functionality. The application provides a framework upon which races can be added by users enhancing the benefit of the application. Future development of the Web GIS application will offer a basic form for a user to complete, filling out basic details about a race. The user will be allowed to add

racers to the map, but it will be incumbent upon the developer to revise the app, adding nearby lodging and dining, and incorporating race course details.

### **3.2. Geodatabase Development**

This section documents the design process for the development of a spatial database for the purpose of providing runners with tools to enhance their race preparation process and race experience.

The first step in developing a spatial database is compiling all of all the necessary data and developing an excel spreadsheet. For this geodatabase, the developer acquired data about each race, including website, month of race, address, average temperature, and terrain, type of race, Boston qualifier, music themed, lottery requirement, and number of participants. The majority of data was gathered from race websites and the remaining data from the websites findmyrace.com and marathonguide.com. The excel sheet was saved as a csv file. The spreadsheet in Table 1 includes a list of the fifty races. The attributes listed above were based on research documented in the Related Works section. This Web GIS application is a building block with a framework designed to add additional data as the developer sees fit. If, down the road users input the desire to have additional criteria or information added, the database can be modified to incorporate such additions.

In order to convert the database to a map, the data had to be “geocoded” which assigns a spatial value, or longitude and latitude to a given attribute in the database, in this case, the city. This way the data can be assigned to a location on the map. All the associated data will also be associated with the location on the map based on the geodatabase.

Table 1. Spreadsheet of Races

| NAME           | ADDRESS      | CITY        | STATE | ZIP_CODE | TYPE  | PARTICIPATE | DATE_APP | QUAL | REG | LOTTERY   | TERRAIN | MEAN_TETBQ | MUSIC_TH |
|----------------|--------------|-------------|-------|----------|-------|-------------|----------|------|-----|-----------|---------|------------|----------|
| 1 Boston       | 560 Boylston | Boston      | MA    | 2116     | Road  | 30000       | 18-Apr   | YES  | NO  | DOWNHILL  | 49      | YES        | NO       |
| 2 New_York     | 322 Colum    | New York    | NY    | 10023    | Road  | 50000       | 6-Nov    | YES  | NO  | ROLLING_I | 51      | YES        | NO       |
| 3 Marine_Cc    | 201 Water    | Fort Wash   | MD    | 20745    | Road  | 30000       | 30-Oct   | NO   | YES | MOSTLY_F  | 55      | YES        | NO       |
| 4 Big_Sur_In   | 3618 The f   | Carmel      | CA    | 93923    | Road  | 3300        | 24-Apr   | NO   | YES | HILLY     | 54      | YES        | NO       |
| 5 Rock_N_Ri    | 3570 South   | Las Vegas   | NV    | 89109    | Road  | 3200        | 12-Nov   | NO   | NO  | ROLLING_I | 56      | YES        | YES      |
| 6 Honolulu     | 3435 Waia    | Honolulu    | HI    | 96816    | Road  | 31000       | 11-Dec   | NO   | NO  | MOSTLY_F  | 75      | YES        | NO       |
| 7 Walt_Disn    | 3111 Worl    | Orlando     | FL    | 32830    | Road  | 20000       | 8-Jan    | NO   | NO  | PANCAKE_  | 58      | YES        | NO       |
| 8 Twin_Citie   | 2635 Univ    | St Paul     | MN    | 55114    | Road  | 8800        | 9-Oct    | NO   | NO  | MOSTLY_F  | 51      | YES        | NO       |
| 9 LA           | 871 Figuer   | Los Angele  | LA    | 90012    | Road  | 21000       | 14-Feb   | NO   | NO  | DOWNHILL  | 61      | YES        | NO       |
| 10 Houston     | 720 North    | Houston     | TX    | 77024    | Road  | 7700        | 15-Jan   | NO   | NO  | PANCAKE_  | 52      | YES        | NO       |
| 11 Rock_N_Ri   | 100 Park B   | San Diego   | CA    | 92101    | Road  | 4300        | 6-Jun    | NO   | NO  | DOWNHILL  | 65      | YES        | YES      |
| 12 Grandmas    | 250 Canal    | Duluth      | MN    | 55802    | Road  | 6000        | 18-Jun   | NO   | NO  | MOSTLY_F  | 61      | YES        | NO       |
| 13 Country_I   | 1 Titans W   | Nashville   | TN    | 37213    | Road  | 2700        | 30-Apr   | NO   | NO  | ROLLING_I | 61      | YES        | YES      |
| 14 Napa_Valle  | 1375 Trow    | Napa        | CA    | 94558    | Road  | 3000        | 5-Mar    | NO   | NO  | DOWNHILL  | 51      | YES        | NO       |
| 15 St_George   | 300 South    | St George   | UT    | 84770    | Road  | 7400        | 1-Oct    | NO   | YES | ROLLING_I | 50      | YES        | NO       |
| 16 Pikes_Peal  | 441 Manit    | Colorado S  | CO    | 80829    | Trail | 800         | 21-Aug   | YES  | NO  | VERY_HILL | 64      | YES        | NO       |
| 17 Baltimore   | 1 West Prz   | Baltimore   | MD    | 21201    | Road  | 2500        | 15-Oct   | NO   | NO  | HILLY     | 55      | NO         | NO       |
| 18 Steamtown   | 200 North    | Scranton    | PA    | 18502    | Road  | 2200        | 9-Oct    | NO   | NO  | DOWNHILL  | 53      | YES        | NO       |
| 19 Flying_Pig  | 644 Linn S   | Cincinnati  | OH    | 45203    | Road  | 3800        | 1-May    | NO   | NO  | HILLY     | 58      | YES        | NO       |
| 20 Cal_Intern  | 1315 10th    | Sacramento  | CA    | 95814    | Road  | 5600        | 4-Dec    | NO   | NO  | DOWNHILL  | 47      | YES        | NO       |
| 21 Shamrock    | 2800 Shon    | Virginia Be | VA    | 23451    | Road  | 1850        | 19-Mar   | NO   | NO  | PANCAKE_  | 48      | YES        | NO       |
| 22 Fargo       | 800 North    | Fargo       | ND    | 58102    | Road  | 1600        | 21-May   | NO   | NO  | PANCAKE_  | 59      | YES        | NO       |
| 23 New_Jerse   | 175 Ocean    | Oceanport   | NJ    | 7757     | Road  | 2000        | 1-May    | NO   | NO  | PANCAKE_  | 54      | YES        | NO       |
| 24 Portland    | 1202 South   | Portland    | OR    | 97205    | Road  | 7000        | 9-Oct    | NO   | NO  | ROLLING_I | 56      | YES        | NO       |
| 25 Mayors_M    | 3550 Provi   | Anchorage   | AK    | 99508    | Road  | 800         | 18-Jun   | NO   | NO  | ROLLING_I | 56      | YES        | NO       |
| 26 Newport     | 175 Memc     | Newport     | RI    | 2840     | Road  | 600         | 9-Oct    | NO   | NO  | ROLLING_I | 54      | YES        | NO       |
| 27 Missoula    | 123 Carou    | Missoula    | MT    | 59802    | Road  | 1000        | 10-Jul   | NO   | NO  | MOSTLY_F  | 66      | YES        | NO       |
| 28 Deadwood    | 180 Sherm    | Deadwood    | SD    | 57732    | Trail | 500         | 5-Jun    | NO   | NO  | HILLY     | 65      | YES        | NO       |
| 29 Rock_N_Ri   | 305 Harris   | Seattle     | WA    | 98109    | Road  | 2000        | 11-Jun   | NO   | NO  | ROLLING_I | 62      | YES        | YES      |
| 30 Philadephi  | 2600 Benji   | Philadelph  | PA    | 19130    | Road  | 10000       | 20-Nov   | NO   | NO  | MOSTLY_F  | 43      | YES        | NO       |
| 31 Route_66    | 9717 East    | Tulsa       | OK    | 74146    | Road  | 2600        | 20-Nov   | NO   | NO  | ROLLING_I | 48      | YES        | NO       |
| 32 North_Fac   | 591 Tenne    | Mill Valley | CA    | 94941    | Trail | 260         | 5-Dec    | NO   | NO  | VERY_HILL | 51      | NO         | NO       |
| 33 Golden_Hi   | 2501 Grizz   | Orinda      | CA    | 94563    | Trail | 104         | 10-Oct   | NO   | NO  | VERY_HILL | 64      | NO         | NO       |
| 34 Catalina_Is | 1 Casino     | W Avalon    | CA    | 90704    | Trail | 400         | 19-Mar   | NO   | NO  | VERY_HILL | 53      | NO         | NO       |
| 35 Duke_City   | 401 2nd St   | Albuquerq   | NM    | 87102    | Road  | 400         | 16-Oct   | NO   | NO  | MOSTLY_F  | 57      | YES        | NO       |
| 36 Hamptons    | 23 Main St   | Southamp    | NY    | 11968    | Road  | 300         | 1-Oct    | NO   | NO  | ROLLING_I | 58      | YES        | NO       |
| 37 Wineglass   | 1 Museum     | Corning     | NY    | 14830    | Road  | 2000        | 2-Oct    | NO   | NO  | DOWNHILL  | 54      | YES        | NO       |
| 38 Rock_N_Ri   | 111 West I   | Phoenix     | AZ    | 85281    | Road  | 2500        | 15-Jan   | NO   | NO  | MOSTLY_F  | 56      | YES        | YES      |
| 39 Baystate    | 300 Arcani   | Lowell      | MA    | 1852     | Road  | 1500        | 16-Oct   | NO   | NO  | MOSTLY_F  | 47      | YES        | NO       |
| 40 Moab_Tra    | 36 South 1   | Moab        | CO    | 84532    | Trail | 480         | 5-Nov    | NO   | NO  | VERY_HILL | 49      | NO         | NO       |
| 41 Eagle_Cree  | 501 West 1   | Indianapol  | IN    | 46204    | Trail | 100         | 30-Jul   | NO   | NO  | MOSTLY_F  | 60      | NO         | NO       |
| 42 Chicago     | 337 East R   | Chicago     | IL    | 60601    | Road  | 40,000      | 9-Oct    | NO   | NO  | PANCAKE_  | 57      | YES        | NO       |
| 43 Fort_Laudi  | 801 Seabr    | Fort Laude  | FL    | 33316    | Road  | 750         | 19-Feb   | NO   | NO  | PANCAKE_  | 69      | YES        | NO       |
| 44 Maui_Para   | 2435 Kaan    | Lahaina     | HI    | 96761    | Road  | 700         | 18-Sep   | NO   | NO  | MOSTLY_F  | 79      | YES        | NO       |
| 45 Rocket_Cit  | 700 Monrr    | Huntsville  | AL    | 35801    | Road  | 1300        | 10-Dec   | NO   | NO  | MOSTLY_F  | 45      | YES        | NO       |
| 46 Little_Rock | 1200 Presi   | Little Rock | AR    | 72201    | Road  | 2200        | 6-Mar    | NO   | NO  | ROLLING_I | 50      | YES        | NO       |
| 47 Mesa_Falls  | 168 South    | Ashton      | ID    | 83420    | Trail | 120         | 27-Aug   | NO   | NO  | DOWNHILL  | 61      | YES        | NO       |
| 48 Sugarloaf   | 5092 Acce    | Carraasset  | ME    | 4947     | Road  | 600         | 15-May   | NO   | NO  | DOWNHILL  | 54      | YES        | NO       |
| 49 Run_Wood    | 10866 Ced    | Pinckney    | MI    | 48169    | Trail | 110         | 10-Sep   | NO   | NO  | ROLLING_I | 58      | NO         | YES      |
| 50 Mississippi | 380 South    | Jackson     | MS    | 39201    | Road  | 800         | 7-Jan    | NO   | NO  | ROLLING_I | 45      | YES        | YES      |

The database was converted into a spatial geodatabase using both ESRI ArcMap 10.3 and Google Maps. As described in the following section, Web Platform Construction, the developer chose to use Google Maps for this application. Explaining the construction of both databases is significant to understanding the process of developing the geodatabase, but detailing the process of the ESRI geodatabase is not included, since it was not used for this project. Once the spreadsheet was constructed, it was exported into a google sheets file, geocoded and imported into Google Maps and Awesome Table. Figures 13 through 16 chronicle the database development process. A flowchart of the development of the database is represented in Figure 17.



## EXCEL SHEET (CSV FILE)

| ID | NAME       | ADDRESS        | CITY           | STATE     | ZIP_CODE | TYPE  | PARTICIP | DATE   | APP    | QUAL | RECL      | LOTTERY | TERRAIN | MEAN | TEBQ | MUSIC_TH |
|----|------------|----------------|----------------|-----------|----------|-------|----------|--------|--------|------|-----------|---------|---------|------|------|----------|
| 1  | Boston     | 569 Boylst     | Boston         | MA        | 2116     | Road  | 30000    | 18-Apr | YES    | NO   | DOWNHILL  | 49      | YES     | NO   |      |          |
| 2  | New York   | 1222 Colum     | New York       | NY        | 10023    | Road  | 50000    | 6-Nov  | YES    | NO   | ROLLING   | 51      | YES     | NO   |      |          |
| 3  | Marine     | 2201 Water     | Fort Wash      | MD        | 20745    | Road  | 30000    | 30-Oct | NO     | YES  | MOSTLY_F  | 55      | YES     | NO   |      |          |
| 4  | Big Sur    | Jr 3618 The    | Carmel         | CA        | 93923    | Road  | 3900     | 24-Apr | NO     | YES  | HILLY     | 54      | YES     | NO   |      |          |
| 5  | Rock N     | R 3570 South   | Las Vegas      | NV        | 89109    | Road  | 3200     | 12-Nov | NO     | NO   | ROLLING   | 56      | YES     | YES  |      |          |
| 6  | Honolulu   | 3435 Wai       | Honolulu       | HI        | 96816    | Road  | 31000    | 11-Dec | NO     | NO   | MOSTLY_F  | 75      | YES     | NO   |      |          |
| 7  | Walt       | Dir 3111 West  | Orlando        | FL        | 32830    | Road  | 20000    | 9-Jan  | NO     | NO   | PANCAKE   | 59      | YES     | NO   |      |          |
| 8  | Thim       | Ch 2635 Univ   | St Paul        | MN        | 55114    | Road  | 8000     | 9-Oct  | NO     | NO   | MOSTLY_F  | 51      | YES     | NO   |      |          |
| 9  | LA         | 871 Figue      | Los Angel      | LA        | 90012    | Road  | 21000    | 14-Feb | NO     | NO   | DOWNHILL  | 61      | YES     | NO   |      |          |
| 10 | Houston    | 720 North      | Houston        | TX        | 77024    | Road  | 7700     | 15-Jan | NO     | NO   | PANCAKE   | 52      | YES     | NO   |      |          |
| 11 | Rock N     | R 100 Park     | San Diego      | CA        | 92101    | Road  | 4900     | 6-Jun  | NO     | NO   | DOWNHILL  | 65      | YES     | YES  |      |          |
| 12 | Grandma    | 250 Canal      | Duluth         | MN        | 55802    | Road  | 6000     | 18-Jun | NO     | NO   | MOSTLY_F  | 61      | YES     | NO   |      |          |
| 13 | Country    | 311 Titans     | W Nashville    | TN        | 37213    | Road  | 2700     | 30-Apr | NO     | NO   | ROLLING   | 61      | YES     | NO   |      |          |
| 14 | Napa       | Val 11375      | Trove Napa     | CA        | 94558    | Road  | 3000     | 5-Mar  | NO     | NO   | DOWNHILL  | 51      | YES     | NO   |      |          |
| 15 | St. George | 300 South      | St. George     | UT        | 84770    | Road  | 7400     | 1-Oct  | NO     | YES  | ROLLING   | 50      | YES     | NO   |      |          |
| 16 | Pikes      | Pe 441 Manit   | Colorado       | CO        | 80829    | Trail | 800      | 21-Aug | YES    | NO   | VERY_HILL | 64      | YES     | NO   |      |          |
| 17 | Baltimore  | 1 West         | Pratt          | Baltimore | MD       | 21201 | Road     | 2500   | 15-Oct | NO   | HILLY     | 55      | NO      | NO   |      |          |
| 18 | Steamtown  | 200 North      | Scranton       | PA        | 18902    | Road  | 2200     | 9-Oct  | NO     | NO   | DOWNHILL  | 59      | YES     | NO   |      |          |
| 19 | Flying     | Pig 644 Lin    | St. Cincinnati | OH        | 45203    | Road  | 3800     | 1-May  | NO     | NO   | HILLY     | 59      | NO      | NO   |      |          |
| 20 | Cal        | Interr 1315    | 10th Sacramen  | CA        | 95814    | Road  | 5600     | 4-Dec  | NO     | NO   | DOWNHILL  | 47      | YES     | NO   |      |          |
| 21 | Shamrock   | 2800 Shor      | Virginia B     | VA        | 23451    | Road  | 1850     | 19-Mar | NO     | NO   | PANCAKE   | 48      | YES     | NO   |      |          |
| 22 | Fargo      | 800 North      | Fargo          | ND        | 58102    | Road  | 1400     | 21-May | NO     | NO   | PANCAKE   | 59      | YES     | NO   |      |          |
| 23 | New        | Jers 175 Oscar | Oceanport      | NJ        | 7757     | Road  | 2000     | 1-May  | NO     | NO   | PANCAKE   | 54      | YES     | NO   |      |          |
| 24 | Portland   | 1202 South     | Portland       | OR        | 97205    | Road  | 7000     | 9-Oct  | NO     | NO   | ROLLING   | 56      | YES     | NO   |      |          |

