Improving Maintenance Efficiency in Kelowna Parks using a Mobile Application

by

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Abstract

Water is our world's most valuable resource, and the sustainable management of that resource is increasingly important with human population growth increasing the demand for water and climate change affecting its availability. While research efforts for irrigation sustainability have been successful, they have traditionally focused on reducing water usage through automation and optimization, and have primarily targeted agricultural and residential water users. Limited research has been done for municipalities, which use large amounts of water to irrigate parks, sports fields, and other recreation areas. Irrigation sustainability for city parks requires more than just efficient water usage; it needs continual maintenance of equipment, consideration of soil, vegetation, landscape, and climate at the parks, and a commitment from the irrigation technicians who maintain the parks.

Advances in mobile technology provide new opportunities to support irrigation technicians with the management and maintenance of city parks. This thesis describes a mobile-friendly web application, the irrigation management application, which was developed to provide irrigation technicians with information on the parks they maintain and aid with maintenance activities out in the parks. A case study was performed with the Kelowna Parks Services department to evaluate the effectiveness of the application using a hybrid approach of questionnaires and scenario-based testing of maintenance activities. The results showed that irrigation technicians unfamiliar with particular parks were able to complete maintenance activities faster when using the irrigation management application than those without; in addition, they performed on par with, and in many cases better than, technicians with years of familiarity of those parks.

The irrigation management application allowed irrigation technicians to be more efficient with their time and resources at the parks, and simplified decisions regarding park irrigation and practices. The City of Kelowna Parks Services department was enthusiastic about using the irrigation management application in the future.

Preface

The study in this thesis was conducted with the approval of the UBC Okanagan Behavioural Research Ethics Board (BREB) under the certificate number H13-03194.

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Dedication

For my family and friends; thank you for all of the love and support.

Chapter 1

Introduction

Water is our world's most valuable resource. Population growth and climate change are putting an increased demand on our water resources, making sustainable management of those resources incredibly important. This is particularly so for municipalities, where large amounts of water are used for the irrigation of city parks, sports fields, golf courses, and other recreation areas. While there has been significant research efforts made towards improving irrigation sustainability, most of those efforts have been from industry and commercial systems [Rai14, Ind14, Tor14]. As well, much of the research has traditionally focused on agriculture and residential water users; there has been very little research done with regards to municipal water users and city parks.

Parks and other green spaces are an important component of cities, as they are used for recreation, sporting events, outdoor activities, and entertainment venues. The turf grass and trees in parks have been shown to remove carbon dioxide from the atmosphere, filter air pollution, reduce air borne dust, capture organic chemical pollutants, and condition the soil [Car06]. Additionally, green spaces in cities have been shown to offer significant cooling effects by reducing the surface air temperatures of adjacent buildings [Car06] and contribute to overall energy savings of nearby buildings and homes [JB85, BG94]. Finally, parks and green areas in cities are known to improve the health and quality of residents and make metropolitan areas more attractive to residents and tourists [OEC14].

Most cities use commercial irrigation systems for watering their civic parks, and there have been efforts to improve the irrigation at parks through the use of automated control systems [FCTL12, ZBZ07]. However, these projects have focused primarily on automating and reducing water usage in the irrigated areas. Irrigation sustainability for city parks involves more than just efficient water usage; it requires the proper maintenance of the equipment and layout of the irrigation system at each park, consideration of the soil composition, climate, plants, and landscape at the parks, and most importantly, a commitment from the people who manage and maintain those parks. Maintenance of city parks is an endless endeavour, and irrigation employees are the front line for any changes and improvements in the sustainability and efficiency of the irrigation in city parks.

In the City of Kelowna, located in the central interior of British Columbia in the Okanagan Valley, the Parks Services department is responsible for maintaining over 300 unique irrigation sites, which includes city parks. With a small but dedicated staff of only six full-time irrigation technicians to maintain these irrigation sites each year, the sustainable management of these city parks is a daunting task. While irrigation technicians can eventually become very knowledgeable about the parks they are responsible for maintaining, including the layout of equipment and any irregularities such as a recurring wet or dry areas, they usually know little to nothing about those parks when they are first hired and very little about any parks outside the ones they regularly maintain. Since each park is different in terms of layout and landscape, it can take years for the irrigation technicians to learn all the ins and outs of their parks.

Advances in mobile and web technology provide new opportunities to aid irrigation employees in managing their resources and improving their irrigation practices at the parks they maintain. An application was developed in collaboration with Kelowna's Parks Services department to provide employees with information about the parks they maintain, including the irrigated areas, historic and expected water usage, and the global positioning system (GPS) locations and layouts of equipment at the parks. The application also features an interactive map allowing for real time positioning of the user in relation to equipment locations, and the ability to create, view, and edit maintenance notes for each park. It is believed that the application will allow irrigation technicians to be more efficient with their time and resources while performing maintenance activities in city parks, and that the application will simplify decisions regarding park irrigation and practices.

This thesis seeks to demonstrate that real time mobile access to park data will improve park maintenance efficiency. The contributions of the thesis are:

- The collection and integration of park and irrigation data, including the GPS locations of equipment at each park in Kelowna
- The development and testing of a mobile application for park maintenance and irrigation management
- And the development and implementation of a user study to evaluate the effectiveness of the application

This thesis describes the irrigation management application that was developed for Kelowna Parks Services, and presents the sustainability and efficiency study that was performed with the irrigation technicians of that department. Chapter 2 provides an overview of current water use and irrigation, research on existing irrigation solutions, advances in mobile technology, and usability concerns. Chapter 3 describes the irrigation management application that was developed. The sustainability and efficiency study performed with Kelowna's Parks Services department is presented in Chapter 4, and an analysis of the results of that study is discussed in Chapter 5. Finally, Chapter 6 provides conclusions and recommendations for future work.

Chapter 2

Background

This chapter covers the motivating factors and background research which have contributed to this thesis. The first section focuses on irrigation, including water use, irrigation management, and research into irrigation management software, applications, and projects. The second section discusses mobile technology, including the opportunities and challenges that it presents and some research projects which have used mobile technology to aid employees out in the field. The next section presents usability concerns, including development and testing of applications for mobile devices. Finally, the last section discusses the Parks Services department of the City of Kelowna.

2.1 Irrigation

It is estimated that over the last century, the growth in global water demand has been more than double the rate of global population growth [OEC14]. With world population levels expected to exceed 9 billion by the year 2050 [OEC14], the demands for water are only going to continue to increase. As such, it is increasingly important to develop and implement sustainable management and usage practices for our water resources. Worldwide, agriculture is the biggest water user, with irrigation accounting for 70% of global fresh water usage [UNWWAP14]. Industry and municipalities make up the remaining 30% of global fresh water usage, typically described as 10% and 20% respectively [UNWWAP14, Rai03].

2.1.1 Automated Control Systems

As agricultural irrigation accounts for the vast majority of fresh water use worldwide, it should come as no surprise that the majority of research and development on irrigation management and sustainability has focused on agriculture. There is a large selection of commercial irrigation systems available providing a variety of different technologies and solutions, with the three biggest names in the industry being Toro [Tor14], RainBird [Rai14], and Hunter Industries [Ind14]. These companies offer several products and technologies for irrigation management, including simple automated irrigation timers and more sophisticated irrigation controllers. Many of these controllers calculate optimal watering time requirements based on local weather conditions and evapotranspiration (ET), which is the expected water loss as a result of evaporation and transpiration from the plants, and automate the irrigation. Other controllers make use of sensor-based shut-off systems that use rainfall sensors or soil moisture sensors to apply water only as needed. These companies also offer wireless, centrally controlled irrigation systems to handle irrigation over large areas. However, these commercial systems often have issues in regards to deployment, expensive costs, tuning for optimal water usage, interoperability with other systems, and maintenance.

There has also been an extensive amount of work on agricultural irrigation systems [ABR+12, GVMNGPG14, KF13] from a research perspective. In [KF13], the authors describe an irrigation control system using a commercial irrigation controller and control software that they developed which calculates the watering requirements and optimal watering times based on meteorological data collected from a weather station. The meteorological data included barometric pressure, dew point, temperature, solar radiation, wind speed and direction, and rainfall amounts. They wanted to know if there would be any advantages to irrigation at certain times of the day, with an overall goal of preventing water loss due to evaporation when temperatures are high. They found that evaporation becomes a significant factor of water loss during daylight hours and that soil moisture levels peaked late at night into early morning. The authors determined that approximately 20% savings in water and 24% savings in energy could be achieved by running the irrigation at night instead of during the day.

In [ABR+12], the authors present a theoretical automated irrigation system for Boro rice cultivation. They suggest using a combination of soil moisture and water level sensors to determine watering requirements and availability, digital circuitry to control the irrigation and redundant water sources, and a control unit that would use short message service (SMS) to monitor the entire system. The control unit would automate the irrigation based on the readings from the soil and water sensors, and automatically alert managers of any failures in the system using the short message service.

Finally, in [GVMNGPG14], the authors developed an automated irrigation system using a sensor network to determine watering requirements for agricultural irrigation. The system consisted of a distributed wireless network of temperature and soil moisture sensors in the field, and a controller unit that automated the irrigation and controlled the amount of water used based on those sensor readings as well as predetermined threshold values of temperature and soil moisture. The authors also implemented a basic web page that allowed users to view the collected data and program the irrigation scheduling. Their goal was to optimize water use for irrigating agricultural crops. The automated system and sensor network were tested in a greenhouse for organic sage production, and they were able to achieve a nearly 90% savings in water usage compared to the traditional irrigation practices at the farm. The system was also tested at three additional nearby locations, with an approximately 60% savings during those trials.

There have been some research efforts that specifically target municipal irrigation in city parks and green spaces [FCTL12, ZBZ07]. In [FCTL12], the authors described an adaptive irrigation control system for city parks that uses wireless soil moisture sensors to measure water content in the soil and dynamically calculate the watering requirements for the turf grass based on those readings. The adaptive irrigation controller connects to existing commercial irrigation systems and automatically applies the appropriate amount of water as needed, without any human intervention after initial set up. The motivation for this project was that a significant portion of municipal water is used for irrigation, particularly city parks during summer months. The goal of the project was to see if significant water savings could be achieved by deploying the adaptive irrigation controller in a city park, in comparison to the water usage of the existing irrigation system. The system was set up in a park in the City of Kelowna and several moisture sensor nodes were installed at the park. The sensor nodes communicated wirelessly to the adaptive controller that was connected to the existing irrigation controller at the park, which had the ability to override the watering events based on calculations made from the sensor readings. The adaptive controller also sent all collected data wirelessly to a server, where the information was stored in a database. The status of each part of the system was monitored and analyzed, and the collected readings were displayed on a website interface. The system ran in two phases during the summer. The first phase was to monitor the existing watering patterns of the commercial irrigation controller and compare it against the readings from the soil moisture sensors. The second phase had the adaptive irrigation controller in full control of the amount of water being used based on the real-time sensor readings. The volume of water used by the adaptive irrigation system was compared to the existing watering trends at the park, and both of those were compared against the expected water usage based on weather models. The usage for the existing watering trends closely matched the expected usage for the park; however, the amount of water used by the adaptive system was significantly lower than both those values. The adaptive irrigation system reduced water usage by 50% over a two-month period, which resulted in 210,000 litres of water being saved at the park, and these savings were achieved without notable impact or stress to the turf grass. While the water savings from the adaptive irrigation system were great, one significant issue was the cost of installation and maintenance of the system. These maintenance costs were larger than the cost of water, which resulted in the system being infeasible as a long-term solution for irrigation at the park.