Figure 13 – CSV File of Races

## GOOGLE SHEET

| NAME              | ADDRESS          | Latitude      | Longitude    | CITY            | STATE | ZIP CODE | TYPE  | PARTICIPANT | DATE (Month) |
|-------------------|------------------|---------------|--------------|-----------------|-------|----------|-------|-------------|--------------|
| Baltimore         | 1 West Pratt Str | 39.285196     | -76.6170697  | Baltimore       | MD    | 21201    | Road  | 2500        | October      |
| Baystate          | 300 Arcand Driv  | 42.6475208    | -71.3131013  | Lowell          | MA    | 1852     | Road  | 1500        | October      |
| Big Sur Internats | 3618 The Barny   | 36.5552       | -121.9233    | Carmel          | CA    | 93923    | Road  | 3300        | April        |
| Boston            | 569 Boylston Str | 42.3500639    | -71.0761142  | Boston          | MA    | 2116     | Road  | 30000       | April        |
| California Intern | 1315 10th Street | 38.5765874    | -121.4932453 | Sacramento      | CA    | 95814    | Road  | 5600        | December     |
| Catalina Island   | 1 Casino Way     | 33.3879       | -118.4163    | Avalon          | CA    | 90704    | Trail | 400         | March        |
| Chicago           | 337 East Randol  | 41.8827891    | -87.6198229  | Chicago         | IL    | 60601    | Road  | 40000       | October      |
| Country Music     | 1 Titans Way     | 36.1665479    | -96.7713989  | Nashville       | TN    | 37213    | Road  | 2700        | April        |
| Deadwood Mick     | 180 Sherman St   | 44.3767       | -103.7296    | Deadwood        | SD    | 57732    | Trail | 500         | June         |
| Duke City         | 401 2nd Street   | 35.0853       | -106.6056    | Albuquerque     | NM    | 87102    | Road  | 400         | October      |
| Eagle Creek       | 501 West Washi   | 39.7668124    | -96.1682026  | Indianapolis    | IN    | 46204    | Trail | 100         | July         |
| Fargo             | 800 North Univ   | 46.8772       | -96.7898     | Fargo           | ND    | 58102    | Road  | 1600        | May          |
| Fort Lauderdale   | 801 Seabreeze E  | 26.113767     | -80.109677   | Fort Lauderdale | FL    | 33316    | Road  | 750         | February     |
| Flying Pig        | 644 Lin Street   | 39.1019116    | -84.5287534  | Cincinnati      | OH    | 45203    | Road  | 3800        | May          |
| Golden Hills      | 2501 Grizzly Pk  | 37.882349     | -122.2245362 | Orinda          | CA    | 94563    | Trail | 104         | October      |
| Grandmas          | 250 Canal Park   | 46.788755     | -92.0942836  | Duluth          | MN    | 55802    | Road  | 6000        | June         |
| Hamptons          | 23 Main Street   | 40.8599       | -72.5678     | Southampton     | NY    | 11968    | Road  | 300         | October      |
| Honolulu          | 3435 Wai'alea    | Al 21.2843227 | -157.8026227 | Honolulu        | HI    | 96816    | Road  | 31000       | December     |
| Houston           | 720 North Oak    | P 29.7798703  | -95.4561893  | Houston         | TX    | 77024    | Road  | 7700        | January      |

Figure 14 – Data geocoded and imported into Google Sheet

## GOOGLE MAP -MY MAP

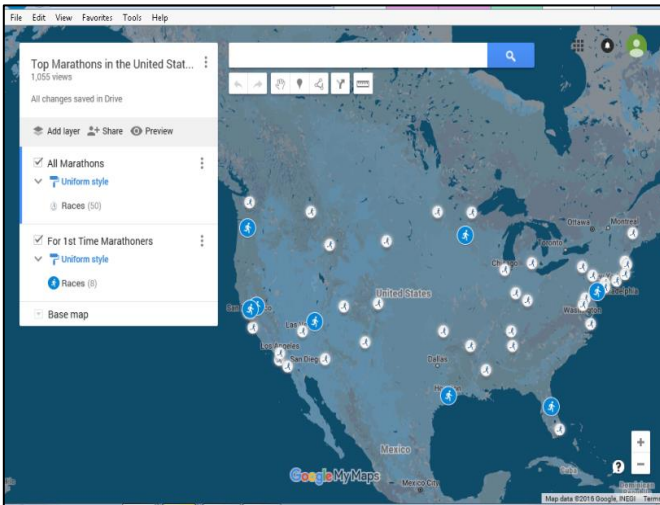


Figure 15 – Database imported into web-map

## AWESOME TABLE

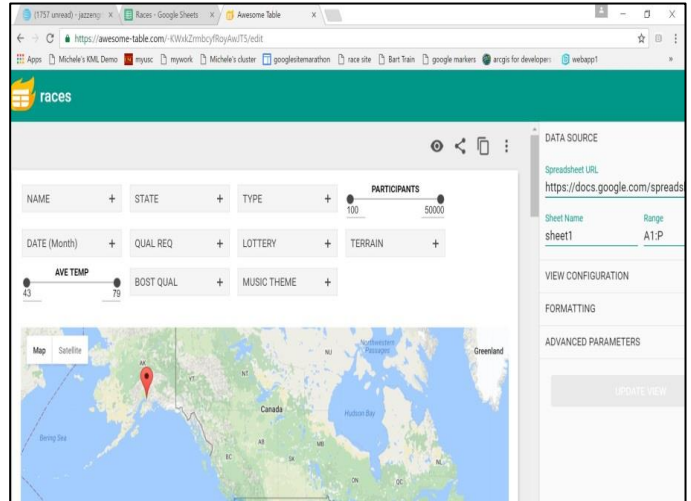


Figure 16 – Database geocoded and formatted in table

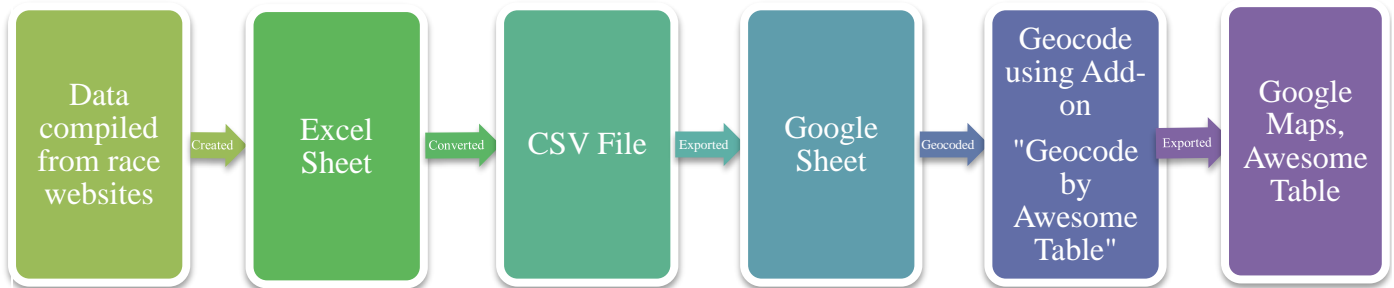


Figure 17 – Flowchart of database development

### 3.3. Web Platform Construction

In conjunction with related work research and web GIS development skills, the application was developed using three different platforms and geospatial tools to test the functionality and produce the most powerful application possible.

#### 3.3.1. Arc Map

Using ArcMap 10.3 Web App Builder, a Web GIS application was constructed and a geodatabase added. The map was exported to ArcGIS Online and tested (see Figure 18).

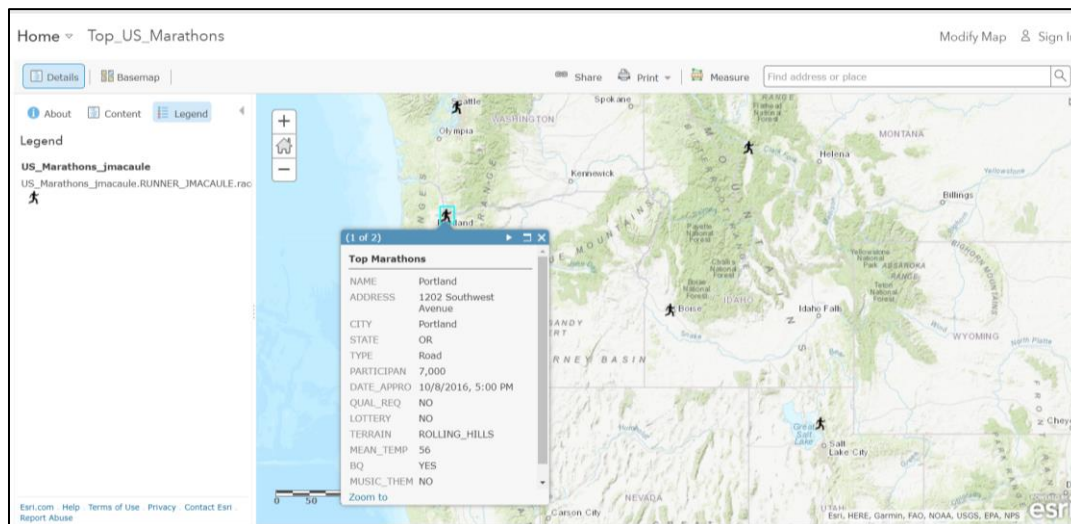


Figure 18 – Implementation of Web GIS application in ArcGIS 10.3 Web App Builder

#### 3.3.2. Google API

A web-GIS map was created using Google API, requiring HTML, Javascript, and CSS programming skills (see Figure 19). Google API allows for great flexibility and control, although was not a feasible option due to time constraints.



Figure 19 – Implementation of Web GIS application using Google API

### 3.3.3. Google Sites

Google Sites is a free web creation software package offered as part of Google’s G Suite Productivity Suite. It offers custom email addresses and allows embedding of customized Google Maps, HTML data and other gadgets. A Google Sites Web GIS application was constructed using a blank template (see Figure 20).

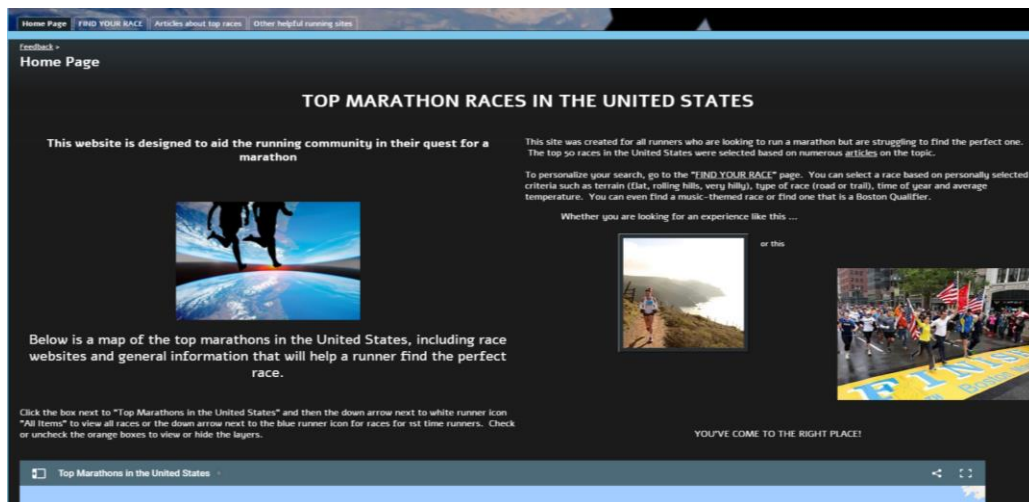


Figure 20 – Implementation of Web GIS application using Google Sites

Factors considered in selecting Google Sites as the platform included aesthetic appeal, strength of functional capabilities, and level of required technical skills. While extensive effort was conducted in ESRI’s ArcMap, its capabilities were lacking for the purpose of this app,

specifically the query function and configurability. Additionally, ESRI software is very costly to continue developing this application beyond the scope of this project. Programming a Web GIS application using Google's API gives the most flexibility and produced the best app visually and operationally, however, the time constraint to acquire the necessary technical skills for the level of this application led to the selection of Google Sites for the platform. Google Sites allows customization of pages and elements of the app, including importing the geodatabase into a table allowing query functions. Furthermore, Google maps can be customized and easily embedded into the app, adding custom HTML, CSS and Javascript and other useful gadgets. It is free to develop, user friendly, easy to navigate, develop and update. The primary benefit of Google Sites is its cross platform usability. The site can be customized and viewed in both iOS and Android environments, websites, mobile devices and tablets. It also allowed for the numerous technologies that were required for the development of this application.

The process of constructing the web GIS app began with creating a Google Sites account. Two versions of Google Sites exist; Google Sites Classic and New Google Sites. Testing both versions, Google Sites Classic was selected due to greater flexibility and functionality.

Formatting choices are detailed in the UX Design section. Five primary tools were used to add GIS Maps and other gadgets to the application: Insert Image, Link, Embed Gadget, Map and Include gadget (iframe) to your page. The Image function allowed functionality to add images either by URL or personal file upload. The Link function provided capability to insert text and link that text to another web location. The Embed Gadget function allowed for embedding of HTML and CSS code to be added to the page, which are programming codes that allow customization. The Map function offered the ability to embed maps created in both Google Maps and Google Earth. The Include Gadget or iframe to your page allowed the

developer to add applications linked with a URL (web link) such as other websites or applications. Inserting a link and including a gadget differentiate in that inserting a link is just highlighting text that routes you to a different web based location, whereas adding a gadget actually adds the web information or page directly into your document (also called framing). Figures 21 through 23 show tools in Google Sites used to add functionality to the Web GIS application.

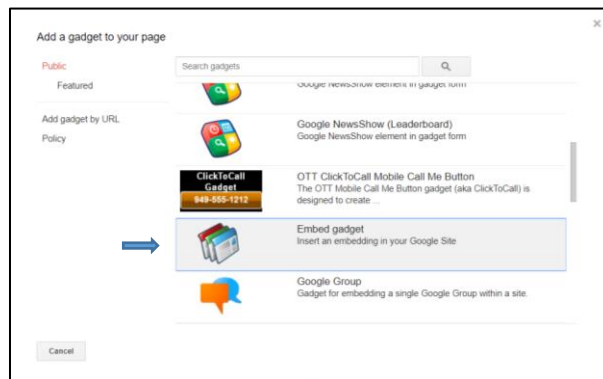


Figure 21 - Embed Gadget

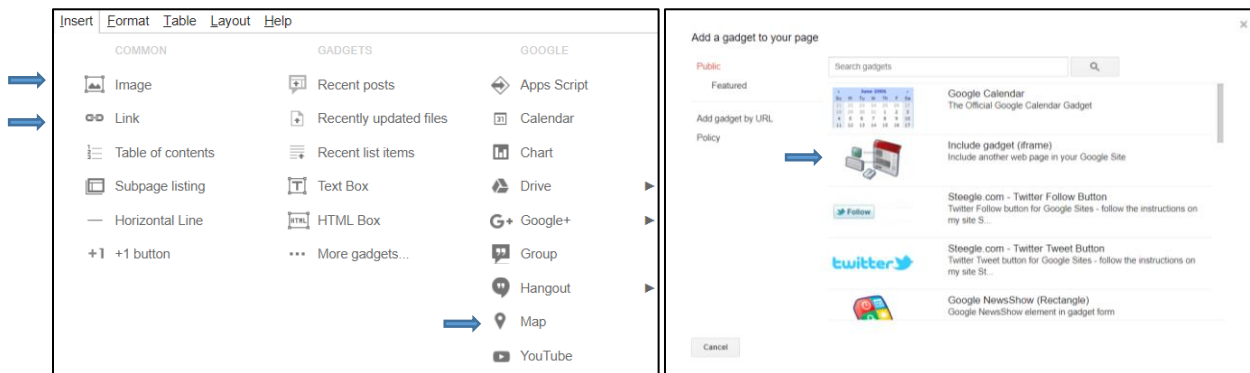


Figure 22 - Insert Image, Link and Map tool

Figure 23 - Include Gadget (iframe)

### 3.4. GIS Map Development

One of the main goals was to develop a Web GIS application that would be available to as many users as possible on any device and with any browser. Determining which technology to use in the course of developing GIS maps for this web GIS-app involved analyzing and testing

several environments. Many limitations and compatibility issues arose during the development of this app, but in the end, an app was created that is available in any environment, and contains slight limitations for the 3D interactive option since it is only available with Google Chrome browser.