In [ZBZ07], the authors describe an automated irrigation system that calculates and applies water to green spaces. Soil moisture sensors are used to monitor water levels in the green space, and an irrigation controller calculates the watering requirements based on preset thresholds and the readings from the sensors. The controller automatically turns on the irrigation when soil moisture levels reach the minimum threshold and turns off when the maximum threshold is reached. The authors tested the system in a green space located on the campus of Beijing Forestry University for six months. The system successfully applied only the amount of water required at the green space as measured by the soil moisture sensors for the duration of the test.

Each of the previously described irrigation systems have shown the ability to reduce and regulate water usage when implemented, with varying levels of automation and human input required; however, these systems fail to account for some of the other important resources that are required for sustainability and efficiency in irrigation systems. The costs of labour, deployment, and maintenance of these systems can often be more significant than the costs of the technology itself, which is discussed in greater detail in the following section.

2.1.2 Decision and Management Support

Irrigation sustainability involves the sensible irrigation of plants to meet current watering needs without endangering the needs of future generations. Irrigation sustainability requires the continual maintenance of irrigation equipment, the proper layout of irrigation zones and sprinkler heads, and consideration for the soil composition, climate, vegetation, and landscape at the irrigation sites. Most importantly, sustainability requires commitment from the people who manage and maintain the irrigation systems. For municipal irrigation of city parks in particular, these people are the irrigation technicians who regularly maintain the parks. They are the front line for any improvements in efficiency and continued sustainability of the irrigation systems within city parks. For irrigation technicians to make sustainable decisions in regards to the irrigation practices in city parks, they need to have the resources available to make those decisions. As described in the United Nations Water Report for 2014, "lack of data puts water resources management at a political disadvantage in terms of priority decision-making" [UNWWAP14]. This is particularly true for municipalities, where they need to justify their budget spending for city park maintenance each year.

One of the most common tools used to aid in the management and decision making of water and irrigation resources is geographic information systems (GIS). GIS is defined as technology that combines databases, maps, and modelling tools to allow users to query, analyze, visualize, and interpret data to understand any relationships, patterns, or trends within those data [Esr14a]. The ArcGIS software by Esri [Esr14b] is one of the most popular commercial GIS products, although there are several free and open source alternatives such as GRASS GIS [GIS14] and QGIS [QGI14]. The core strengths of GIS are their geographic analysis and spatial modelling tools that allow for powerful calculations to be performed on data, such as the data often associated with water use and irrigation. Most GIS software has traditionally been limited to desktop computers, since they require a lot of processing power to operate, but this is changing with advances in mobile technology and cloud computing. GIS can be a valuable tool to aid in the decision making aspects of irrigation practices.

There have been some research efforts that have used GIS to aid in the management of irrigation [ZXY09, AJS+12, TS03]. In [ZXY09], the authors developed a decision support system application to aid in the decision making and management of irrigation resources for optimal agricultural water use in arid regions. The motivation for this application was that increases in the salt content of soil in arid areas as a result of improper or inappropriate irrigation practices are a leading cause of desertification. Desertification is the process of fertile land losing its vegetation and transforming into a desert. The goal of the decision support system was to support analysts, planners, and managers in the decision making of their irrigation resources to mitigate those issues. The decision support system application was developed using GIS software and software from the United States Geological Survey (USGS) called MODFLOW [USG14] which is used for modelling, simulating, and predicting ground water and surface water interactions. The decision support system application contained a database of relevant information for climate, soil, land use, and irrigation, models for ground water flow and calculating water storage, and an interface for planning, evaluating, calculating, and visualizing the information. The authors performed a case study in the Yutian Oasis in southern Xinjiang, China using their decision support system. The system was useful for the organization and management of soil data mapped to areas throughout the oasis, hydrologic and ground water quality data, climate data, and satellite remote sensing data. It was also useful for calculating the watering requirements for the area, and in particular for decisions involving the different irrigation programs and schedules.

In [AJS+12], the authors developed a tool to aid farmers in estimating the water irrigation requirements for their fields. The application was developed using GIS software called MABIA-Region, which is a regional irrigation evaluation and scheduling tool that had been previously developed. The application uses databases of land use, climate, soil condition, and water allocation conditions to calculate irrigation requirements for each of the farmers. Their goal was to enhance irrigation management and practices for agriculture by computing the irrigation requirements at a field and regional level for irrigation advisors. The authors performed a case study to evaluate the irrigation performance of sixty-three farms in the irrigation district of Cherfech, Tunisia. They found the irrigation practices of the farmers to be seasonally variable. During their winter, water usage far exceeded the estimated watering requirements as calculated by their application, while during the summer water usage was 44% of the calculated irrigation watering requirements. Their study also revealed a high variability in irrigation practices between the different cultures and different farms in the region. This demonstrates the importance of making informed decisions in regards to irrigation practices.

In [TS03], the authors present an irrigation management system to be used by irrigation associates, departments, and institutions. The system uses ArcGIS software to combine information about climate conditions, soil and water system characteristics, irrigation methods, and cropping patterns to estimate irrigation requirements for agricultural land in southern Italy. The goal was to provide an irrigation model and a crop productivity model that could be used to aid farmers in deciding how much water to use when irrigating their crops. Since the application was developed as an extension of the ArcGIS software, it can take advantage of many of the analytical and visualization features of the underlying software.

These research projects, while still targeted towards agriculture instead of municipal irrigation, focus on providing the people who manage those irrigation systems with the resources for making better decisions about their irrigation practices. One of the most obvious disadvantages presented in all of the above research efforts has been that the decision support tools have been limited to desktop applications. While this can be beneficial to managers in the office and aid in overall sustainable irrigation goals, they are of little help with the day-to-day aspects of the irrigation technicians out in the field. This is where advances in mobile technology can be used to aid employees to be more efficient in their irrigation practices while out in the field.

2.2 Mobile Technology

The biggest competitors in the mobile industry are Google's Android smartphones and tablets [And14a], Apple's iPhones and iPads [App14a], Microsoft's Windows smartphones and tablets [Win14], and BlackBerry's smartphones and tablets [Bla14]. Advances in mobile technology and wireless data communication services have made these mobile devices increasingly affordable and more widely available to the public. As well, dramatic improvements in the ability to transmit data have allowed mobile devices to compensate for many of their computational constraints [WD10], resulting in mobile phones and tablets becoming the primary computing devices for a rapidly growing number of users worldwide. Recent estimates have placed the number of worldwide mobile subscriptions to be nearly 7 billion, which is equivalent to about 96% of the world population [Uni14]. However, as many people own and use multiple mobile devices, the actual number of mobile users is smaller but still significant at 4.6 billion, which is approximately 65% of the world population [Eri14]. Mobile technology is becoming increasingly integrated into our society, and many of the unique features of mobile devices present new opportunities in aiding the sustainable management of city parks and green spaces.

2.2.1 Features, Constraints, and Considerations

Some of the unique features of mobile technology include their portability, location and spatial awareness, built-in cameras, touch screen interfaces, and remote data access. Many mobile devices are small, thin, and lightweight, making them easy to carry and hold. This portability allows smart phones and tablets to be used in places where other more cumbersome devices cannot. As well, most smart phones and tablets have a global positioning system (GPS) built into the devices, which allows for satellite navigation for the user, and dynamic maps to display the user's location in relation to nearby places of interest. An internal gyroscope also allows the devices to respond to changes in travel speed, direction, and orientation. Additionally, built-in cameras allow for pictures and video to be recorded easily, and touch screen technology allows for new ways for users to interact with the interfaces of the devices. Finally, mobile devices with data services allow for near instantaneous access to and sharing of information at the touch of our fingers.

Along with the unique features that mobile devices offer, there are several unique constraints and challenges that must be considered for the development of any mobile application. The authors of [WD10], [Chi06], and [PRR03] explore some of these challenges, which include data and network issues, physical device limitations, and user expectations.

The issue of network load and wireless spectrum allocation for data services is discussed in [WD10]. The authors explain that with the increase in the number of mobile devices being used, there has been an increase in data traffic and consumption of wireless bandwidth. Since there is only a finite amount of the wireless spectrum that is usable, telecommunication companies and providers are being stretched to their limits and must focus on improving their data services to meet the increasing demand.

There are several physical constraints that affect mobile devices, as covered in [WD10, Chi06, PRR03]. Almost all of the physical constraints are a result of the size limitations of the devices. To be small, thin, and lightweight for portability, mobile devices must use smaller batteries and less powerful hardware in comparison to larger devices such as desktop or laptop computers. This means there is less memory and computational resources available on the devices, which affects their ability to run more complicated applications or tasks. Other physical constraints include smaller screen sizes, limited screen resolution, limited processing power, and variations in interface input methods such as small keypads or touch screens.

The final and perhaps the most notable challenges are those based on the user expectations of mobile devices and applications, as discussed by [WD10, Chi06]. Users expect that applications on mobile devices will respond to their actions and requests accurately and in a timely manner, such as when taking a photo, using the GPS to navigate, or changing the orientation of the device. They also expect a certain level of interactivity with mobile devices, such as the ability to zoom or scroll when viewing content. Finally, users expect applications to be user friendly.

In addition to these challenges and constraints, there are some other aspects that must be considered for mobile applications. In [PRR03], the authors address some significant factors that should be considered when developing mobile applications. The first is that the way users input information and interact with applications on mobile devices differs significantly from desktops or laptops. There is no standard input method such as the keyboard, mouse, or trackpad. Input mechanisms on mobile devices can include real and virtual keypads, touch screens, and even voice commands, and even these methods can vary greatly between the different models of mobile devices. Several other considerations when developing mobile applications involve the context of use, specifically the auditory environment, the visual environment, and the level of attention. Desktop and laptop computers are often used in controlled environments, whereas many mobile devices are used in settings where the user has limited control of their surroundings. Sound use may be limited if the mobile devices are used in public or outdoor settings, where outside and background noises can prevent the user from hearing the intended sound. For the visual environment, mobile devices may be used in a variety of lighting conditions, ranging from total darkness to bright sunlight. Finally, the level of attention that users can devote to the applications on their mobile devices may be limited due to interruptions from the environment or other activities competing for the user's attention.

2.2.2 Research Applications

There have been some recent research projects utilizing the advances in mobile technology and unique features of mobile devices to aid managers and workers out in the field with decision making and during their regular activities [FXC13, KNYS11, LDK$^+$13]. In [FXC13], the authors present an iPad application that extends a previously developed Road Management System for road maintenance and management in China. Their motivation was that although the Road Management System had been reasonably developed over the past 20 years, further research was required to make the system more applicable and inexpensive for use in daily road maintenance management and decisions. The authors wanted to combine the GIS data processing functions of the existing Road Management System with the mobility, user-friendliness, small-size, multi-function features, and remote transmission capabilities of the iPad. Their goal was to provide managers and field workers with a tool to help them make better decisions and manage the roads better, particularly in the more remote areas of China. The authors developed hardware to sense road conditions out in the field, software to extend the existing GIS functionalities of the Road Management System, and an iPad application to remotely interact with the Road Management System. The authors claim that they were successful in implementing the application to provide real-time road maintenance information for industry management departments.

In [KNYS11], the authors developed a mobile-phone based system for logging field and fruit conditions to aid in high quality Satsuma mandarin production. The motivation is that it has been getting harder to share the specialized agricultural skills needed for Satsuma mandarin production in recent years as the number of household mandarin farmers has declined. Their goal was to see if the cultivation, production, and quality of Satsuma mandarins could be improved by using a mobile phone application to record fruit and field conditions about the crops, and then view that collected data both in and out of the field. Modern information communication technology could be used to aid this, but those technologies are expensive and unaffordable for most farm households. The system used a combination of low-cost measurement tools in the field, a mobile phone application for logging the field and fruit conditions, and a web-based interface for visualizing the data. The mobile application for logging fruit and field conditions was built using Java with a simple interface for manually entering the observed data. The web interface for visualizing the collected data was developed as a Flash application with a time-series graph of conditions and a prototypical advisory system for determining watering needs. Field tests were performed at a Satsuma mandarin farm over a three month period with participation from farm workers and fruit tree researchers. The authors were successful in demonstrating a cost-effective solution for collecting and viewing Satsuma mandarin field and fruit conditions during production by the field workers. A completion survey revealed it was important to store information about the various fruit and field conditions, and in particular, to view that information on a time-series graph. The greatest weakness with this system was the lack of usability and user-friendliness in the mobile application for recording the data in the field. These usability issues were not addressed during the development of the application, which may have a serious impact on whether farmers and field workers will continue to use this system.

Finally, in [LDK$^+$13], the authors developed a decision support system for sustainable irrigation water usage. The system features knowledge integration and machine learning analysis of weather, soil moisture, and water availability data from three environmental sensor databases to calculate suggested daily irrigation watering requirements for farming areas in Australia. The system also features an Android application that provides that information to farmers and agricultural managers. The motivating factor for this project is the lack of reliable surface water for irrigation in many parts of Australia, which means Australian farmers need to determine how much water they think they will need to use for their crops, and purchase it in advance. Despite regular weather data being available to farmers, they typically rely on their experiences and intuition to make their decisions, which may not result in the most efficient management of their water resources. The watering requirement calculations for this system are run on a cloud computing infrastructure, and the results are displayed on the mobile application.

Each of these projects demonstrates how mobile applications can be used to help with maintenance activities and management decisions, particularly for those people who are working in the field. This approach can easily be used by municipalities to aid in the sustainable management of their city parks and green spaces; however, as was discussed earlier, there are many challenges and constraints that must be considered for any mobile development. To address these issues properly, we will need to explore the research into usability concerns and evaluating mobile applications.

2.3 Usability Concerns

Advancements in mobile technology are providing new opportunities to aid and improve maintenance and management practices in the field; however, the usability of these mobile applications must be considered for users to accept them or to be able to use them effectively. Usability can be defined as characteristics of a system that makes it easy to use, which includes factors such as how quickly a task can be performed, how many mistakes are made, and how satisfied the users are when using the system. Usability testing is a means of measuring the quality of the user experience when interacting with a system or application. There has been a significant amount of research into usability and usability testing of computer applications, which is a major component of the field of human computer interaction (HCI). HCI is the 'discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them' [HBC+14]. Some common methods for measuring the usability of applications from HCI include heuristic evaluation, scenario-based testing, and questionnaires [JMWU91, PHVS04, Sim11].

Heuristic evaluation is a technique for finding usability problems by having a small number of experts or trained evaluators scrutinize the user interface or application using a set of relevant heuristics, which are broad guidelines, principles, or rules of thumb for identifying design problems. The results from the evaluators are combined and any problems found are prioritized based on their severity or level of impact on the usability of the application. Scenario-based testing is a technique of having users perform a series of tasks while using the application. The scenario tasks are representative of actual activities, work, and tasks that the users would conceivably perform while using the application. Observations can be made by evaluators while the scenarios are taking place and users can provide feedback during testing and after completion. Scenario-based testing can help developers determine usability issues that would only become apparent with real world use, and can provide insight into how the application is changing the user activities.

Questionnaires are a series of questions that participating users answer to collect information about them such as their demographics, perceptions, views, and interests. They can also be used to gather information on the proficiency and skill level of each user regarding the application being tested (pre-test survey) or provide a comprehensive overview of the application once testing has been completed (post-test survey). One well known questionnaire is the Computer Anxiety Rating Scale (CARS), developed and validated in [HJGK87], which is used to measure the self-efficacy, anxiety, and attitudes of users towards computers and the internet.

As mobile technology has advanced and gained in popularity, HCI and usability research has expanded these techniques for measuring usability, and many others, to investigate the usability of mobile applications. Some of that research is explored in [CSS+04, ERdQSF09, LG04]. In [CSS+04], the authors discuss some of the major design requirements for developing efficient and user-friendly mobile applications. They recognise that mobile applications with a well-designed user interface and high usability are easier to learn and use, will reduce errors and training time, and will allow users to be more productive, competent, and confident in their jobs. The authors identify four guiding principles for a good user interface: simple, aesthetic, productive, and customizable. Simplicity consists of minimizing the number of steps to complete tasks, using symbols or terminology that are obvious and meaningful, and reducing the opportunities for mistakes. Aesthetics refers to the design, which should be visually appealing and follow visual design guidelines such as clarity, consistency, alignment, contrast, and proportions. Productivity refers to the application being task sensitive, reducing work steps to a minimum, and providing convenience features. Finally, customizability refers to allowing the user to set characteristics to suit their preferences and needs. The authors recognize that following these design principles is required to make the mobile application as user-friendly as possible.

In [LG04], the authors discuss general factors for usability testing and considerations for usability testing on mobile devices. As well, the authors suggest a new usability testing method for mobile applications that is based on heuristic evaluation, questionnaires, and a scenario-based testing approach. Five factors for usability testing that the authors describe are: 1. learnability, which states that a system should be fairly easy to learn to use; 2. efficiency, which is that high levels of productivity should be possible when using the system; 3. memorability, that the system should be easy to remember and not require retraining if not used after a period of time; 4. error forgiveness, which states that the system should have minimal errors, allow users to recover from errors easily, and prevent catastrophic errors from occurring; and finally, 5. satisfaction, that the system should be pleasant to use and users will like using it. Some considerations for usability testing on mobile devices that the authors mention include: context awareness, such as geographic location, spatial orientation, time and date, and environmental conditions; user familiarity and comfort with mobile devices; and user perceptions of relevance, appeal, and distraction potential. The authors recommend several steps for implementing their hybrid usability testing method. Those steps include preparing guidelines for the heuristic evaluation, developing prototypes for early testing of the system, creating scenario-based tasks for testing with users, preparing presentations to inform evaluators and participating users, conducting the actual heuristic and scenario tests, and finally, debriefing the participants and evaluators and having them complete any post-test questionnaires.

Similarly, the authors in [ERdQSF09] also suggest a hybrid strategy for testing the usability of mobile applications including standard inspections, user performance measurements, and user inquiries. Standard inspection is a method of determining whether a product, service, material, process, system, or application meets standard requirements. User performance measurements are techniques of monitoring user activities in real time to collect data on the effectiveness and efficiency of a user with the application, much like the scenario-based approach. Finally, user inquiry is a broad method of gathering user subjective satisfaction through the use of questionnaires, think-aloud comments, and unstructured interviews and dialogue. Each of these evaluation techniques provides different information about potential usability problems with the applications, and when combined, they provide a more comprehensive view of the usability of the system.

While there has been a lot of research into the usability considerations and testing approaches for mobile applications, these efforts have rarely been applied towards management and maintenance activities in the field. One example that attempted to use these considerations and testing approaches for the usability of mobile applications in a utility industry setting is presented by the authors of [MDO04].

In [MDO04], the authors investigated the usability requirements for a mobile field data collection application, developed a prototype application for use in the utility industry, and performed a usability evaluation on their prototype. The motivation for this research was that current paper-based systems for collecting field data are often time-consuming, prone to errors, and have difficulties when it comes to sharing that information, particularly with the utility industries for water, roads, and electricity. Their goal was to see if a mobile application could be used as a more efficient means to sharing information among the workers in the field and managers in the office. The authors reviewed several of the usability requirements that have been discussed, and developed a prototype application for collecting Underground Utility Closure (UUC) field data for South Africa's largest telecommunication utility service provider Telkom. They performed usability testing on the prototype mobile application with Telkom employees using a mixture of scenario-based tasks and observations, as well as questionnaires, to gather their data. The authors found that the employees were able to use the prototype quite effectively despite only a short introduction to the application, and that the efficiency of the prototype was comparable to paper sourcing techniques the employees had previously used. The feedback from the employees was great; overall, they were very satisfied with the prototype and enthusiastic about using the mobile application in the field again since the employees believed that it made their work easier and was more efficient than their current practices.

As demonstrated by [MDO04], mobile technology will undoubtedly be used to support management and maintenance employees in the field. The approach used for a mobile solution in the utility industry can easily be adapted and applied to the management and maintenance activities in city parks and green spaces.

2.4 Mobile Development

Another aspect to consider during the development of mobile applications is the debate between native mobile applications and responsive web applications for mobile devices, as each option presents its own advantages and disadvantages. Native mobile applications are developed for particular mobile platforms such as Google's Android smartphones and tablets [And14a] and Apple's iPhones and iPads [App14a] and are installed directly onto the devices. Some of the advantages of native mobile applications include: the ability to operate without an active internet connection; direct access to functions and features of the mobile device such as the camera, GPS, and list of contacts; the ability to incorporate gestures for touch screens; and use of the device's notification system. The biggest disadvantage, however, is that each mobile platform requires its own development tools and process. Android applications use the Android Standard Development Kit (SDK) and are written in the Java programming language [And14b], while Apple applications use the Xcode SDK and are written in the Objective-C programming language [App14b]. If a developer wants to have an application that runs on multiple mobile platforms, they must write separate code-bases and use multiple SDKs for each potential device the application may have to run on.

Web applications, on the other hand, are websites on the internet that mimic the look and feel of native applications, and are accessible through the web browser on the mobile devices. They are typically written with web programming languages such as PHP and JavaScript [PHP14, Net14b], use formatting languages such as HTML5 and CSS [Net14a, (W314], and are 'installed' onto mobile devices by creating a bookmark to the website on the home screen. The biggest advantage is that the developers can create a single web application and automatically have it run across many different devices, making it easier and more manageable in terms of improving existing features, implementing new functionality, and maintaining the code for the application. As well, data can be stored on-line in a database such as MySQL [Ora14] and any calculations or other functionalities can be performed server-side, which reduces the amount of memory, storage, and processing power the application requires from the device itself. The disadvantages of web applications are that they require an active internet connection, and they rely on the browser to support the web technologies used by the application. Many older browsers do not fully support the features and functionality of HTML5 and JavaScript. Nonetheless, advances in mobile technology and the capabilities of modern web browsers makes web applications a more feasible option than previous technology allowed. For example, the HTML5 Geolocation API now allows web applications to request GPS information from the mobile device directly, whereas previously only native device-based applications had that capability.