Four main functions for this app yielded four separate maps to allow the user to easily navigate through the race selection and planning process. The four steps converted to individual maps include: (1) Viewing races including pertinent information about each race; (2) Finding race including query capability to search by selected criteria; (3) Navigate race allowing users to view race courses and terrain in a 3D environment interactively as well as street view to mentally prepare for the course; (4) Plan race offers a map of nearby lodging and dining aiding in the logistics of travel involved for the race.

#### *3.4.1. View Race*

The majority of the construction of the “View Race” map has been described in section 3.2 and 3.3 of this thesis. Once the geodatabase was built and exported into a Google Map, each race was edited and customized, and images were added as demonstrated in Figures 24 and 25. Initially, the intention of the Web GIS application was to include the race course layer in the same map, however Google Sites limits the number of layers to ten and features within the layers to two thousand. This limitation prevented the courses to be added in Google My Maps and instead were added as a separate page using Google Earth. Ultimately, the limitation proved advantageous to the end result of the Web GIS application. Creating separate maps on separate pages actually resulted in better navigation and display of the race selection and planning process. Pages were added with tabs that followed a natural progression in selecting and preparing for a race.



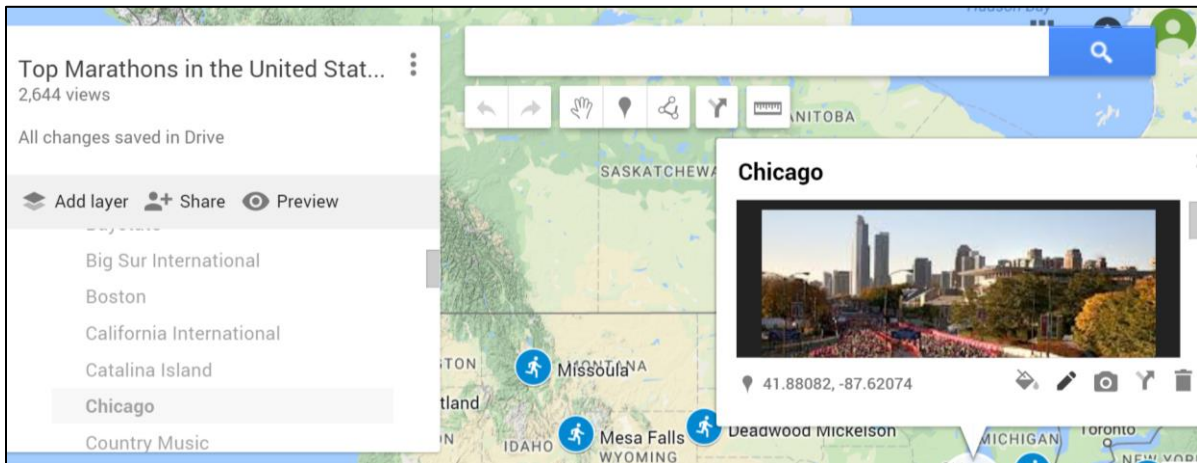


Figure 24 - Example of Race Image added to Layer

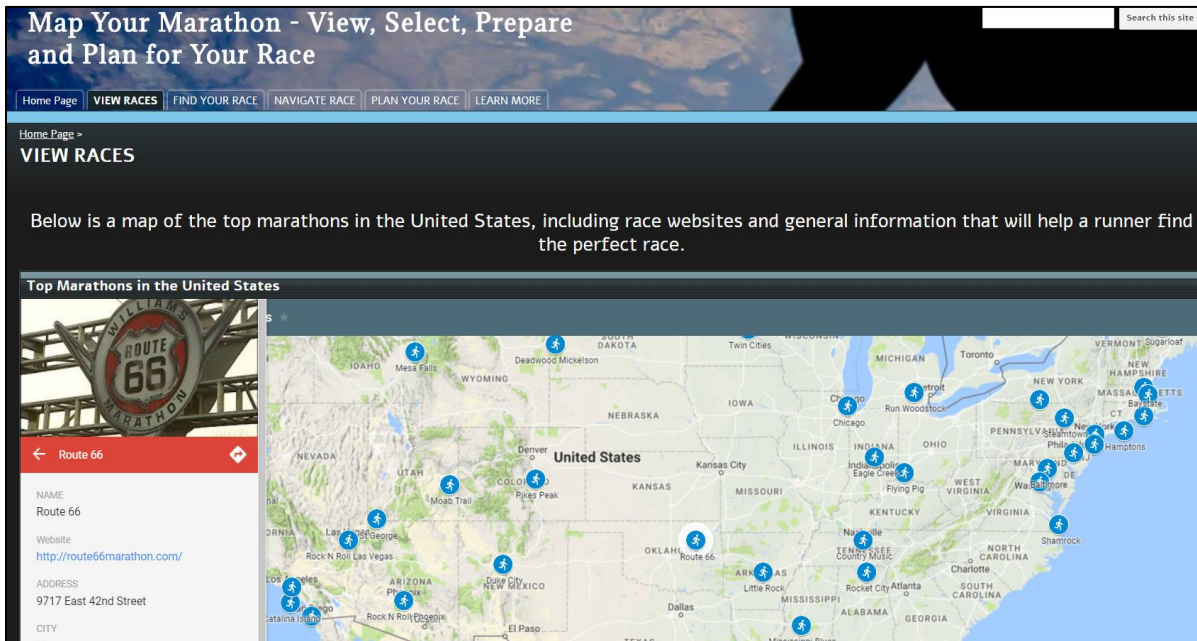


Figure 25 - Example of View Races page: Race Selected and Race Data in Left Panel

### 3.4.2. Find Race

The Find Race map utilized a web application, Awesome Table which adds filter capabilities to a spreadsheet and displays the results in both a map and list format. Parameters for the spreadsheet were added to allow for the filters and then configured and formatted the table display, illustrated in Figures 26 through 28.

| NAME           | ADDRESS           | Latitude        | Longitude      | CITY      | STATE          | ZIP CODE     | TYPE          | PARTICIPANTS    | DATE (Month)   | QUALIFICATI    | LOTTERY        | TERRAIN        | AVERAG   | BOSTO       | MUS  |
|----------------|-------------------|-----------------|----------------|-----------|----------------|--------------|---------------|-----------------|----------------|----------------|----------------|----------------|----------|-------------|------|
| Categoryfilter | HiddenFilter      | MapsLat - Hidde | MapsLong - Hid | NoFilter  | Categoryfilter | HiddenFilter | Categoryfille | Numbrangefilter | Categoryfilter | Categoryfilter | Categoryfilter | Categoryfilter | Numbrang | CategoryFil | Cate |
| Baltimore      | 1 West Pratt Stre | 39.285186       | -76.6170697    | Baltimore | MD             | 21201        | Road          | 2500            | October        | NO             | NO             | HILLY          | 55       | NO          | NO   |

Figure 26 - Parameters set in Line 2 of Race Spreadsheet to add filter capabilities

The interface shows a map of the United States with several race locations marked by colored circles (blue, red, yellow). The sidebar on the right includes sections for 'DATA SOURCE', 'VIEW CONFIGURATION' (Visualization type: Maps with table, # of items displayed: 52, Maps height: 500px), 'LAYOUT' (Filters, map, table), 'FORMATTING', and 'ADVANCED PARAMETERS'. An 'UPDATE VIEW' button is at the bottom of the sidebar.

Figure 27 – Find Race page of Web GIS application – table configured and formatted for filters

The 'FIND YOUR RACE' interface includes a search bar and several filter controls: NAME (+), STATE (+) (set to NY), TYPE (+), PARTICIPANTS (range 100-50000), DATE (Month) (+) (set to October), QUALIFICATIONS (+), LOTTERY (+), TERRAIN (+) (set to 55), AVERAGE TEMPERATURE (range 45-60), BOSTON QUALIFIER (+), and MUSIC THEME (+). The map shows race locations in the Northeast. Below the map is a table with the following data:

| NAME               | CITY                | STATE | TYPE | PARTICIPANTS | DATE (Month) | QUALIFICATIONS | LOTTERY | TERRAIN                | AVERAGE TEMPERATURE | BOSTON QUALIFIER | MUSIC THEME |
|--------------------|---------------------|-------|------|--------------|--------------|----------------|---------|------------------------|---------------------|------------------|-------------|
| Hamptons Wineglass | Southampton Corning | NY    | Road | 300          | October      | NO             | NO      | ROLLING HILLS DOWNHILL | 58                  | YES              | NO          |

Figure 28 – Example of Find Race Query



### 3.4.3. Navigate Race

While implementing an interactive 3D map of race courses, the goal was to create a map that allowed the user to view race courses on the map, zoom in and interactively view the terrain and street view of the course. The map layer from Google Maps “Top Marathon Races in the US” already created, containing the geocoded spreadsheet was converted to a KML file.

KML files of all the race courses for the fifty races were obtained from a variety of sources. The majority of KML files for the courses were exported from an application called MapMyRun. An example is illustrated in Figure 29, exporting race data for the Chicago Marathon as a KML file. A few files were obtained from miscellaneous sources and the remaining files were created manually utilizing MapMyRun. The course for the Saint George Marathon is an example of a course that was created manually and is shown in Figure 30.

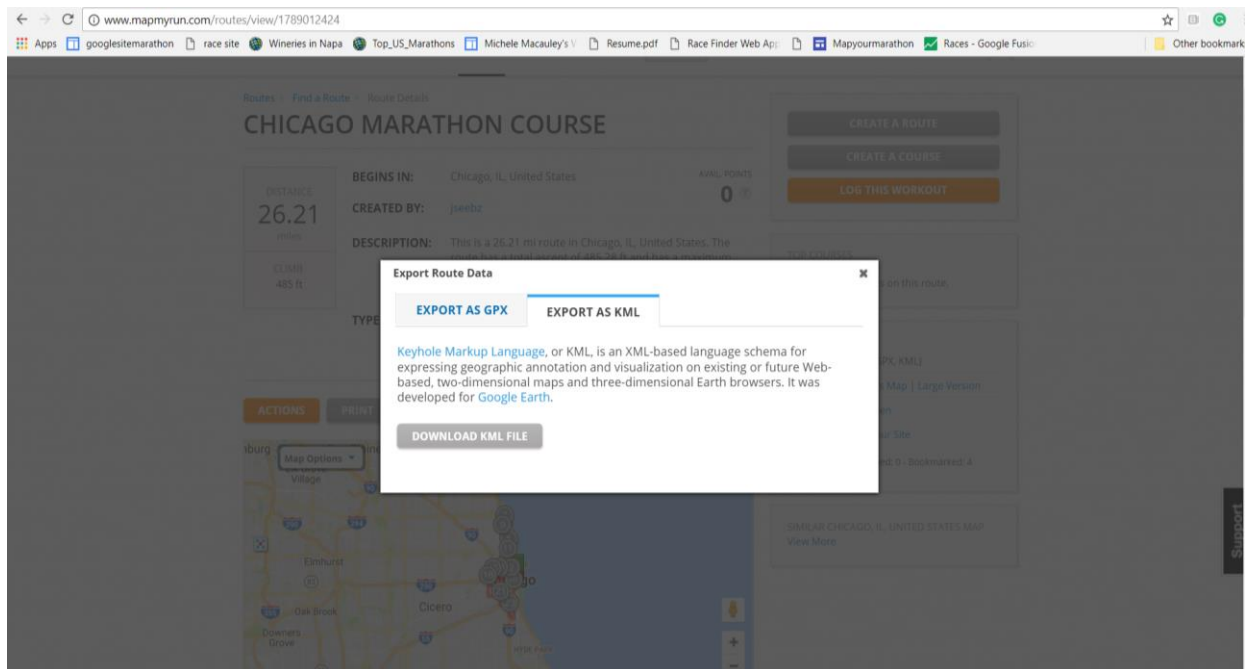


Figure 29 – Exporting Race Route from MapMyRun as KML file

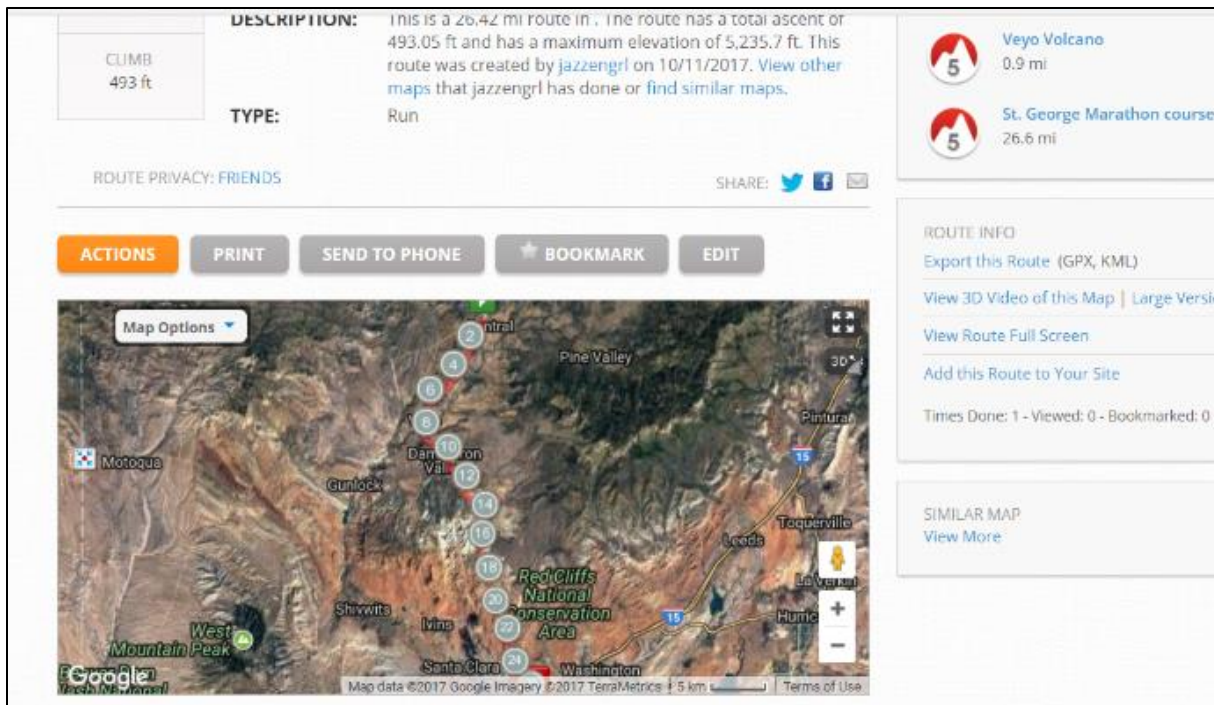


Figure 30 – Race Route manually created for Web GIS application using MapMyRun

Google Earth Pro for Desktop was downloaded, the Top Races KML file imported, and race route KML files imported and customized. When attempting to embed the Google Earth map into the Web GIS application, it was discovered the Embed Google Earth feature was no longer supported due to licensing issues. Fortunately, Google Earth did implement a feature for users to access Google Earth without downloading or requiring a plug in, <https://earth.google.com/web/>. It is a web based application that only requires a Google Chrome browser. Two separate links in the Web GIS application allowed for users to access race course routes with or without Google Chrome, but only those with Google Chrome have access to the 3D interactive version. For the 3D option, the developer imported the KML files into Google Earth Web. For those without Google Chrome who wish to view the courses in Map View, Satellite View or Street View, there is a link to the published Google Drive. Figures 31 through 33 include examples of the Navigate Race page.