Of course, with enough resources a developer could feasibly create both web and native device versions of their mobile applications if they felt it was necessary and appropriate to do so. Ultimately, the decision to develop either a web application or a native device application depends on the needs of the users, the goals of the developers, and the intended purpose of the application.

2.5 Kelowna Parks Services

Canada has consistently ranked as one of the world's largest consumers of fresh water, with a per capita water use of 1150 m^3, which is much higher than many other industrialized nations [OEC14, Can11]. The City of Kelowna, located in the central interior of British Columbia's Okanagan Valley, has ranked among the highest water users within Canada itself for several years [oK10]. This is particularly alarming since the Okanagan Valley is a semi-arid region with low annual rainfall. While efforts have been made to significantly reduce residential water use in the city [oK10], a considerable amount of water is still used for irrigation, particularly for city parks and green spaces. Approximately 20% of peak summer time water usage can be directly attributed to park irrigation [Won08].

The City of Kelowna Park Services department maintains over 300 unique irrigation sites. The majority of these sites, comprising approximately 200 irrigated spaces, are city parks, green spaces, beach accesses, and sports fields. The remaining irrigation sites include cul-de-sacs, road medians, boulevards, and other irrigated features. The irrigation systems typically run from mid-April through the summer months until the end of September when the systems are shut down for the winter.

The Parks Services department includes six full-time employees, whose responsibilities include the management and maintenance of irrigation equipment in city parks. These employees have become very knowledgeable about the parks they regularly maintain. They know all the ins and outs of their parks, including layout of irrigation zones and equipment, the different types of equipment that works best for various landscapes and plants, any trends in usage over the course of the summer, whether the park has been requiring more water than historic or expected usage, and irregularities such as recurring wet or dry areas in the parks. However, since each employee can be responsible for up to 80 individual irrigation sites, it takes a significant amount of time for them to become knowledgeable and familiar with each of the parks they maintain, and they often know very little when it comes to the other parks outside of their regular responsibilities.

Irrigation technicians may be able to visit up to 20 parks during their work day to perform the minimum routine maintenance activities required. However, if greater maintenance is required for a specific park, then they may only be able to visit that single park during a day, or they may have to spend several days at that park until the problems have been resolved. Some of the tasks that irrigation technicians commonly perform at city parks, as determined through the course of this research, include:

– Locating major pieces of equipment and irrigation lines

– Identifying any problems or malfunctions with the irrigation system

– Repairing or replacing damaged and worn-out equipment

– Determining watering requirements for turf and plants

– And ensuring new installations have minimal impact on equipment

Another challenge the Parks Services department often faces is a high turn-over rate of new employees in their department. Employees will work a year or two maintaining the irrigation systems in city parks and then move on to other jobs or departments in the city. These new employees spend a significant portion of their time learning about each park they are responsible for, particularly during the first few months. As well, due to this frequent transition of new employees and steep learning curve, years can go by before fundamental issues at a park are actually identified and properly addressed, such as modifying the irrigation zone layout at a park to provide better coverage and reduce unnecessary water waste.

Despite these challenges, the City of Kelowna and the Parks Services department are committed to sustainability in city parks [oK10, Can13, Wis14]. They have taken several approaches to use their water resources more efficiently, including the addition of flow meters to measure water consumption, and local weather stations to aid in calculating expected water usage requirements. As well, they have participated with previous research efforts in reducing water usage in city parks [FCTL12].

2.6 Summary

From an irrigation management perspective, sustainability and efficiency in city parks is concerned with how to best manage all of the different resources for all of their parks. This includes the time and labour of the employees in the field, the type and layout of equipment used in the parks, and of course, efficient water usage. Advances in mobile technology provide new opportunities for supporting management decisions, which will contribute to sustainable resource management, and will help with maintenance processes in the field. The increasing popularity and widespread use of mobile devices means that they will no doubt play a crucial role in the maintenance and management of irrigation resources in agriculture, industry, and municipalities.

The usability of these mobile applications must be considered for these applications to be accepted or used effectively by users. Research efforts have suggested using a hybrid method that combines the aspects of different usability testing methods to most effectively ensure the usability of any developed mobile application. A usable mobile device may offer many benefits for city park maintenance and irrigation management. For the irrigation technicians of the Kelowna Parks Services department, this would mean real time access to irrigation data and park information on the parks they maintain.

Chapter 3

Irrigation Management Application

I developed a mobile application in collaboration with the Kelowna Parks Services department to provide employees with information about the parks in the City of Kelowna. This information includes the irrigated and total areas of individual parks, categories and organizational classifications of each park, as well as the historic, current, and expected water usage. The application also includes descriptions, locations, and layout of irrigation equipment in the field and features an interactive map that allows for real time Global Positioning System (GPS) navigation that positions the user in the park in relation to displayed equipment locations. Additionally, the application allows the user to create, view, and edit maintenance notes for each park using text and images.

3.1 Development

The irrigation management application was developed using an Agile software development method involving frequent user contact and feedback. Monthly meetings with Kelowna Parks Services managers and supervisors were used to demonstrate the application throughout the development stages to receive feedback on the features, functionality, and appearance of the application, and to ensure the usability of the system. As well, irrigation technicians were provided a couple of opportunities to request features and provide feedback on the appearance of the application, but were otherwise not involved in the development process. The irrigation management application was developed as a web application using PHP and JavaScript, and uses Bootstrap [Boo14], a popular HTML, CSS, and JS framework for a responsive layout on mobile devices. All information and data is stored in a MySQL database on a secure server. While the layout of the application was optimized for the Apple iPad, the application works well on desktop computers and internet-capable mobile devices.

The decision to develop a web application instead of a native device application resulted from the intention of the Parks Services department to use the irrigation management application on two different platforms: desktop computers in the office and cellular-network enabled iPads in the parks. For this research effort, the development of a single web application that automatically runs across many different computers and mobile devices was a more feasible option than developing separate native device applications for each platform. If this application had been developed by a larger company with more developers, then it would have been feasible to create separate native device-based applications. Additionally, if the Kelowna Parks Services department decides to use different technology in the future, such as Android tablets or BlackBerry smartphones instead of iPads, then they can continue to use this application on the new devices immediately without any additional development or changes to ensure compatibility.

All of the park information and irrigation data were collected and integrated into the irrigation management application. The current, historic, and expected water usage for parks with irrigation meters was provided by Kelowna Parks Services managers, as was other details for each park such as address, irrigated area, category classification, and water supplier. The park boundaries were retrieved from the City of Kelowna Open Data Catalogue [oK14]. The GPS locations of equipment in several Kelowna city parks were initially collected by myself and a Kelowna Parks Services employee during the summer of 2013, and the GPS data for the remaining parks was collected by the Kelowna Parks Services department during the summer of 2014. The GPS data were collected using a professional Global Navigation Satellite System (GNSS) handheld computer, the Trimble Geo 7 series, and the equipment locations were uploaded to the irrigation management application through the administrative panel of the application.

3.2 Architecture

An overview of the architecture for the irrigation management application is shown in Figure 3.1. The web application runs and is hosted on an Apache web server, and the park information and irrigation data is stored in a MySQL database on that server. When a user logs into the irrigation management application, data are retrieved from the database and displayed to the user. The irrigation management application uses a responsive layout to adapt to the screen size of the device for each user.

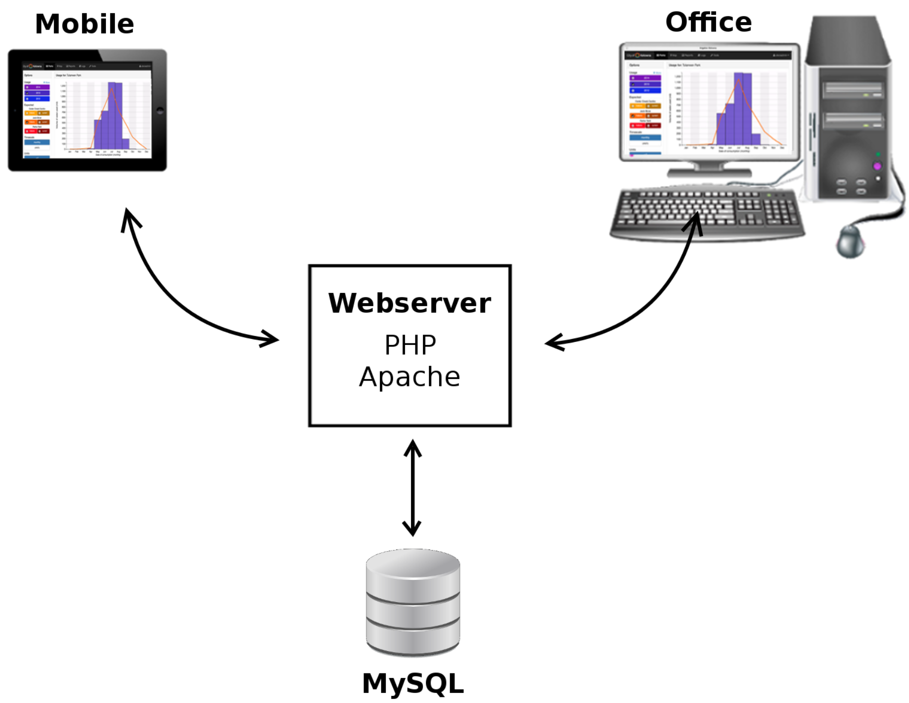


Figure 3.1: Architecture diagram for the irrigation management application showing the web application on two different platforms, one on a desktop computer in the office and the other on a mobile iPad.

3.3 Features

The irrigation management application possesses a number of features and functions to aid in the management and maintenance of the irrigation systems in city parks, which are described below.

3.3.1 Sign In

For any user to access the application, they must enter their username and password into the secure sign in screen, as shown in Figure 3.2. Any attempts to bypass the secure login, or entering of the wrong information, will redirect the user back to the sign in screen with a notification of the incomplete login.

Figure 3.2: Secure login screen for the irrigation management application.

3.3.2 Park Listing

Once signed in, the first thing the user sees is the main listing of all parks currently in the database (Figure 3.3). The list provides an overview of details on each park such as the name, location, irrigated area, category of park, and last recorded visit by a user. All of the columns of the list are sortable by clicking on the title at the top of each column.

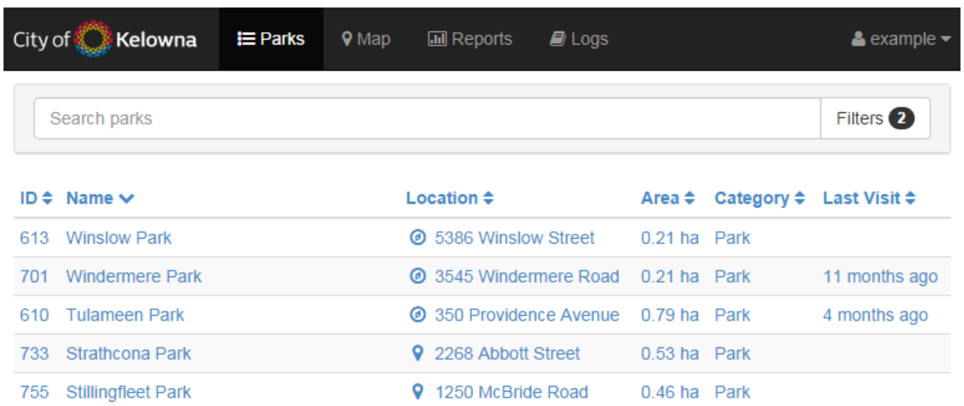


Figure 3.3: Screenshot of the list of Kelowna parks with 2 filters applied.

At the top of the list is the search and filters tool bar where the user can search for any park based on its name. As indicated by the arrow in Figure 3.4, the filters button shows how many filters are currently being applied to the list, and when the button is clicked, it toggles a panel where the user can filter the list of parks based on the water supplier, the sector the park resides in, and the park category. One usability improvement suggested by employees, and implemented into the system, was to automatically filter the list of parks to those for which the employee is responsible. The employees can then remove or modify the filters as needed to search for other parks outside of their normal responsibilities.

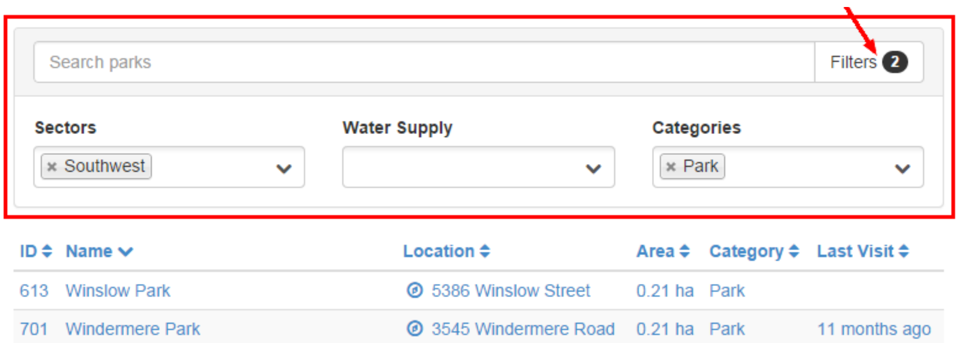


Figure 3.4: The search tool bar and opened filters panel showing two active filters.

3.3.3 Park Details

Clicking on a single park, one row of the list, will bring up more information for that park. The information is divided into four categories: Details, Usage, Equipment, and Logs.

Details

The Details tab displays the summary of information for the park, including the park name, location, WebWork id (an internal id to the City of Kelowna WebWorks management system), water supplier, irrigated and total areas, number of irrigation zones, the current usage, and date of the last visit to the park (Figure 3.5). If the park has GPS information associated with it, a mini-map displaying the location of the park appears on the left side, which links to that specific park on the Map page (see Figure 3.11).

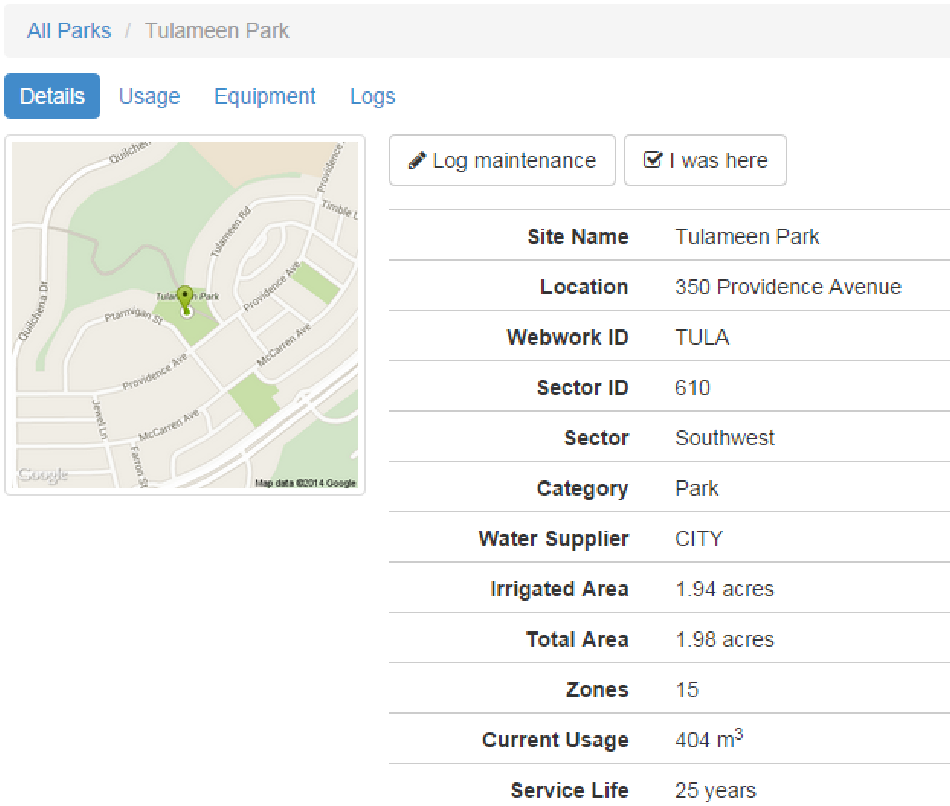


Figure 3.5: Summary of park details for Tulameen Park and the mini-map showing the location of the park.

Located above the park summary are two buttons, one for recording a visit to the park and the other for logging maintenance at the park. Clicking on the 'I was here' button performs a one-time operation to record the current date, time, and user identification of the employee that visited this park into the database. As shown in Figure 3.6, when the button for logging maintenance is clicked, a form pops up that allows the user to record maintenance notes for a park. The user can select any number of activities performed at the park, set the priority of the log, and include any additional notes that may be relevant. As well, the user can press the 'Take pictures' button to use the camera on the device to capture as many new photos as needed and attach them to the maintenance log.

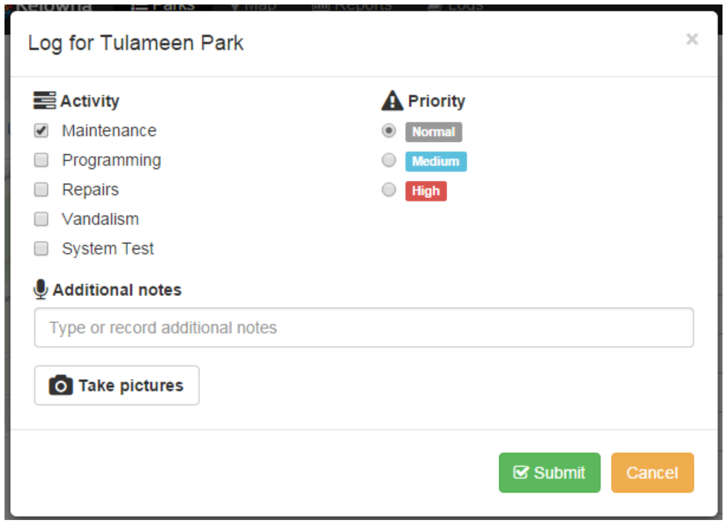


Figure 3.6: Pop-up form for logging maintenance activities at Tulameen Park, with the Maintenance activity selected and the priority set to Normal.

Usage

Clicking on the Usage tab displays an interactive chart of the water usage for the park (Figure 3.7). By default, the chart displays the most recent year's water usage as bars by month, with date of consumption along the x-axis and volume in cubic meters (m^3) along the y-axis. The options menu on the left side allows the user to toggle which usage years are visible on the chart. The three most recent years are available by default, but previous years can be viewed by clicking on the `More` button to expand the list. The expected water usage from different weather stations can also be displayed on the chart. Each weather station has a historic average usage and current expected usage option. Additionally, the user can toggle the chart between monthly or yearly time-scale, and toggle the units between cubic meters and inches/acre.

As highlighted by the first box in Figure 3.8, there is a table displaying a list of all the water meters associated with this park. Each meter has a unique meter id, an account number, address, and a description of the physical location. Clicking on a specific meter expands the table to include all the readings from that meter, including the raw reading values, billed usage values, date the readings were measured, and the read type code for

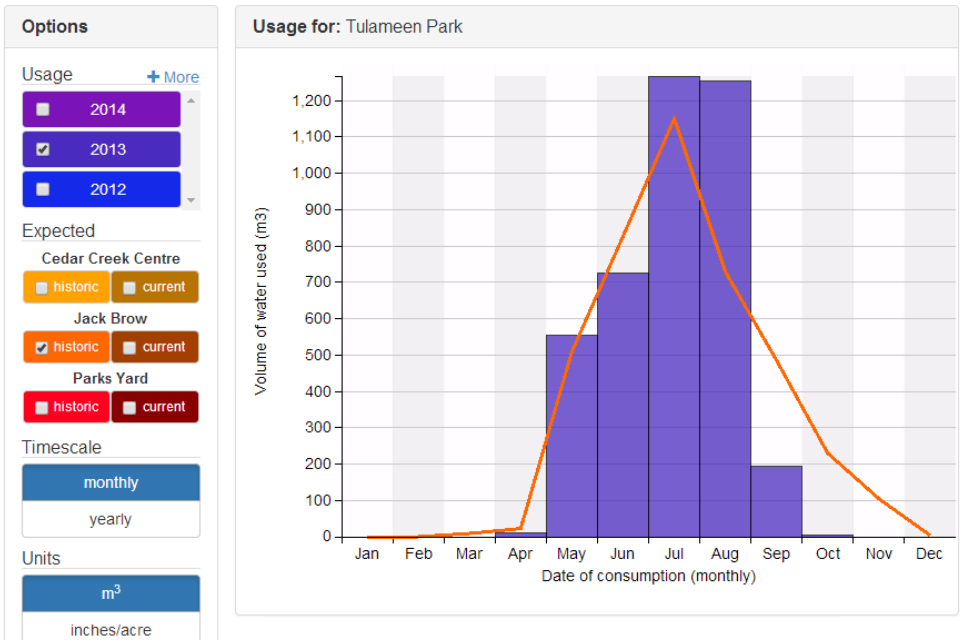


Figure 3.7: Interactive chart for Tulameen Park displaying the 2013 water usage based on monthly consumption in meters cubed (m^3) and the expected usage based on the Jack Brow weather station.

how the reading was determined (for example, MR for manual read and CE for calculated estimate) (Figure 3.8).