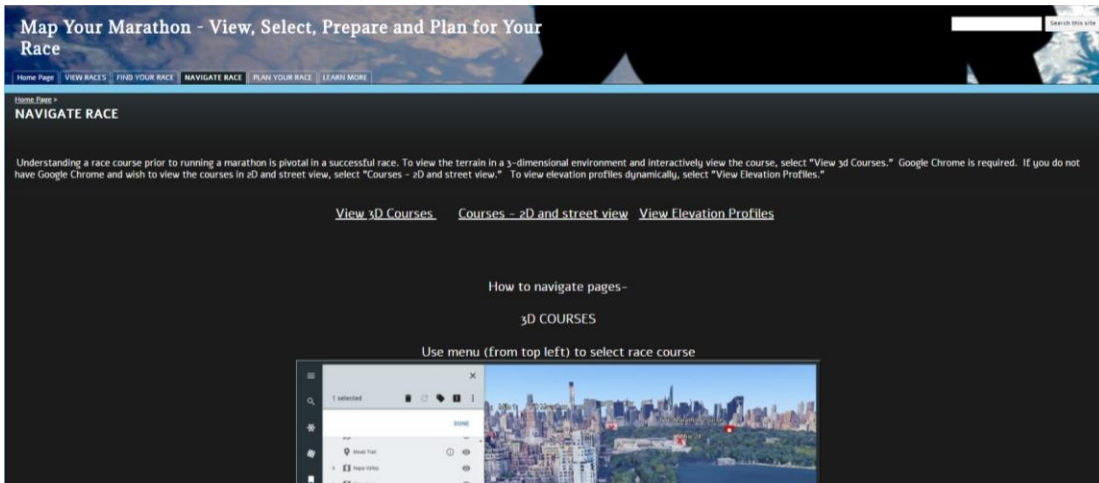


Figure 31 - Web GIS application Navigate Race page with link to 3D Courses

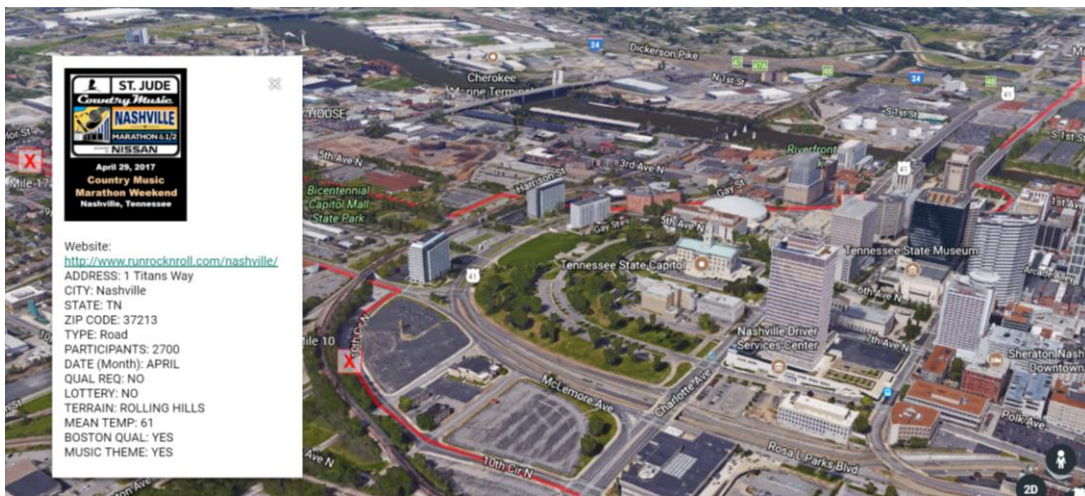


Figure 32 – Example of Navigate Race page 3D



Figure 33 - Example of Navigate Race page 2D



Finally, the KML files of the routes were uploaded into a program, RideWithGPS. This application converted the file into a GPX file displaying the route and elevation profile with an embed option. The file was then embedded into the Web GIS application offering a dynamic display of elevation profiles (shown in Figure 34).

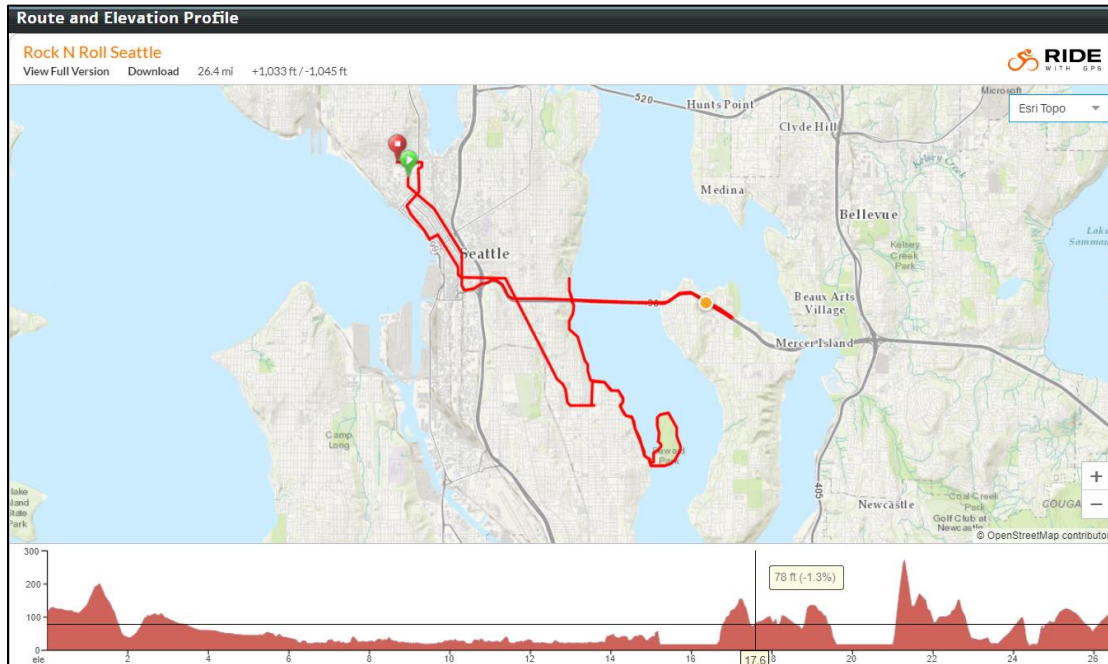


Figure 34 – Example of Navigate Race page - Dynamic Race Course and Elevation Profile

#### 3.4.4. Plan Race

Planning a marathon race involves complex logistics that any runner will appreciate assistance alleviating stress to concentrate on the race itself. This Web GIS application offers the user the ability to view lodging and dining options on a map, along with the race course to make arrangements based on proximity to the start or finish line. Additionally, the Google Earth option allows runners to search for hotels or restaurants close to the course. The “Plan Race” map specifically allows runners to immediately view the dining and restaurant options.

Developing this option required datasets acquired from both ArcGIS Online, exported as KML

files and uploaded to Google Maps and KML files extracted from a search in Google Earth.

Figure 35 includes an example of datasets acquired using ArcGIS Online for lodging and dining in Boston. Figure 36 includes an example of datasets acquired using Google Earth KML files of dining and lodging in Jackson, Mississippi.

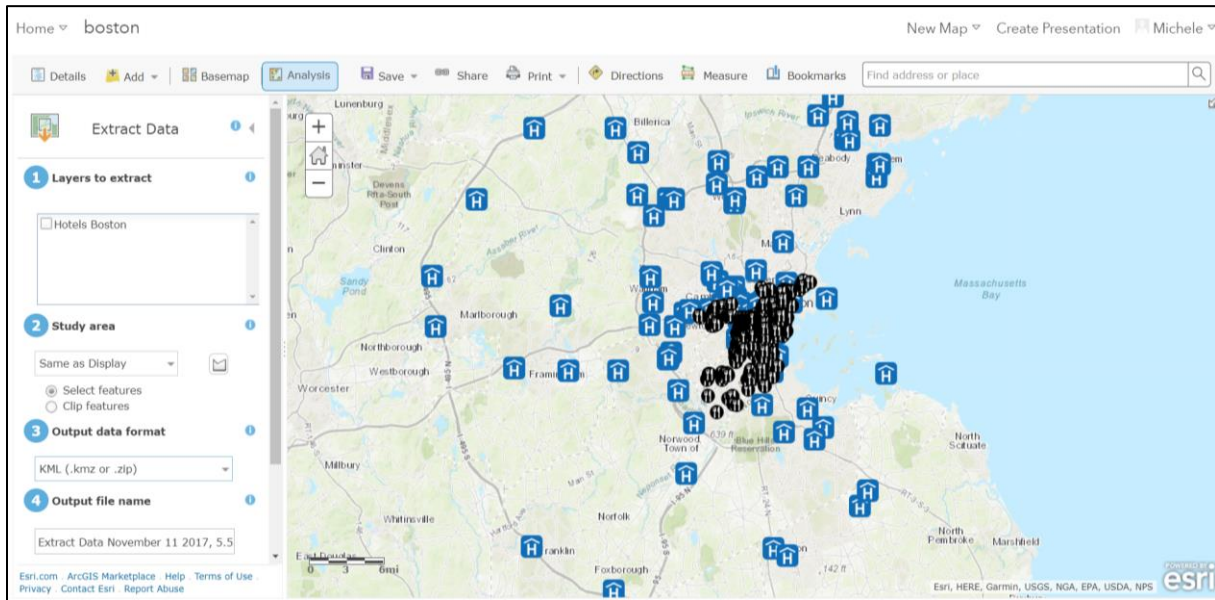


Figure 35 - Dataset extracted from ArcGIS Online of Boston lodging and dining

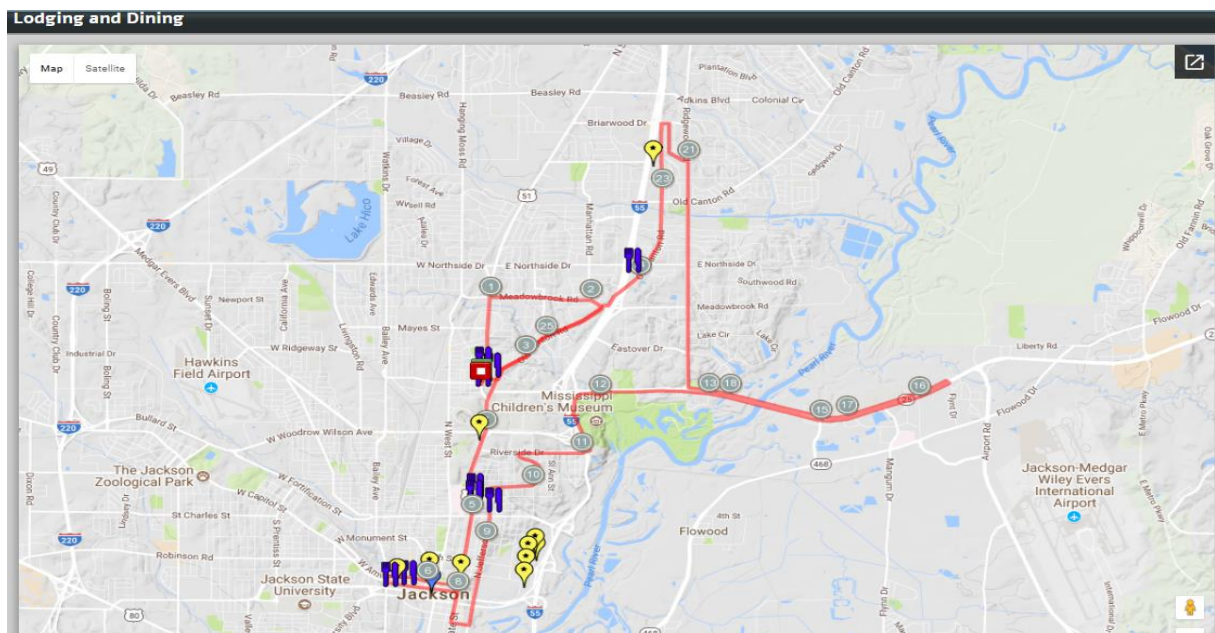


Figure 36 – Example of Plan Race page: Display of lodging and dining options in Jackson, MS

### 3.5. UX Design

UX, or User experience is described as the process of creating products that provide meaningful and personally relevant experiences (Interactive Design Foundation 2016). Careful attention was given to ensure an enhanced experience for the user in the Web GIS application designed in this thesis, incorporating concern for usability, content and function.

Utilizing visualization techniques, a blank template was chosen, using an image depicting a global landscape with runner's silhouette to capture the nature of this application. Tabs at the top divide the user's options into categories to navigate through the marathon selection and planning process. *Top Design Mag* author Bogden Raputa explains that the navigation system is vital to a website and the simplest and most effective form is the use of tabs because the user can visualize a website's structure in a linear way (Raputa 2017).

There is debate on whether to use light or dark colors for background, but the consensus is to allow the content to stand out and offer easy readability. Using the black background and white lettering displays well, particularly with the graphic chosen for the front page. *UX Planet*, an online resource for web designers, cites Richard Hall and Patrick Hannah's scientific research, offering the following benefits of using a black background:

- Style and elegance
- Feel of mystery
- Luxury and prestigious look
- Broad field of using contrast
- Support of visual hierarchy
- Depth in reflection of presented content
- Visual appeal

In addition, the article suggests that the dark background accentuates graphic contents such as pictures, photos and illustrations better than a light background (Hall, Hannah 2016). Since the intention of the Web GIS application is to focus on the GIS web maps and illustrations within the app, the dark background was a logical choice (See Figure 37).

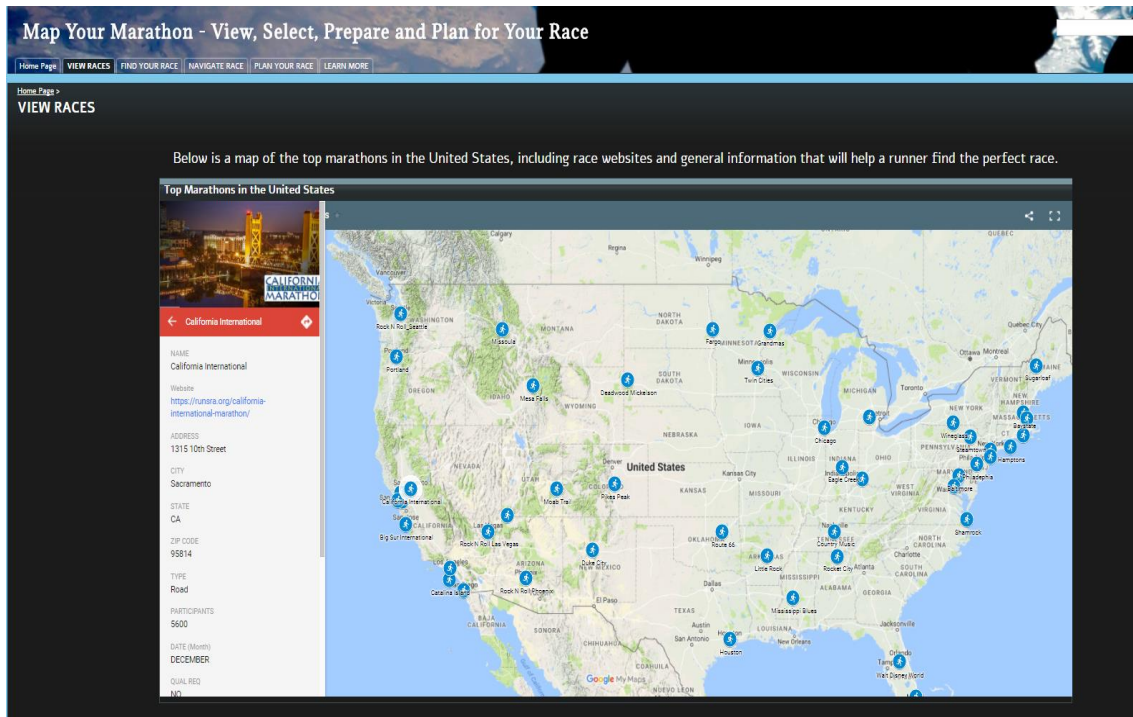


Figure 37 - Web GIS application shows map accentuated by dark background and tabs on top

The remaining sections of the Web GIS application rely primarily on the GIS maps and other gadgets. The maps are illustrated in large 1200x800 pixels to allow the user easy navigation through the maps. Navigation is standard for google maps, using two fingers inside the map to manipulate the map. Scroll bars are included within the gadgets to maximize real estate and images were incorporated to help illustrate the race experience.

Additional functionality was added to the Plan Race tab to further assist runners in planning and preparing for a race. Three webpages were embedded, including Accuweather, which allows a user to view extended weather forecasts up to 90 days and historical averages beyond that;

Yelp, offering the user the ability to rate dining and lodging establishments; and Booking.com, allowing the user to book a hotel for their stay.

### **3.6. Testing Environment and Survey**

The finalization of any project must conclude with substantial testing and evaluation of the product to ensure optimum success. Analyzing the success of this Web GIS application was conducted using two primary methods: testing in multiple environments and a runner's survey.

#### *3.6.1. Testing in Multiple Environments*

The construction of this Web GIS application was a continuous process of testing a variety of methods in order to develop an application that fulfilled all of its intended goals. To begin with, developing the proper platform and application programming interface, as previously described resulted in the utilization of Google API, Google Sites and Google Earth Web for the development of the Web GIS application, the database and the web maps.

Lacking certain functionality from Google, the developer further researched athletic based mapping software, programs and applications such as Mapout, MotionX GPS, and Maps 3D, finally producing web-GIS maps containing race course data and elevation profiles using Mapmyrun and Ridewithgps.

Once the Web GIS application was complete, the product was tested on several devices and environments. Initially, testing revealed that the race courses would not show up in devices not logged on by the developer. In order to resolve this issue, the KML files of the courses were uploaded to Google Drive, then setting was changed to allow public to view files. The link in the Web GIS application was re-routed to the Google Drive files and then the functionality worked. Final testing included the following devices and produced the following results:



Table 2. Testing Environment

| <b>Device</b>     | <b>Type</b>  | <b>Browsers available and tested</b>      | <b>Results</b>                                                                                                                                                                         |
|-------------------|--------------|-------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dell Inspiron     | Hybrid       | Chrome, Explorer, Firefox                 | All components of application worked as intended in Google Chrome<br>3D functionality not available in Firefox or Explorer                                                             |
| Lenovo Edge       | Laptop       | Chrome, Explorer, Firefox                 | All components of application worked as intended                                                                                                                                       |
| Galaxy Tab2       | Tablet       | Chrome, Google Earth                      | All components of application worked as intended                                                                                                                                       |
| Iphone 8plus      | Mobile Phone | Google Chrome, Google Earth               | All components of application worked as intended except Accuweather does not display<br>Font was small for navigation tabs                                                             |
| Samsung Galaxy S8 | Mobile Phone | Google Play                               | All components of application worked as intended except Accuweather does not display and 3D functionality, Satellite view and street view worked<br>Font was small for navigation tabs |
| HP                | Desktop      | Explorer, Firefox, - Chrome not available | All components of application worked except 3D functionality. Satellite view and street view worked                                                                                    |

### 3.6.2. Runner's Survey

A runner's survey was conducted at the completion of the web-GIS project. The survey was sent via Facebook and email to a group of runners known to the developer through a variety of marathon training groups and Team in Training, an organizing in which athletes raise money for Leukemia and Lymphoma Society and train for athletic events such as marathons, triathlons and bicycling events. The survey was anonymous and voluntary. Twenty one runners participated in the survey. The results are detailed in the Results section of this thesis.

### 3.7. Technology and Data Sources

Numerous technologies and methods were incorporated into the production of the Web GIS application. A Web GIS application utilizes both web technology and GIS technology. Several environments were tested in order for the app to contain all the necessary tools and functionality.

#### 3.7.1. Technology

Following itemizes the technology and hardware utilized for the development of the Web GIS application, the user requirements and the usage and limitations of Google Sites:

Table 3. Technology

| Software and Downloads                | Hardware                  | User Requirements                   | Usage and Limitations                                                                                               |
|---------------------------------------|---------------------------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Esri ArcMap 10.4                      | Dell Inspiron 7000 Series | Windows, macOS, Linux, Android, iOS | 100 MB of storage (free account)                                                                                    |
| Esri ArcGIS Online                    | Samsung Galaxy Tab S2     | Size:                               | 10 GB storage for Google App users                                                                                  |
| Brackets text editor                  | iPhone 8 Plus             | Windows: 12.5 MB                    | No open use of Cascading Style Sheets (CSS) or JavaScript                                                           |
| Filezilla (open sources software FTP) |                           | macOS: 35 MB                        | JavaScript can be used within the confines of an embedded gadget or the HTML box                                    |
| Google Earth                          |                           | Linux: 24 MB                        | Inline CSS can be used within the webpage content area                                                              |
|                                       |                           | Android: 8.46                       | Sites that are hosted in Google Sites are not available to residents of countries where Google Services are blocked |
|                                       |                           | iOS: 77.5 MMB                       |                                                                                                                     |
|                                       |                           | Cost - Free                         |                                                                                                                     |

### 3.7.2. Data Sources

Overall, race data is not easily available as datasets or generally in a GIS environment, however, information about races is accessible and was entered into a csv file and converted into a personal geodatabase. Google API allows for customized map layers and KML file creation for Google Earth.

Table 4. Data Sources

| <b>Sources</b>                                      | <b>Contents/Attributes</b>                                                                                              | <b>Format/Technique in GIS Environment</b>                                                                                   | <b>Availability/Process</b>                                                                                                                        |
|-----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| Personal database created in ArcGIS and Google Maps | Database includes numerous attributes for each marathon<br>Added website of races to attributes and images of each race | Excel sheet<br>CSV File<br>Geodatabase in ESRI ArcMap 10.2<br>Created excel sheet<br>Google Sheet<br>Google My Map and Table | Available data – Only non-GIS data<br>Process-searched ArcGIS layers, race websites, created personal geodatabase                                  |
| All marathon websites                               | General information about the marathons was used for attributes such as date, location, number of participants, etc.    | Geodatabase - Data manually entered into database, imported, and geocoded to display in map                                  | Available data – race details were available but had to create database and geocode<br>Process – searched many websites to retrieve necessary data |
| Adobe Stock Images                                  | Subscribed to Adobe for images to add to website                                                                        | Images from adobe to enhance web application design                                                                          | Available data – yes<br>Process – obtained photos for web app                                                                                      |
| Google maps                                         | Adds locations in points and polylines to maps                                                                          | Created markers, save KMZ files, add to Google My Map and Google Earth                                                       | Available data – yes<br>Process – lodging/dining layers from government and Google Earth                                                           |
| Government datasets                                 | Allow user to view nearby lodging and restaurants                                                                       | Added layers to Google Map, format appropriately                                                                             | Available data – possible<br>Alternative – Race sites have lodging/dining                                                                          |
| Mapmyrun                                            | Allows user to view courses on map and elevation profiles                                                               | Mapmyrun for routes<br>Exported to Google map<br>Converted to KML,<br>Added to Google Earth                                  | Available data – Non-GIS data<br>Process – KML files form Mapmyrun                                                                                 |

|              |                                                                           |                                                        |                                                                                                                                  |
|--------------|---------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Google Earth | Allows 3D view of terrain, interactive controls and street view of routes | Converted maps to KML files and export to Google Earth | Available data– yes<br>Process - researched mapping options for 3d view, determined Google Maps can be converted to Google Earth |
|--------------|---------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|

## Chapter 4 Results

The development of a Web GIS application to aid runners in their marathon selection and planning was not a single process, but a complex set of steps and tests. Testing a variety of technologies, formats, and systems, the application was designed with the intention of utilizing geospatial technology to best aid the running community. A runner’s survey helped evaluate the success of the application. Analyzing the challenges posed during the process also helped understand how the project materialized.

### 4.1. Overview of Application

In the end, Google Sites was the platform used in the development of the Web GIS application. The API chosen was Google. Other systems or applications used include Google Earth, Ride with GPS, Mapmyrun and Awesome Table. The incorporation of multiple sources and technologies resulted in a mashup web application. *How Stuff Works* Author Nathan Chandler explains, “Web mashups are one technique that can make Web-based data more useful. Mashups blend information from multiple sources. Mashups present the results in a compelling, innovative fashion. Often, the information is displayed in visually powerful ways that make it much more valuable and understandable to users.” (Chandler 2011). The functionality of this application would have been significantly reduced without combining multiple sources and techniques. For the purpose of this project, a mashup was the ideal method.

Following subsections give an overview of the Web GIS application and examples of each page and are illustrated in Figures 38 through 49.

#### 4.1.1. Home Page

The home page offers an image that conveys the concept “Running around the world.” In addition, the home page describes the purpose of the site and each page and includes links to the other pages.



Figure 38 – Web GIS application Home Page

#### 4.1.2. View Races

The View Races page allows the user to view all of the races on a map. A race can be selected either from the list in the left panel or by selecting it directly on the map. The left panel displays an image of the race and pertinent race data such as website, address, average weather, month of race, etc.

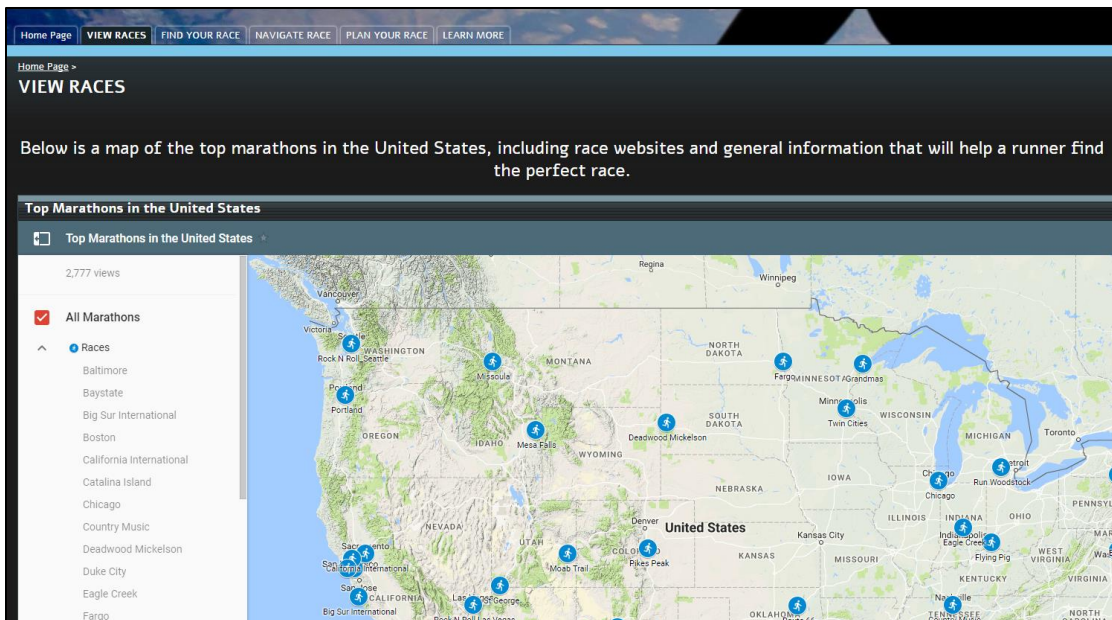


Figure 39 – View Races Page – Main Page

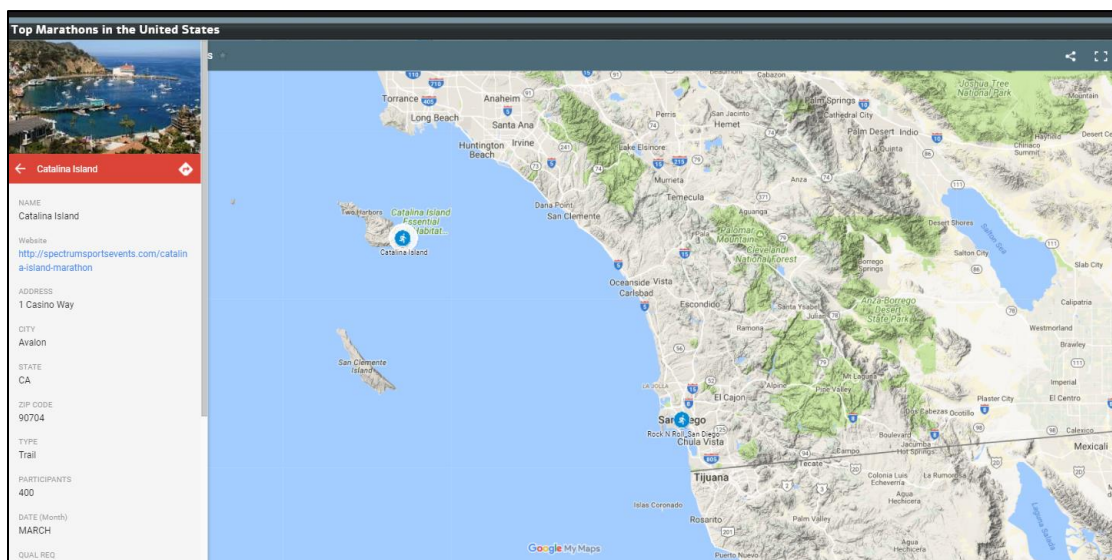


Figure 40 – View Races Page – Catalina Island Marathon

#### 4.1.3. Find Your Race

This page allows a user to find a race based on personally selected criteria. The results display on the map and in a list below. Example below (Figure 42) shows the results for races in New York with an average temperature between 43 and 65 degrees Fahrenheit that are road races in October.

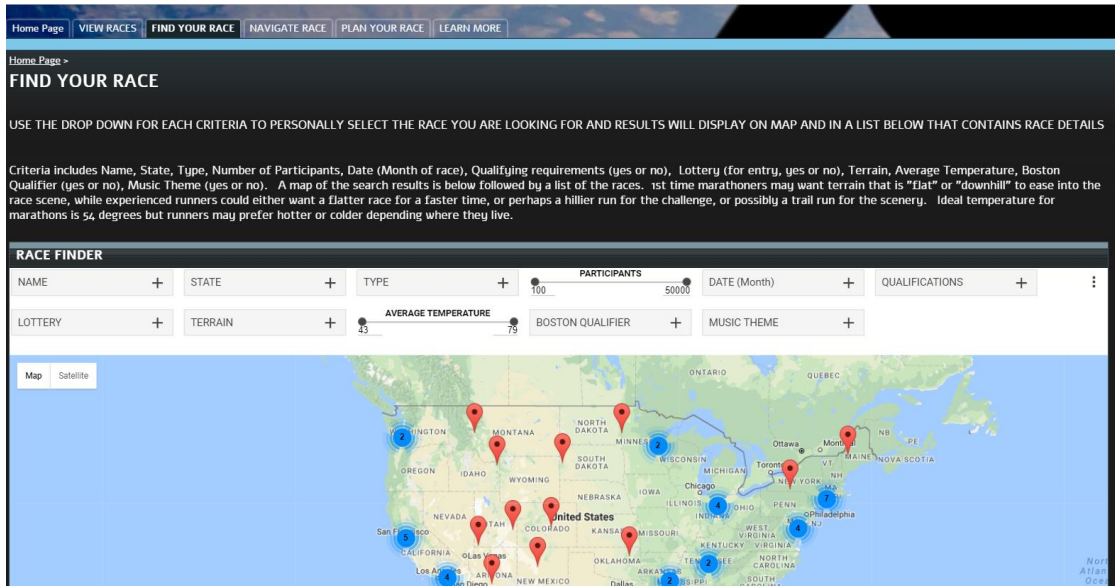


Figure 41 – Find Your Race Page

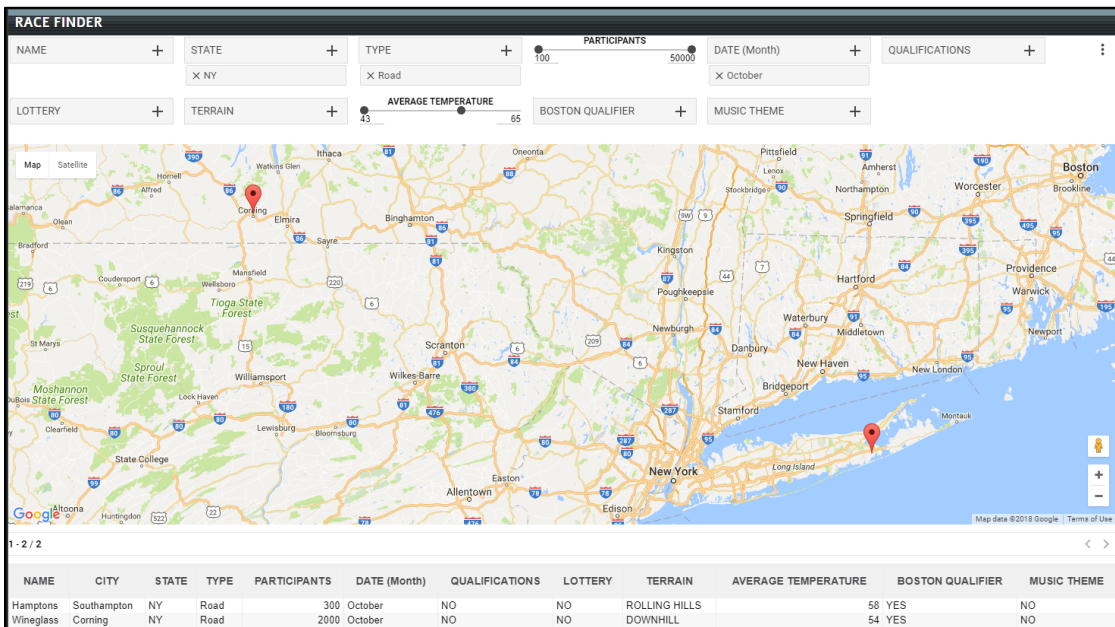


Figure 42 – Web GIS application Find Your Race Page – Search results for road races in New York in October with average temperature between 43-65 F

#### 4.1.4. Navigate Race

Once the user has selected a race, he or she can navigate through the course and view the elevation profiles dynamically. The lodging and dining options close to the start and finish lines are also displayed on this map.