Meter Readings Click rows to view

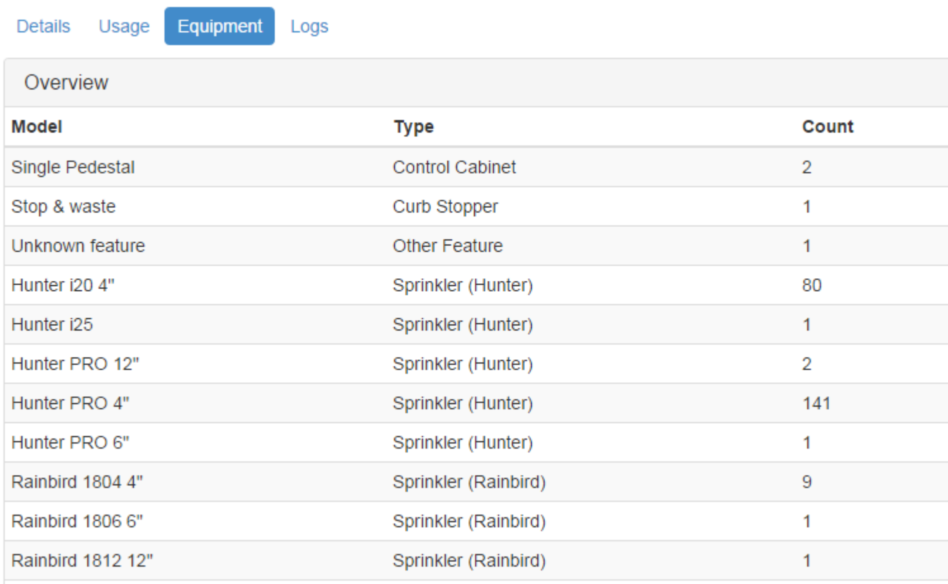
Meter ID	Account #	Address	Location
59536316	1051106	350 Providence Avenue	350 Providence Avenue near road

Date	Measured At	Raw Reading	Billed Usage	Calculated Usage	Read Type Code
2011-05	2011-04-26	0	5		MR
2011-06	2011-05-26	0	585		MR
2011-07	2011-06-26	0	678		MR
2011-08	2011-07-26	0	1270		MR
2011-09	2011-08-26	0	1297		MR

Figure 3.8: List of all of the readings collected for each meter at this park.

Equipment

The Equipment tab provides an overview of the equipment at the park, displayed as a table showing the different types of equipment at the park and the count of each item (Figure 3.9).



Model	Type	Count
Single Pedestal	Control Cabinet	2
Stop & waste	Curb Stopper	1
Unknown feature	Other Feature	1
Hunter i20 4"	Sprinkler (Hunter)	80
Hunter i25	Sprinkler (Hunter)	1
Hunter PRO 12"	Sprinkler (Hunter)	2
Hunter PRO 4"	Sprinkler (Hunter)	141
Hunter PRO 6"	Sprinkler (Hunter)	1
Rainbird 1804 4"	Sprinkler (Rainbird)	9
Rainbird 1806 6"	Sprinkler (Rainbird)	1
Rainbird 1812 12"	Sprinkler (Rainbird)	1

Figure 3.9: List of all the irrigation equipment at this park.

Logs

Finally, the Logs tab displays a list of all maintenance logs recorded for this particular park. As shown in Figure 3.10, there is a search bar to find a particular log by any keyword within the log, as well as buttons for sorting the logs based on either date or priority. Logs are colour-coded based on a user-selected priority with normal or low priority being coloured grey, medium priority logs coloured blue, and highest priority logs coloured red. Activities for the logs are displayed as a bulleted list. Pictures associated with logs are displayed as well, and clicking on the picture thumbnail for a log will pop up a larger version of the image for viewing.

Logs can be edited but only by the user who created them or by administrators. Clicking on the edit button allows the user to change the message

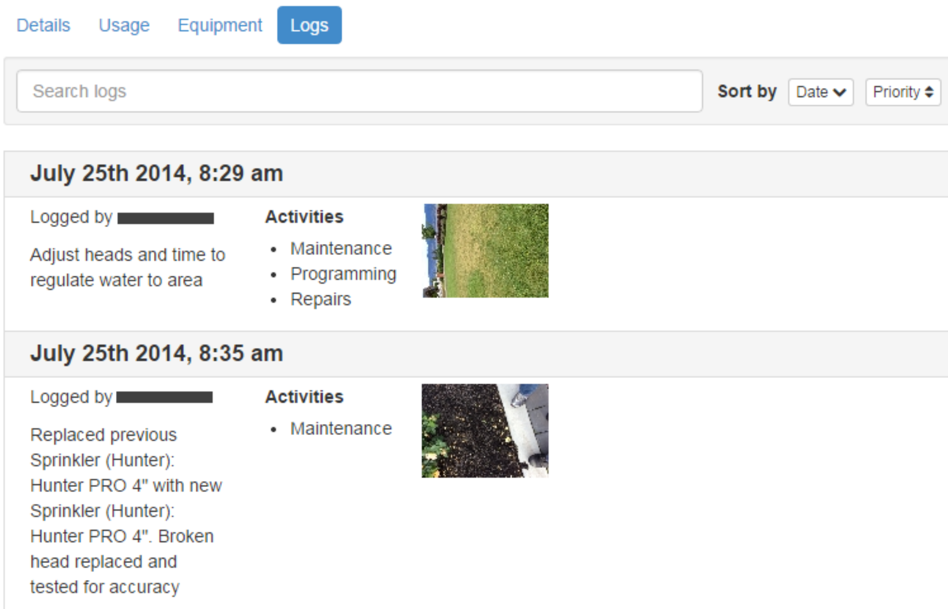


Figure 3.10: List of maintenance logs associated with this park.

content, the priority of the log, alter which activities occurred, and even remove pictures from the log.

3.3.4 Map

Navigating to the map page, either by using the navigation menu along the top or clicking on the mini-map in the Park Details, will bring up an embedded, interactive Google map. As shown in Figure 3.11, the map displays the locations and boundaries of all the parks in the system. Each park is represented by a green rectangular icon labelled with the park's three-digit quadrant ID. Parks that are close together on the map have their pins clustered together into a circular icon, labelled with the number of parks in that cluster, to make it easier to see where parks are located and avoid overcrowding the screen.

Any search or filters applied to the main list of parks is maintained on this page, and the filters can be altered through the drop-down menu along the top-left corner of the map, highlighted by the box in Figure 3.11. The filter panel here also includes buttons to zoom out to view all the parks or zoom in to the user's location. The user location is determined by the

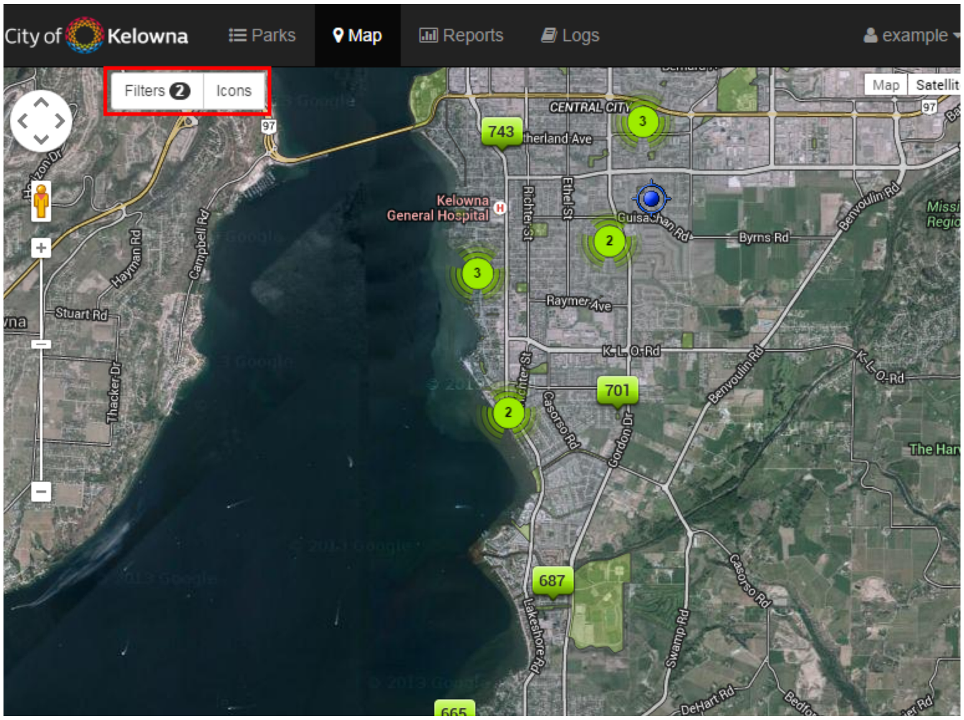


Figure 3.11: Map displaying all the locations of the parks, with clusters indicating the number of parks that are close together at this zoom level.

device they are currently using, so mobile devices with an internal GPS such as the iPad or smart-phones will have more accurate locations than the approximation from a desktop browser. The user location is displayed on the map as a blue compass icon that moves across the screen as the user moves the device around in the park. Next to the filters button is a drop-down menu to toggle the visibility of icons for equipment at parks, including sprinklers, connection points, control cabinets and valve boxes (See Figures 3.11 and 3.12).

Clicking on a park pin will zoom the map into that park, as shown in Figure 3.12, and will display a detailed pop-up with some brief information about the park, such as the address, irrigated area, and date of last visit. The name of the park can be clicked to take the user to the details page for that park. As well, there are buttons on this pop-up that allows the user to record a visit or log maintenance, as previously described in the park details page and shown in Figure 3.6. If the park has any location

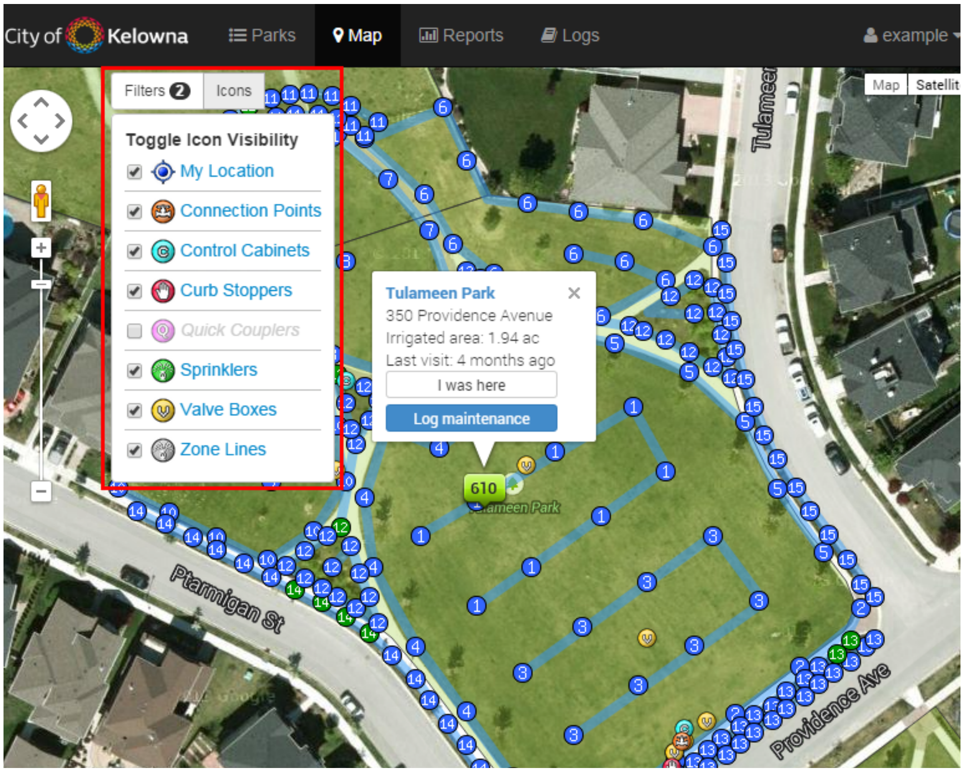


Figure 3.12: Map zoomed into Tulameen Park. The panel to toggle the visibility of equipment icons is highlighted, and the pop-up information window for this park is also displayed.

data for equipment at the site, such as the location of sprinklers and zone lines, then the equipment is displayed on the maps; for example, sprinklers are displayed on the map using coloured circle icons labelled with their zone number. Each icon for equipment can be clicked to bring up more information for that equipment if it is available.