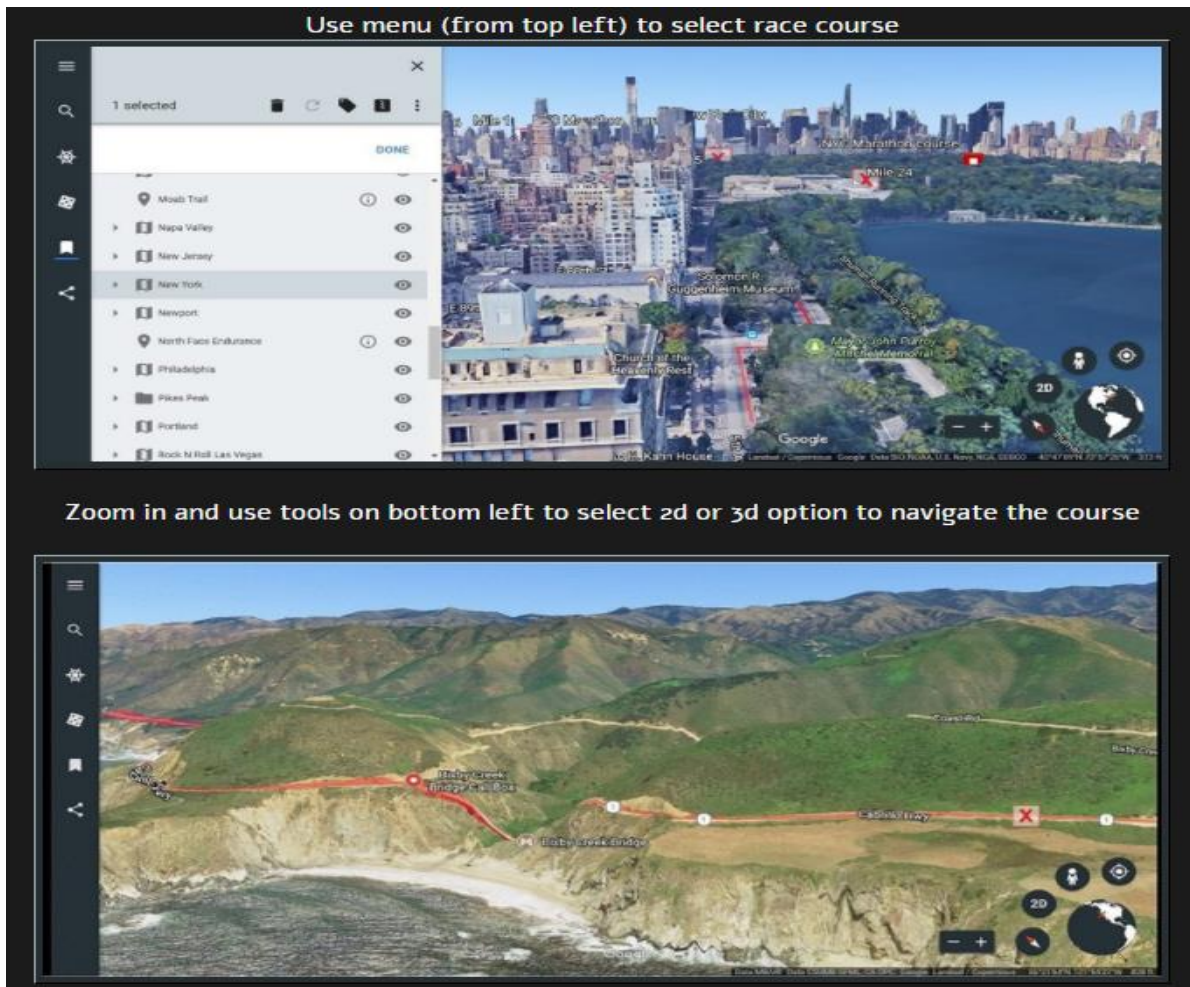


Figure 43 – Web GIS application Navigate Race Page – Main Page

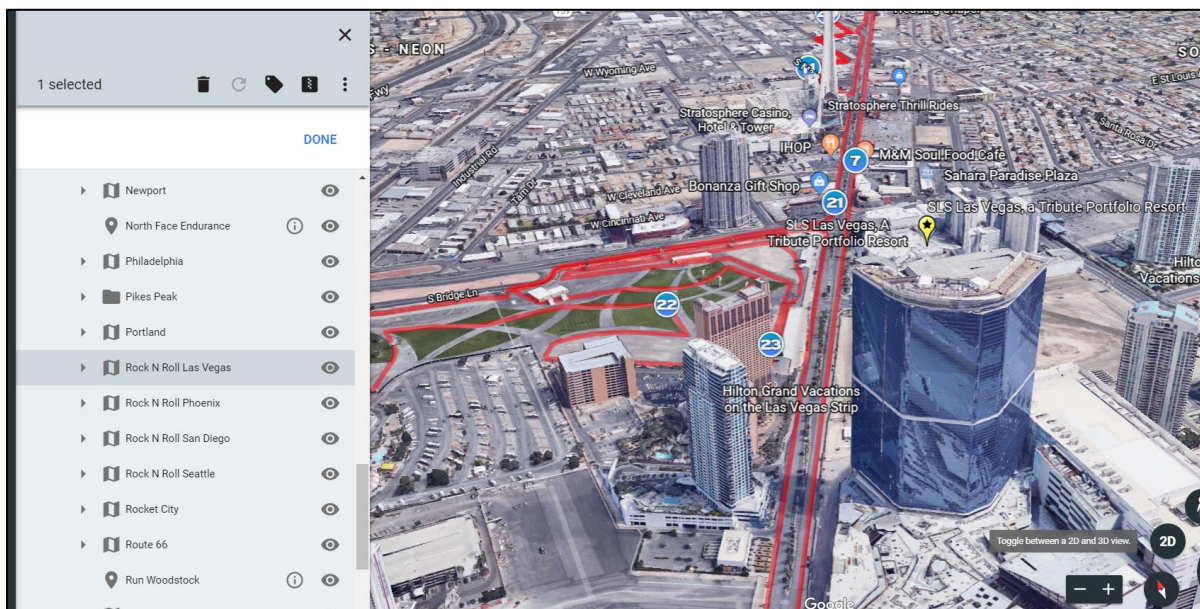


Figure 44 – Web GIS application Navigate Race Page – 3D Results for Rock N Roll Las Vegas Marathon



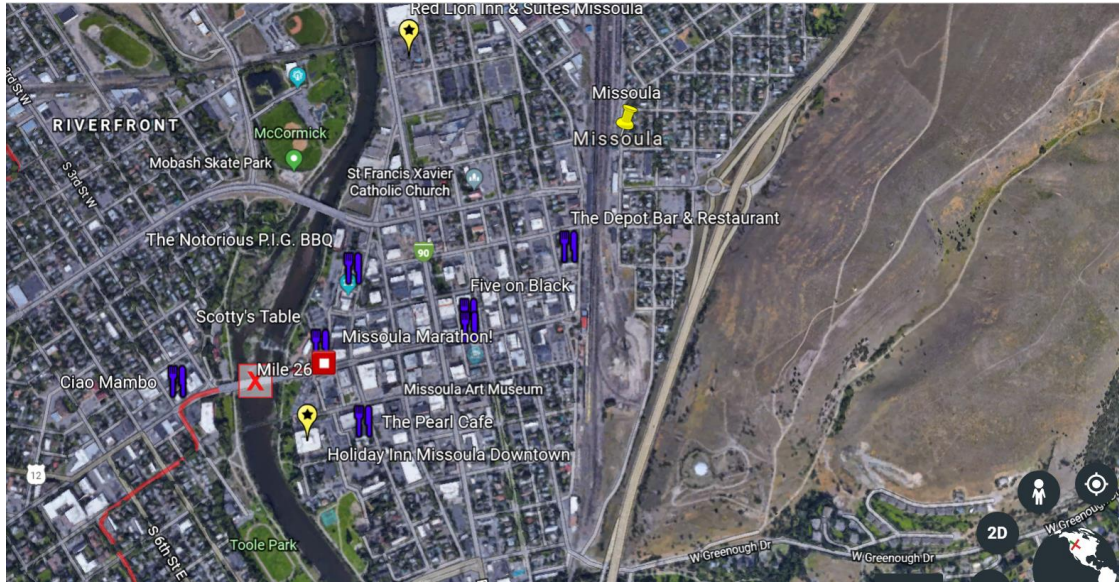


Figure 45 – Web GIS application Navigate Race Page – Dining and Lodging near finish line for Missoula Marathon

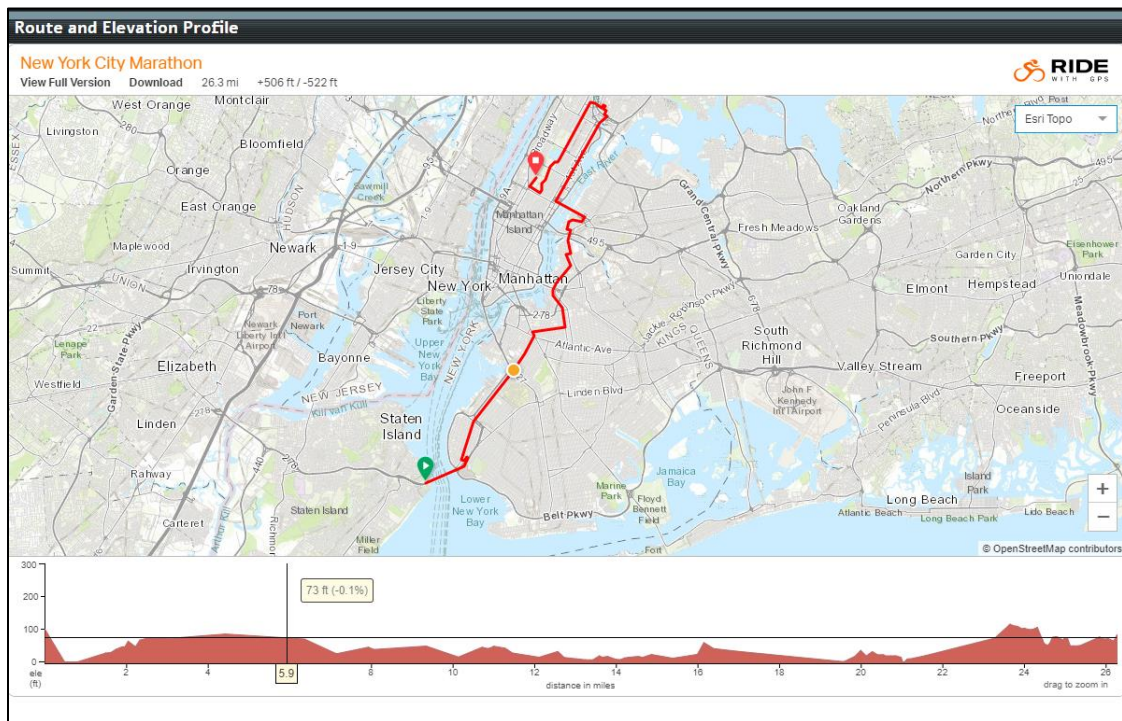


Figure 46 – Web GIS application Navigate Race Page – Elevation Profile for New York Marathon

#### 4.1.5. Plan Race

Once the user has explored the terrain and area surrounding the race, the final step is making arrangements for the travel involved. This page includes a map and three other

webpages embedded into the page. The map shows the race courses and restaurants and lodging near the start and finish lines. The three other pages include Accuweather, Booking.com and Yelp to further help with the planning process.

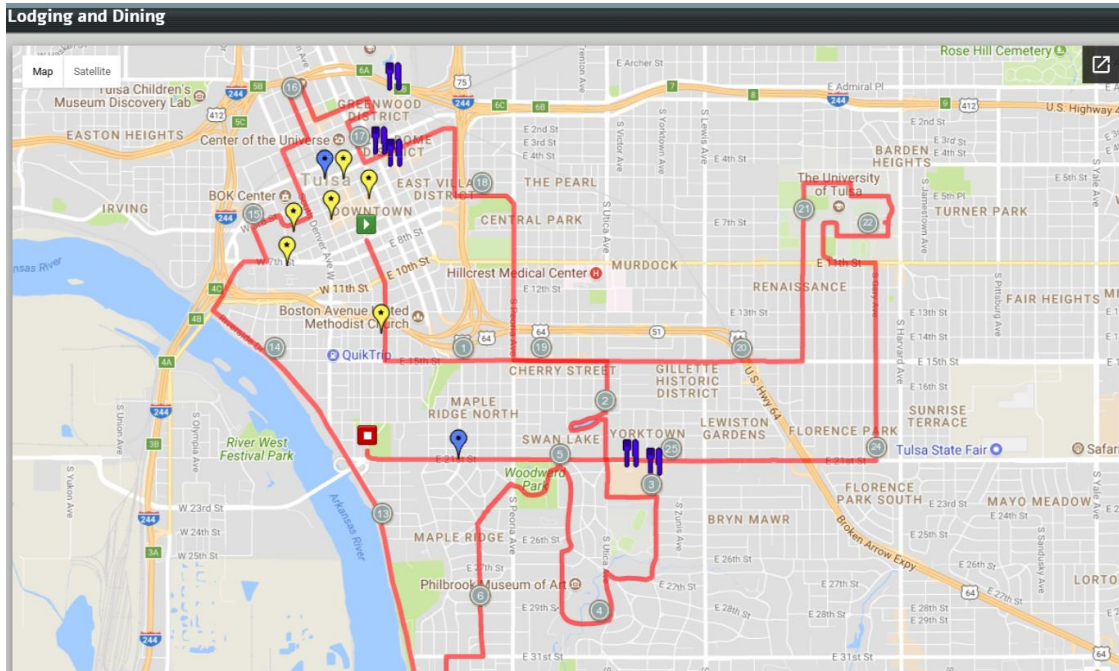


Figure 47– Web GIS application Plan Race Page – Results for lodging and dining for Little Rock Marathon

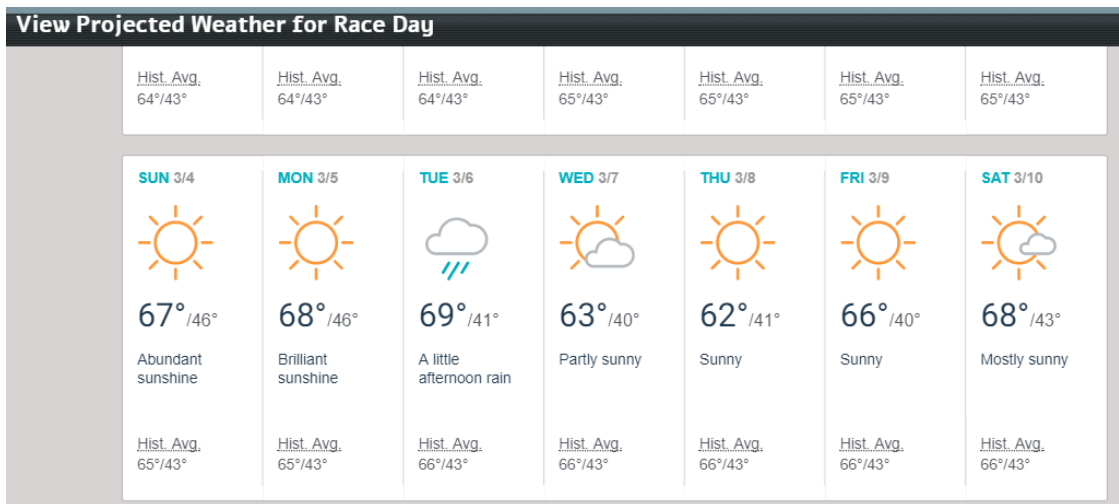


Figure 48 – Web GIS application Plan Race Page – Accuweather extended forecast for Napa Marathon

#### 4.1.6. Learn More

The final page contains links to other resources to help runners and articles used in the development of the application.

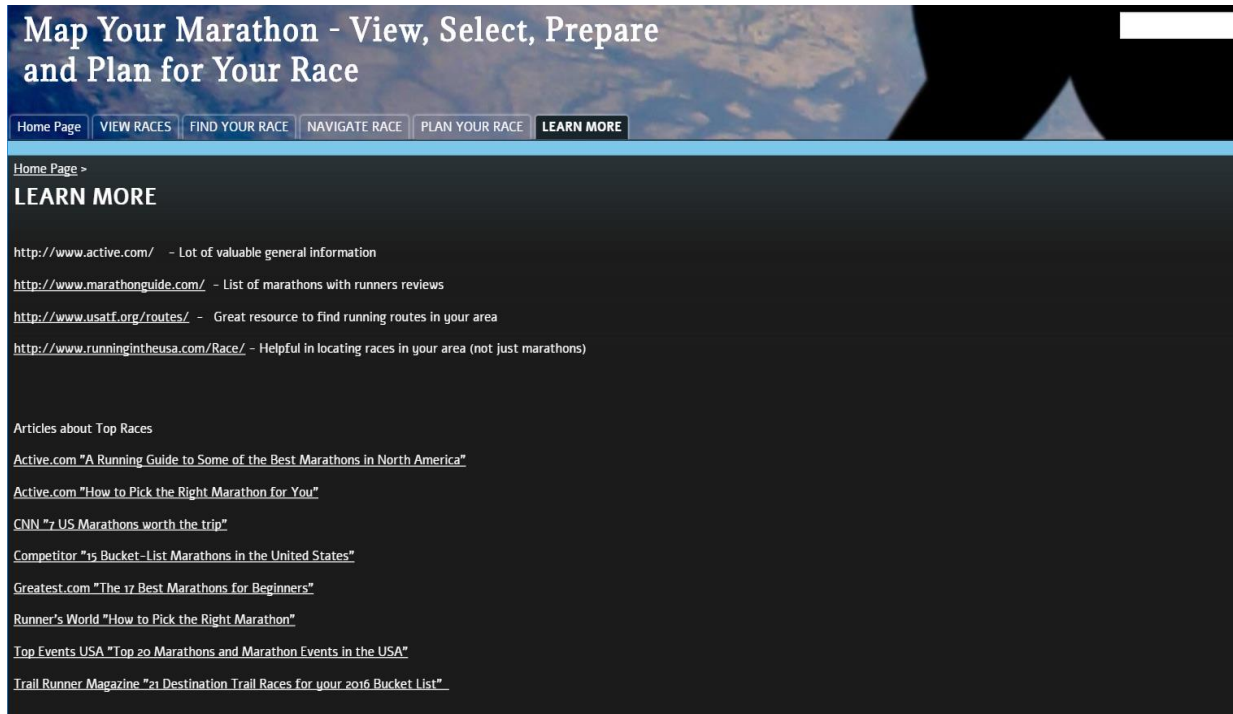


Figure 49 –Web GIS application Learn More Page

## 4.2. Runner's Survey

A runner's survey was conducted at the completion of the Web GIS project. The survey was sent via Facebook and emailed to a group generated through a variety of marathon training groups and Team in Training, an organization in which athletes raise money for Leukemia and Lymphoma Society and train for athletic events such as marathons, triathlons and bicycling events.

The survey was developed using the site Survey Monkey. It is a very basic survey containing ten questions. The questions were designed to obtain general information about the runners (age, number of races completed and goals when selecting a race.) The remaining

questions solicited input regarding the runner’s experience with the Web GIS application. The survey focused on whether the runner felt like the application is unique and useful and if the application was easy to use and navigate. Those asked to participate were advised that the survey was optional and anonymous. Of the athletes solicited, twenty-one runners participated in the survey. This section documents the results of the survey and an analysis of the survey is provided in Section 5.2. Analysis of Runner’s Survey.

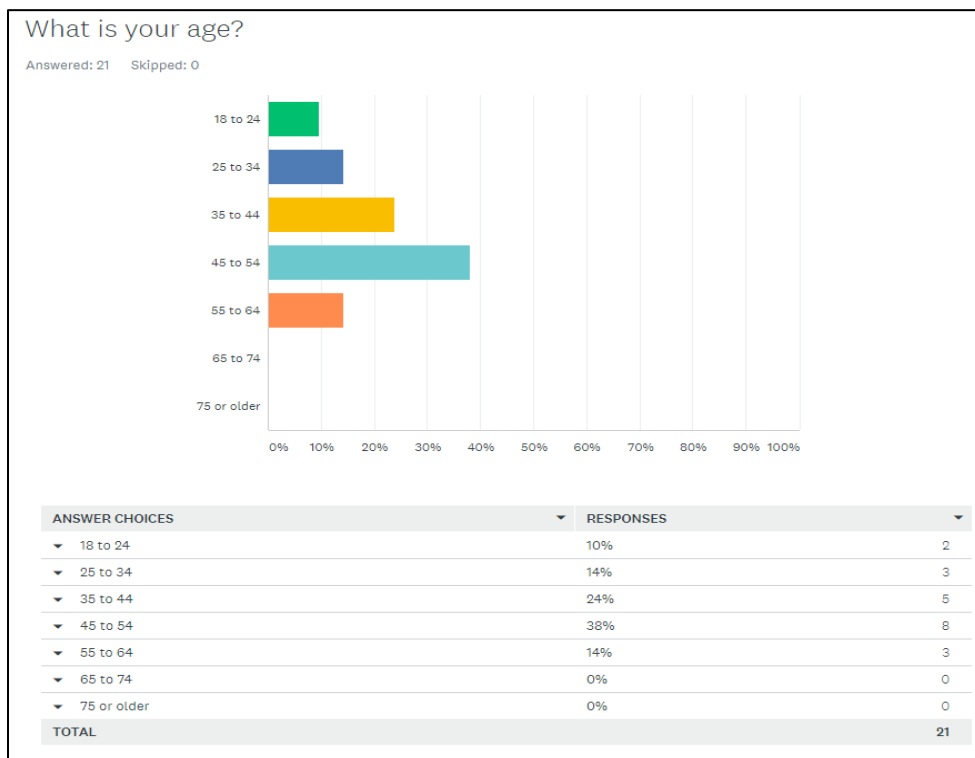


Figure 50 – Runner’s Survey Question 1



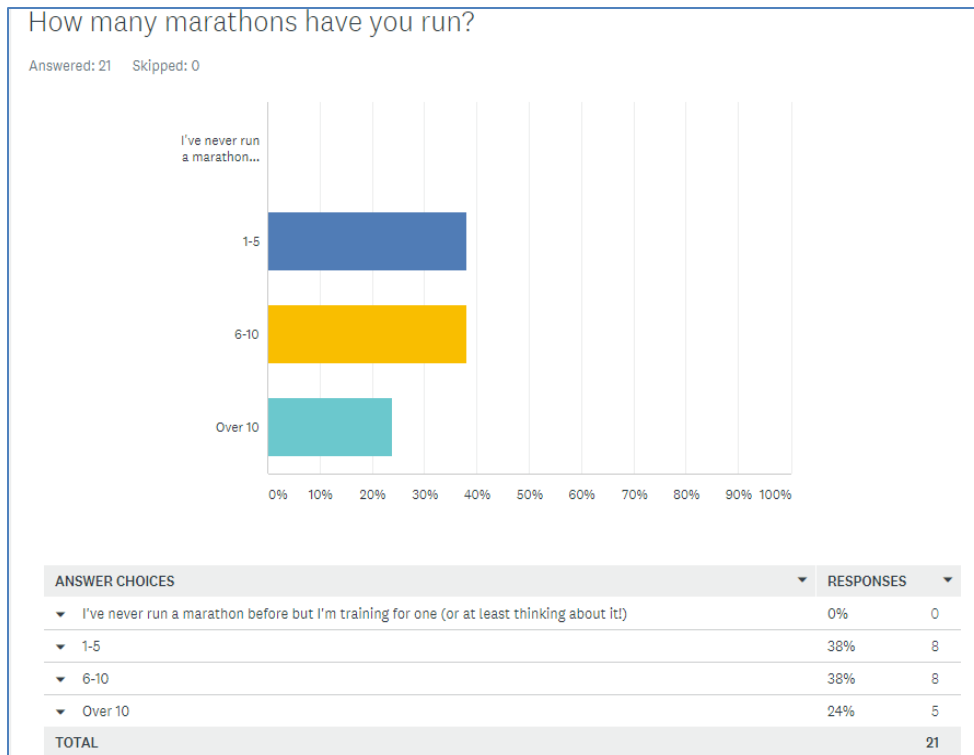


Figure 51 – Runner’s Survey Question 2

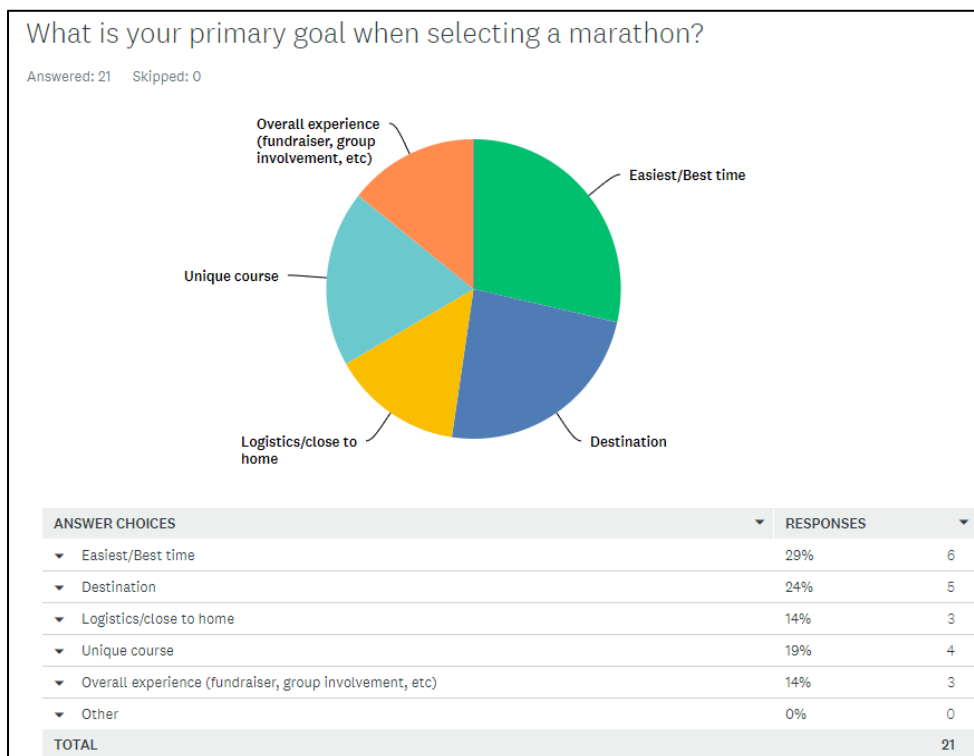


Figure 52 – Runner’s Survey Question 3

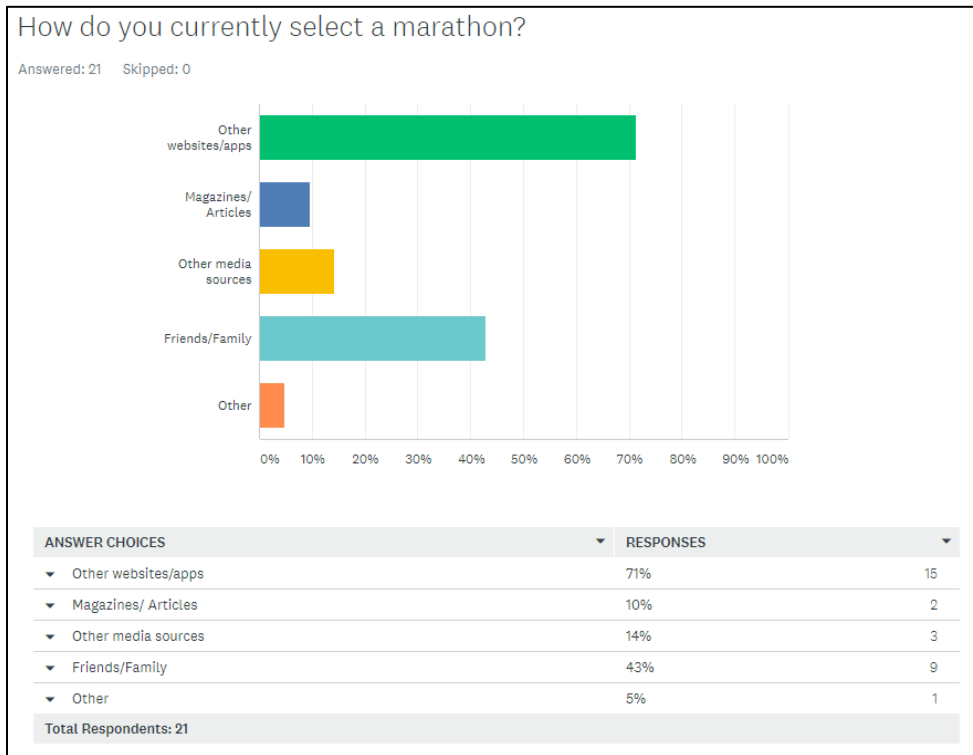


Figure 53 – Runner’s Survey Question 4

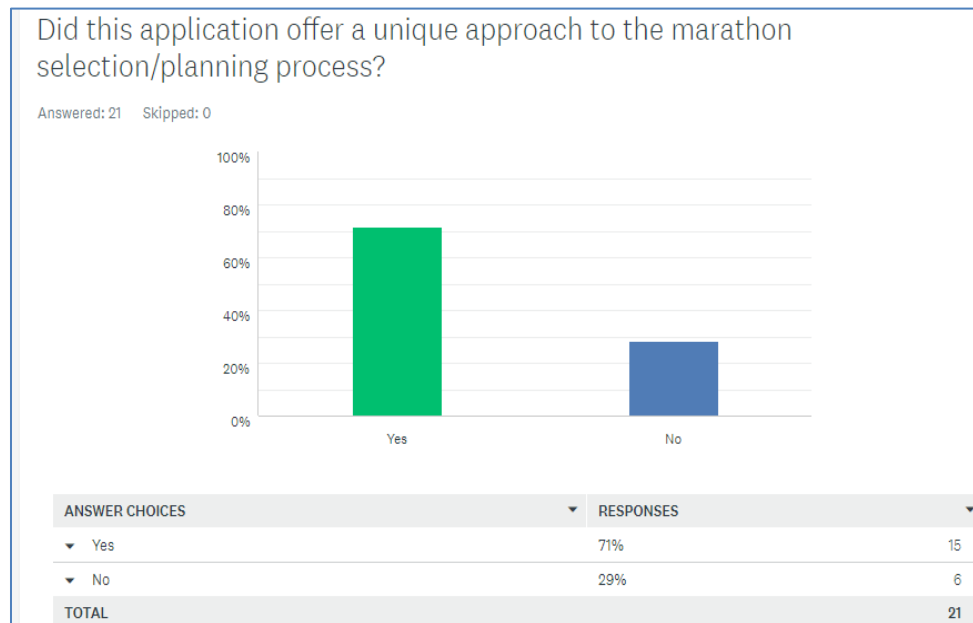


Figure 54 – Runner’s Survey Question 5

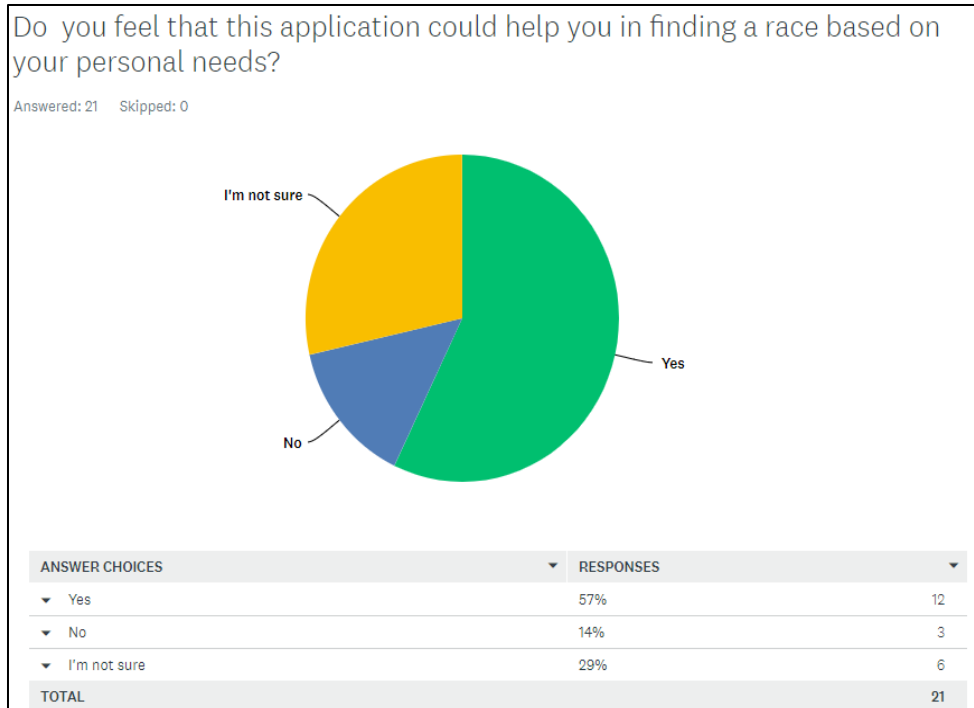


Figure 55 – Runner’s Survey Question 6

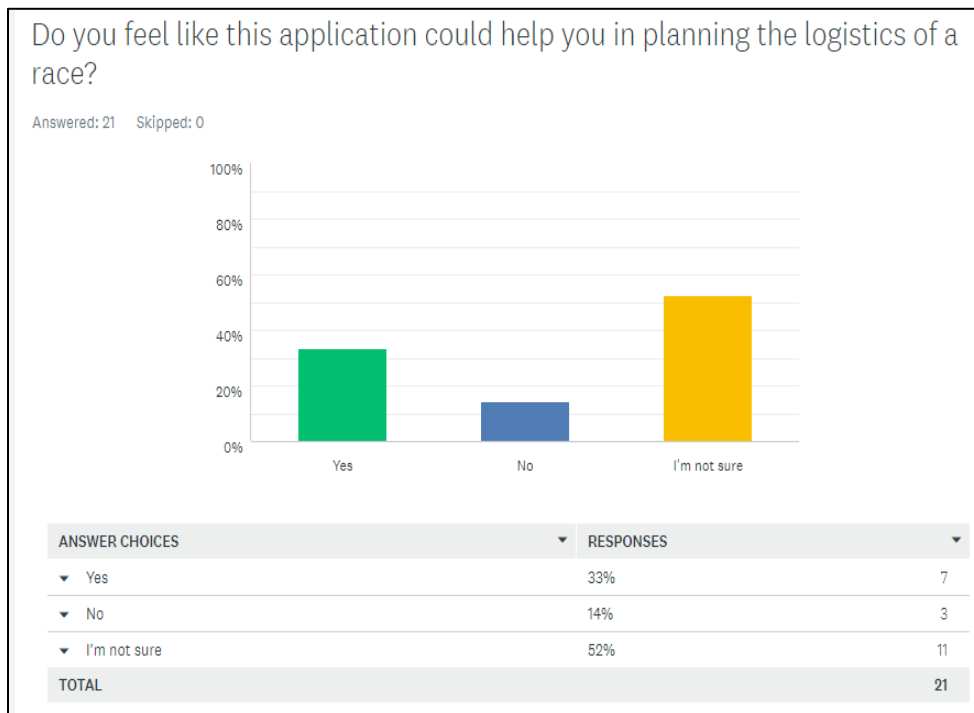


Figure 56 – Runner’s Survey Question 7

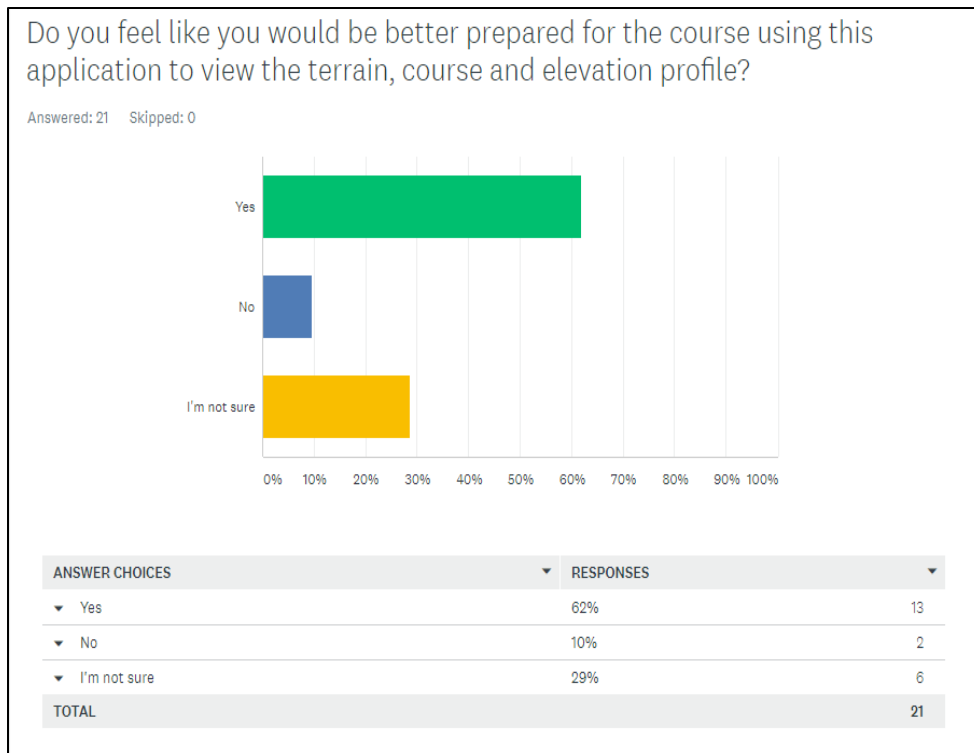


Figure 57 – Runner’s Survey Question 8

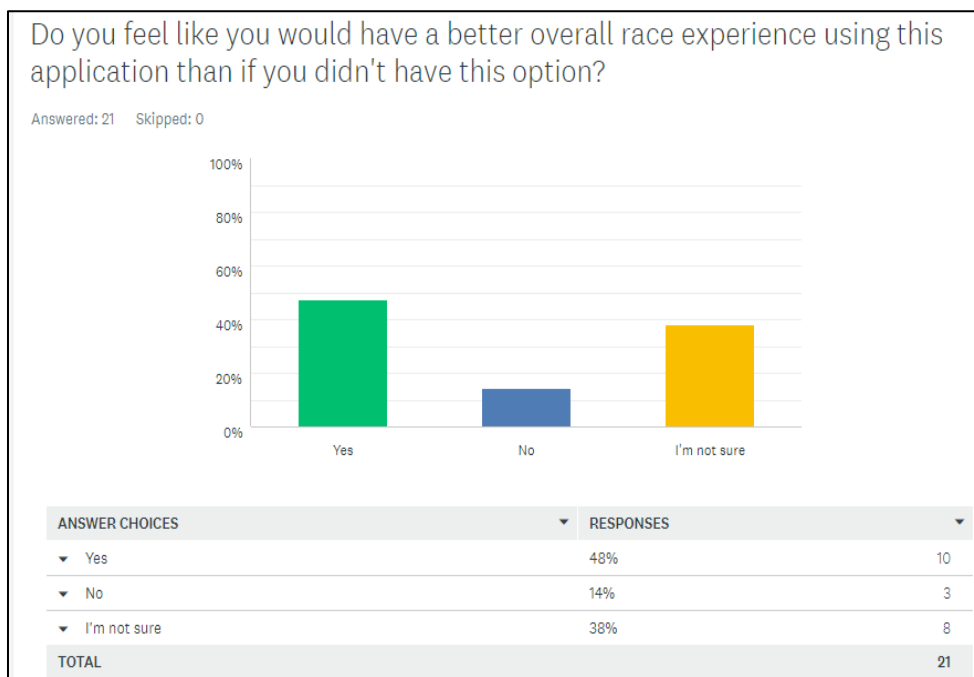


Figure 58 – Runner’s Survey Question 9



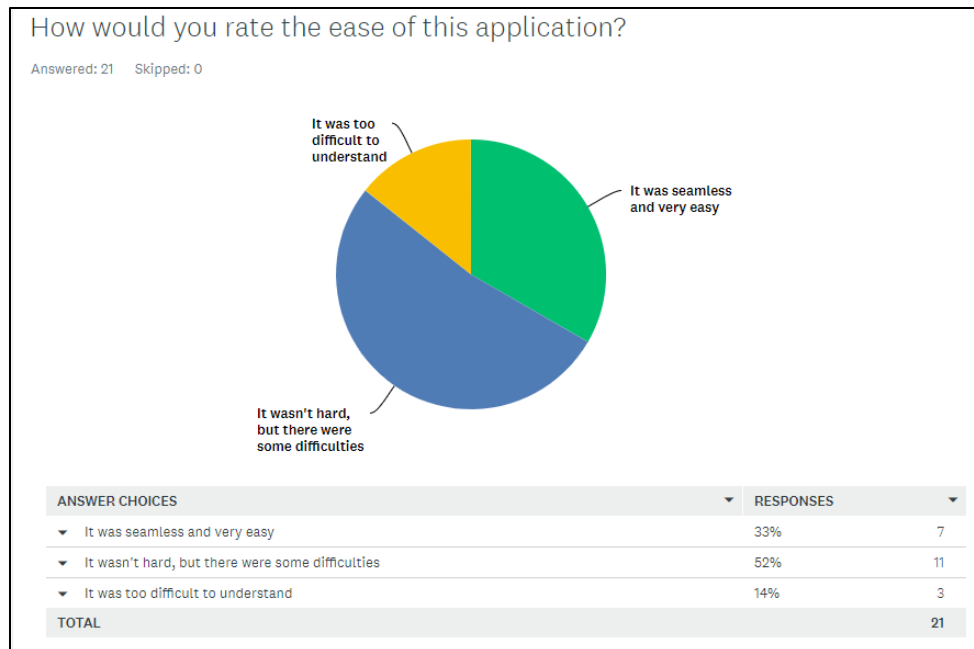


Figure 59 – Runner’s Survey Question 10

The survey results suggest the Web GIS application is beneficial overall but needs further development to increase effectiveness. An analysis of the survey is discussed in section 5.3. Analysis of Runner’s Survey.

## Chapter 5 Conclusions and Discussions

A Web application offering marathon runners a resource to optimize the race experience is a practical and efficient method for a runner’s planning process. Generally speaking, the focus in the preparation for a marathon is on the physical training involved. A Web GIS application that gives runners the ability to select a race based on personal goals, view and analyze race details, study the course and terrain interactively, and view nearby lodging and dining options helps minimize stressful components of a marathon and allow them to focus on the physical challenge ahead of them. Studying the course and managing the organizational aspect could perhaps even enhance the performance for the runner. Analyzing the challenges encountered

while developing the application and resolution process benefits web developers and GIS professionals in future Web GIS development. Examining the results of the runner's survey lends to further understanding runner's needs, as well as evaluating the success of the project. Finally, a look at the future of emerging technologies, especially in the field of geospatial science and web application development will help guide the direction for the future of the Web GIS application developed for this thesis.

## **5.1. Web GIS application Development Challenges**

The challenges encountered while developing the Web GIS application for this thesis were instrumental in producing a viable product not just for the running community, but in providing guidance to database and web application developers. The evolution of constantly changing technology, especially in the arena of geospatial technology, plagues the field and documentation of methodology in the process of developing a Web GIS application aids in future development. Following sections include challenges and limitations in various components that resulted in modifications and revisions to the application.

### *5.1.1. Google Maps Limited Allowance*

The initial intention of the project was to incorporate all the elements of the race planning process into one map, offering multiple layers for the user to select for each component. Unfortunately, creating Google Maps using Google My Maps only allows 10 layers per map and 2000 points. This limitation prevented a one map option for the application. The solution was to create four separate pages for the application so the user could navigate each component separately. Ultimately, it was a more seamless and cleaner approach for the user.

### *5.1.2. Google Earth Embedding Limitations*

Adding a three dimensional element to the project was a key component in the planning process for runners. After researching numerous 3D technologies as previously explained in the literary review, Google Earth Pro for desktop was selected to display the courses and terrain. As explained by Geology.com, “Google Earth is a free program from Google that allows you to "fly" over a virtual globe and view the Earth through high-resolution graphics and satellite images. It is greatly superior to static maps and satellite images.”

Once the KML files for the race courses were created and uploaded to Google Earth, the developer discovered that the ability to embed Google Earth project using the embed KML gadget was deprecated in December 2015. To resolve this issue, the KML files were uploaded to Google Drive and the privacy setting was set as available to the public. The KML files were then imported into the newly developed Google Earth Web Version. The only requirement for this service is Google Chrome. Although the service is not as sophisticated as Google Earth Pro for desktop, it met the needs of the project providing an application available on any device.

### *5.1.3. Creation of Application in Established Website during the Development Process*

One of the most valuable elements of the Web GIS application developed for this thesis offers runners the ability to locate a race based on their unique selected criteria. At the time of the development of the database and web application, no such application existed in the running community, at least none discovered in the research process. Over a year later, during the literature review for the thesis, it was discovered that a similar application had been developed, offering a very similar approach to finding a race. While this was disappointing, as the project initially offered a novel approach, ultimately any resource that helps runners in their journey is good for the community. Ultimately, as documented previously in this thesis, the Web GIS

application still offered a unique approach to the planning process by providing much more functionality such as 3D interactive capability, dynamic elevations and a geospatial view of dining and lodging options close to the start and finish line.

## **5.2. Analysis of Runner's Survey**

The survey conducted contained three primary topics: the demographics of the runners, the motivation for running a race and an evaluation of the Web GIS application. The results of the survey are illustrated in Section 4.

### *5.2.1. Demographics*

Questions 1 and 2 were demographic based (what is your age and how many marathons have you run). The results revealed the majority of runners at 38% were between the ages of 45-54. The number of marathons completed by the runners was divided but the majority was split at 38% each between those who ran 1-5 and those who ran 6-10 marathons with the remaining 24% who ran over 10.