3.3.5 Reports

The reports page can generate and display several different reports that are viewable by clicking on their respective tabs.

Usage

By default the Usage report is displayed, which contains the same interactive chart as described in the park details, shown by Figure 3.13. It has the same functionality for toggling usage years, expected usage from weather stations, and toggling of time scale or units. Along the top of the chart is the search and filter tool bar again (see Figure 3.4), and any search or filters applied from the list of parks or the map are maintained here as well. The search and filter tool bar allows the user to generate usage reports for any individual park or groupings of parks based on the filters they apply.

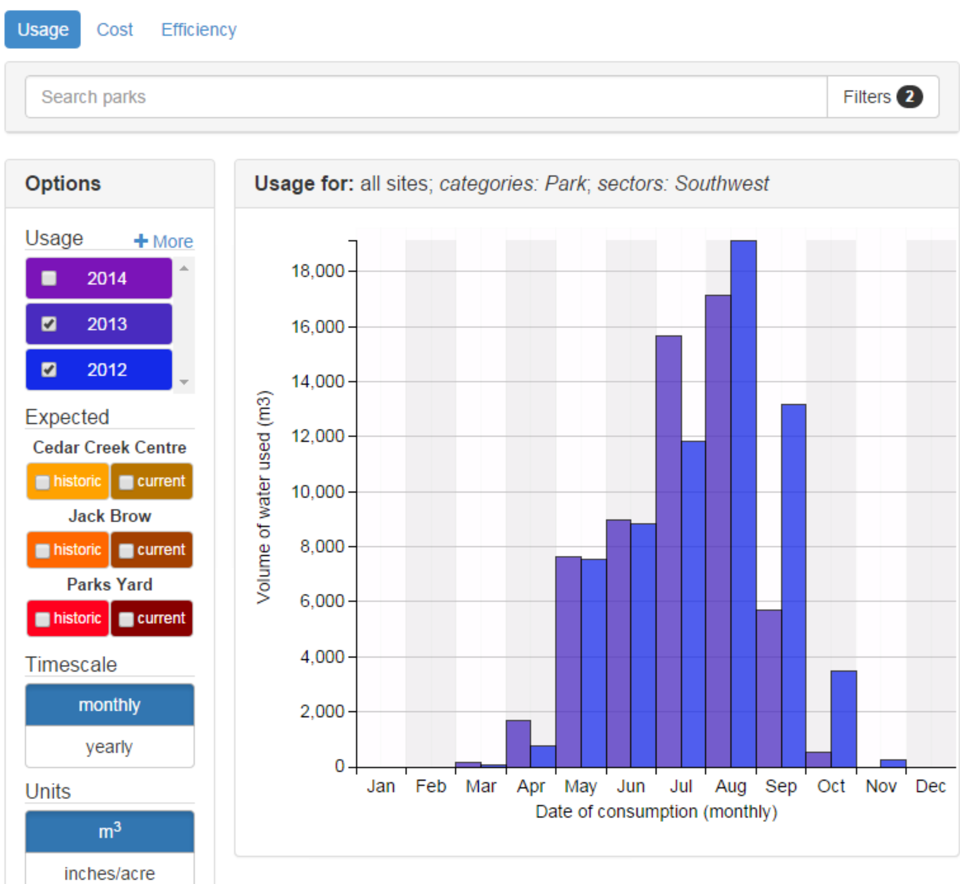
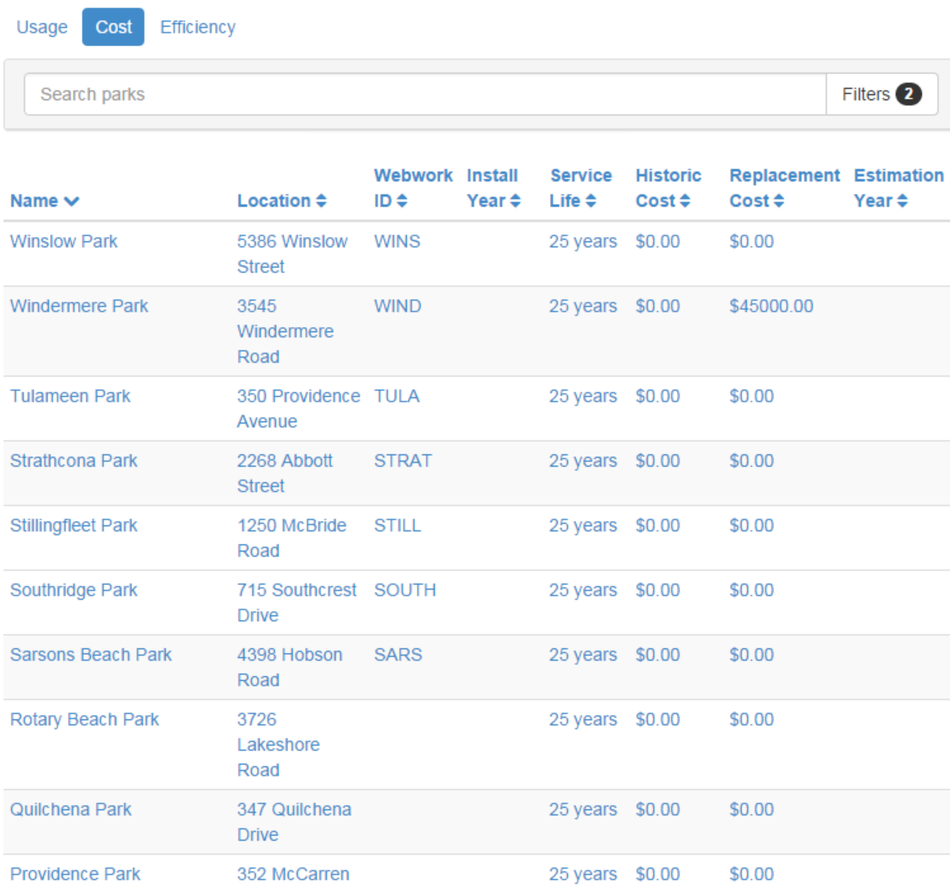


Figure 3.13: Reports page displaying the water usage for all parks in the category of Park and in the Southwest sector.

Cost

The Cost report displays the parks similarly to the main list of parks but with different columns of information such as the installation year, service life, historic and replacement costs, and year of cost estimate. This report allows the user to review the additional information for all the parks, as shown in Figure 3.14.

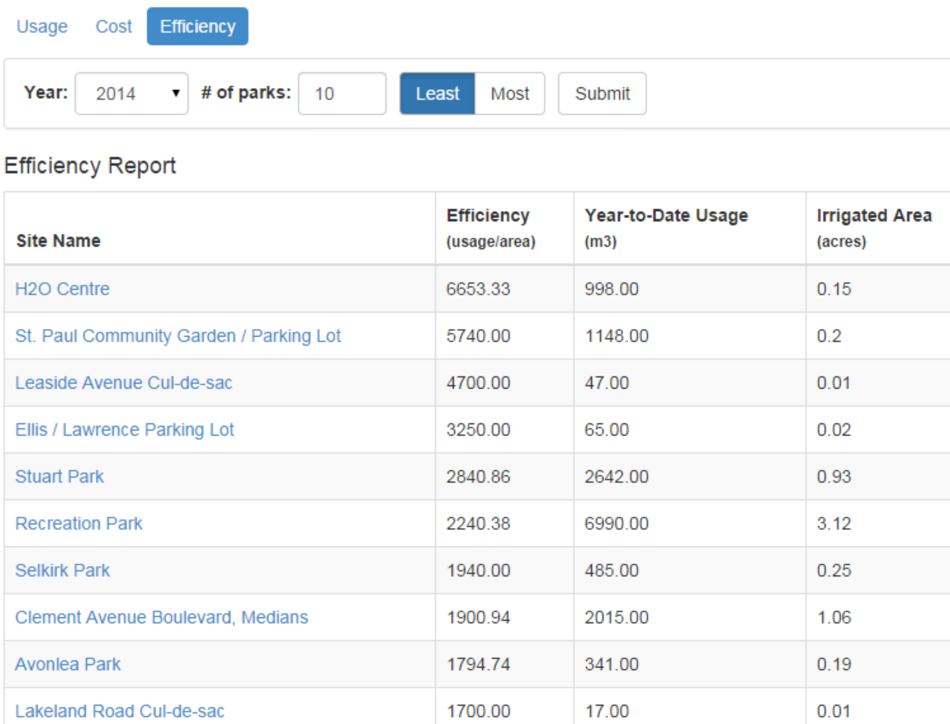


Name	Location	Webwork ID	Install Year	Service Life	Historic Cost	Replacement Cost	Estimation Year
Winslow Park	5386 Winslow Street	WINS		25 years	$0.00	$0.00	
Windermere Park	3545 Windermere Road	WIND		25 years	$0.00	$45000.00	
Tulameen Park	350 Providence Avenue	TULA		25 years	$0.00	$0.00	
Strathcona Park	2268 Abbott Street	STRAT		25 years	$0.00	$0.00	
Stillingfleet Park	1250 McBride Road	STILL		25 years	$0.00	$0.00	
Southridge Park	715 Southcrest Drive	SOUTH		25 years	$0.00	$0.00	
Sarsons Beach Park	4398 Hobson Road	SARS		25 years	$0.00	$0.00	
Rotary Beach Park	3726 Lakeshore Road			25 years	$0.00	$0.00	
Quilchena Park	347 Quilchena Drive			25 years	$0.00	$0.00	
Providence Park	352 McCarren			25 years	$0.00	$0.00	

Figure 3.14: Reports page displaying the costs for all parks with two filters applied. At the time of this screenshot, the Kelowna Parks Services department had not finished adding the cost estimates to each of the parks.

Efficiency

The Efficiency report displays a list of the parks with the lowest water use efficiency based on usage per area (Figure 3.15). The tool bar at the top allows any user to determine which year they want to view, switch between least efficient to most efficient, and limits the number of parks to display. Clicking on a row in the list will bring the user to the details for that specific park.