### *5.2.2. Motivation of Users*

This section of the survey was very significant in its illustration of the diverse goals of runners. While the greatest percentage was 29% who are looking for their best time, the goals were very divided, with 24% looking for a destination race, 19% looking for a unique course, 14% looking for a race close to home and 14% concentrating on the overall experience. Addressing a runner's unique needs is clearly an important component in the race planning process.

### *5.2.3. Evaluation of Web GIS application*

The majority of the survey was dedicated to evaluating the success of the Web GIS application. While the majority of survey-takers believed the application offered a unique approach (71%) and feel like the application would help find a race based on personal needs (57%), the majority of participants (52%) were not sure it would help them plan for the logistics of a race. A significant majority (62%) agreed that using the application would help them prepare for the course based on viewing the terrain, course and elevation profile. While more survey-takers felt they would have a better overall race experience at 48%, there is concern that the other 52% were not sure (38%) or did not feel like they would benefit (14%). Finally, the majority of survey-takers (52%), felt that the Web GIS application was not hard to use but did find some difficulty with it.

Overall, these results indicate that the Web GIS application is a unique approach and beneficial for runners in selecting and planning for a marathon, however future work needs to be done on the project to make it more valuable in planning the logistics and more seamless and user friendly. Much of the limitation of the application stems from the time constraint and knowledge base of the developer. Future development to the application will address the shortcomings and with continuous feedback from runners, the application will be designed to directly meet and hopefully exceed their needs.

## **5.3. Future of GIS Technology**

According to ESRI (2017), trends for GIS technology in 2018 include web services for data, cloud infrastructure for enterprise systems, apps instead of applications, mobile GIS and GIS in 3D. These trends will assist web-developers, and more specifically, the Web GIS application designed for this paper by allowing nearly unlimited data storage, a more web-based

application system accessible on any device instead of desktop applications, a richer and more navigable 3D option, and the ability for a runner to collect their own data to plot a course using mobile GIS (2017).

## 5.4. Future of Web GIS application

Evaluating the challenges of the project, runner's motivations, the runner's survey results, the future of GIS technology, and the progress of other running-based web applications bring forward an enlightened and optimistic perspective of the future development of the Web GIS application.

### 5.4.1. Updated Runner's Survey

While the runner's survey was useful in analyzing the success of the application, it needs to be improved for better evaluation from the users. A new survey has been developed and is going to be distributed (see Figure 60). The new survey was developed using Google Forms, a more manageable format than Survey Monkey. Questions allow text answers for a more comprehensive response from users. There will be a financial incentive offered to users to solicit a greater response, and thus more accurate evaluation.

Friends/Family

Other

If you use other websites/apps what sites or apps do you use?

Short answer text

...

Does this application offer a unique approach to the marathon selection and planning process?

Yes

No

If you answered yes to the above question, what do you find unique about this application?

Short answer text

Figure 60 – New Google Forms Survey (screen shot)

#### 5.4.2. Add Data – Races, Race Criteria, Race Types, and Training Courses

Because the development of this Web GIS application was to provide a template for other web-GIS developers and study the benefits of such an application, the current database is very limited. Future development includes adding many more races, as well as other race criteria such as cost of race experience, elevation loss/gain, charity races, etc.

In addition, adding other type of races such as half marathons or triathlons would benefit other athletic factions. An alternative option would also be to create other Web GIS applications using the template created for this application for each race type separately.

Spatial analysis could aid in locating terrain locally that closely resembles the race course, allowing for better training. *Runner's World* author Scott Douglas recommends

“mimicking the course” in his article “26 Tips for Running Your Best 26.2.” Douglas states,

If at all possible, start doing runs on the same topography as the marathon. For example, go up and down lots of hills if you're running New York City, and get used to several hours of pancake flatness if you're running a course like Chicago. A flat course might seem less challenging, but its lack of variation means you'll be using the same muscles the whole race. You need to prepare for this (Douglas 2016).

The current status of the Web GIS application offers 3D interactive functionality which allows the advantage of studying the course and terrain, but the ability for runners to use the application to create their own training course will add a whole new level of functionality for the user.

On the Navigate Race page, a section could be added for runners to create their own training courses (see section 5.5.4. Allow Crowdsourcing Data). Using predictive analytics, the developer will incorporate machine learning to model the terrain of the race course in order to



locate similar local terrain for the runners and use that data to create training courses that will most closely resemble the race course. This will be the next best option to running the course itself to prepare for the race.

#### *5.4.3. Enhance Overall Application*

Based on the results of the survey, it is evident that the application needs to be enhanced to allow a better option for searching for logistics, as well as streamlining the site overall for ease of use. Considering the trends for this year, technology improvements should help both the developer and the output for the user.

#### *5.4.4. Allow Crowdsourcing Data*

There is perhaps no better addition to the Web GIS application than to offer a more interactive approach to the application. Allowing a user to input their own data into the application will offer a much richer and more dynamic experience. This option was not added due to time constraints and the developer's knowledge base. Users will be able to add races, offer input and feedback regarding the quality of the app and request changes or additions.

Running a marathon is an astounding accomplishment. As Olympic marathon winner Emil Zatopek said, "If you want to run, run a mile. If you want to experience a different life, run a marathon." With the aid of geospatial, web and mobile technology, the experience can be more memorable and successful than ever.

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