Site Name	Efficiency (usage/area)	Year-to-Date Usage (m3)	Irrigated Area (acres)
H2O Centre	6653.33	998.00	0.15
St. Paul Community Garden / Parking Lot	5740.00	1148.00	0.2
Leaside Avenue Cul-de-sac	4700.00	47.00	0.01
Ellis / Lawrence Parking Lot	3250.00	65.00	0.02
Stuart Park	2840.86	2642.00	0.93
Recreation Park	2240.38	6990.00	3.12
Selkirk Park	1940.00	485.00	0.25
Clement Avenue Boulevard, Medians	1900.94	2015.00	1.06
Avonlea Park	1794.74	341.00	0.19
Lakeland Road Cul-de-sac	1700.00	17.00	0.01

Figure 3.15: Reports page displaying the 10 parks with lowest water use efficiency in 2014.

3.3.6 Logs

The logs page displays all the logs for all the parks (see Figure 3.16) in the same manner as the logs tab from the park details. Users can search for a particular log with the search bar or sort the logs by date or priority.

Logs are colour-coded based on priority, include the activities that occurred displayed in a bulleted list, and larger versions of the pictures can be viewed by clicking on the thumbnail. They also include a link to the details page for the park. Logs can also be edited only by the user who created them or users with administrative privileges (Figure 3.18).

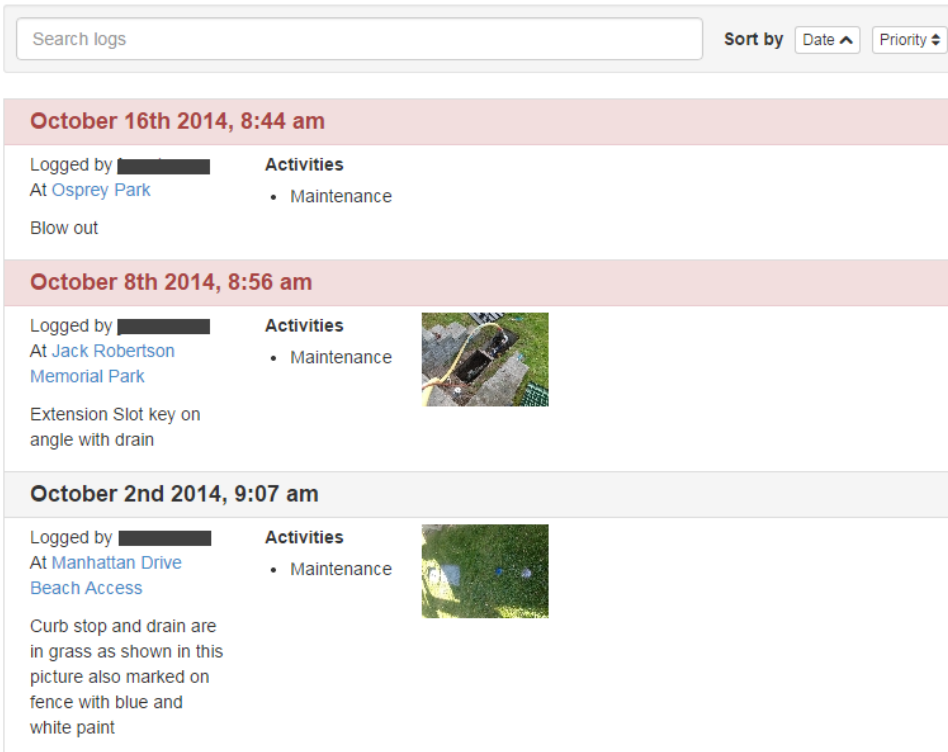


Figure 3.16: List of all maintenance logs in the system recorded by all the users, sorted by date.

3.3.7 Administrative Tools

Users with administrative privileges have additional features and tools available for managing and maintaining the information in the system.

Edit Park Details

Administrators have access to an additional button on the park details page which allows them to edit the information for each park (Figure 3.17).

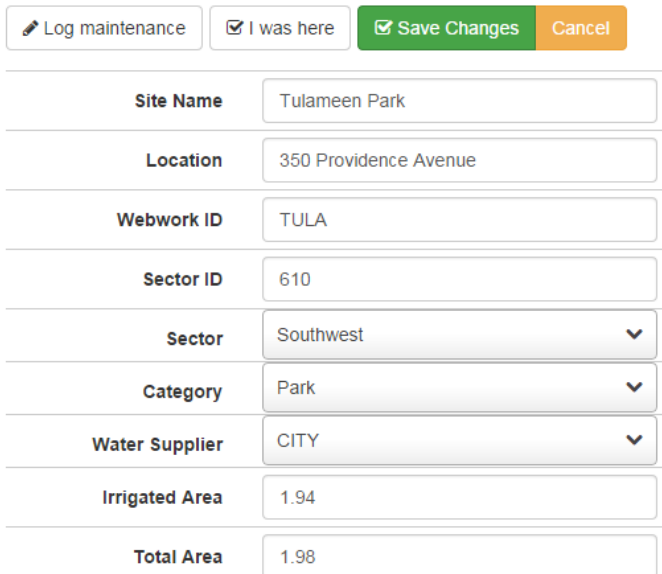


Figure 3.17: Editing screen for Tulameen Park.

Edit Logs

In addition to users being able to edit their own maintenance logs, administrators have the capability of editing any maintenance log to change the message content, the priority of the log, alter which activities occurred, remove pictures from the log, or even delete the log entirely (Figure 3.18).

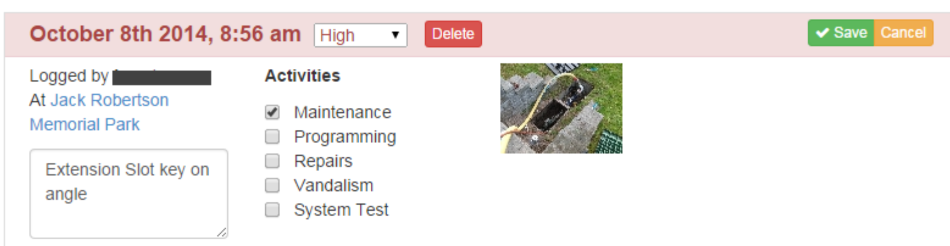


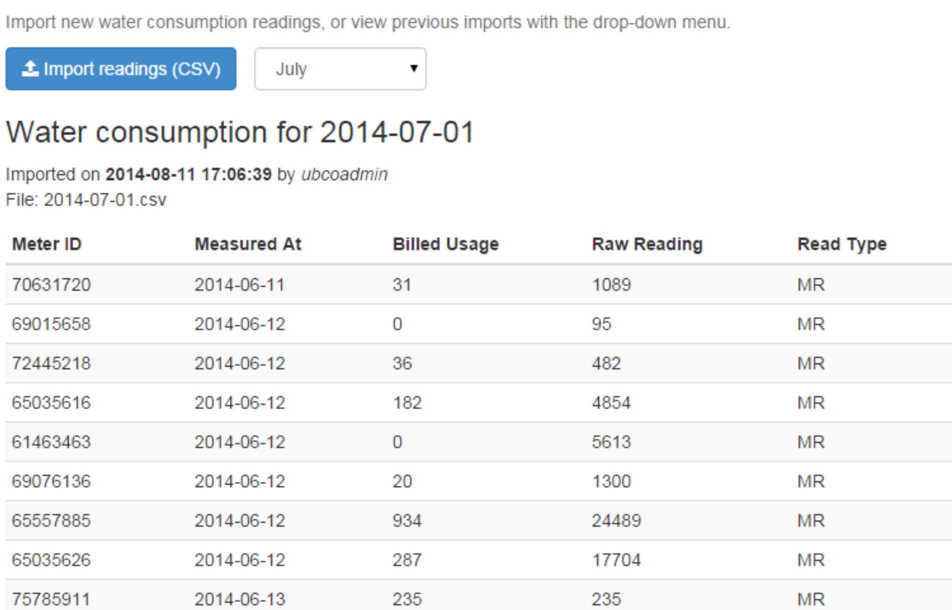
Figure 3.18: Editing screen of a maintenance log.

Meter Readings Tools

Another tool that administrators have for maintaining the information in the system is the Readings Tool page, which allows them to import new water consumption readings or review previous imports. The 'import readings' button allows the administrator to upload a comma-separated value (CSV) spreadsheet of monthly meter readings for city park water consumption.

The system automatically inserts all the information into the database and associates known meters (and their readings) with the correct park. If a new meter is detected, then that meter is displayed in a table of import warnings along with any other warnings or errors that may have occurred during the import process. Administrators can then manually associate the unknown meter (and subsequent readings) with the correct park.

Additionally, administrators can review any previous imports using the drop-down selection list, which displays all the readings for that month and any import warnings which have not been resolved (Figure 3.19).



Meter ID	Measured At	Billed Usage	Raw Reading	Read Type
70631720	2014-06-11	31	1089	MR
69015658	2014-06-12	0	95	MR
72445218	2014-06-12	36	482	MR
65035616	2014-06-12	182	4854	MR
61463463	2014-06-12	0	5613	MR
69076136	2014-06-12	20	1300	MR
65557885	2014-06-12	934	24489	MR
65035626	2014-06-12	287	17704	MR
75785911	2014-06-13	235	235	MR

Figure 3.19: The administrative page for importing and managing monthly meter reading information. The water consumption readings for July 2014 are displayed in the table.

User Management

Administrators also have the ability to manage the users of the irrigation management application. All users of the system are displayed in a table (see Figure 3.20), along with their contact email address, user role indicating whether they are an administrator, employee, or guest, and their status. Administrators can change each user's role in the system, granting or revoking administrative privileges, as well as deactivate or reactivate a user account. Only active users are allowed to log into and use the system; inactive users cannot log in or access any features of the application. Administrators can add new users to the system with the 'add new user' button, which pops up a form for filling out the necessary information.

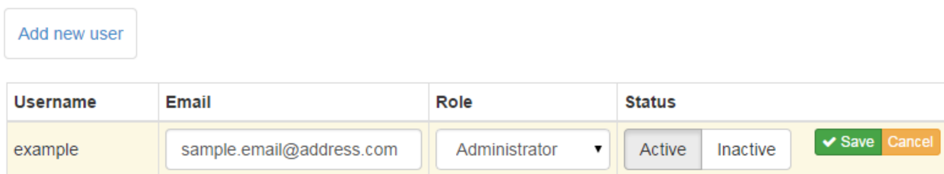


Figure 3.20: List of users in the irrigation management application, with the user 'example' edited by an administrator.

Site and GPS Tools

The last set of tools available to administrators is the Site and GPS Tools page, which allows them to add new parks into the system, manage options such as the types of sectors, categories, and water suppliers available, and to manage the location information associated with each park. Figure 3.21 shows the interface for managing the different organizational options for parks including categories, sectors, and water suppliers. New items can be added to the system with the 'add new' button, or existing items can be edited in-line or removed entirely by clicking on each item.

Administrators can also use the 'add new site' button to enter a new park into the system. Information for the new park such as name, address, water supplier, and irrigated area can be entered using the form that pops up or by editing the information in the park details page (see Figure 3.17).

Finally, administrators can manage the GPS information associated with each park using the 'import/edit site GPS' interface. The interface is split between the tool panel for importing or editing GPS information shown in Figure 3.22, and an interactive map similar to the one previously shown in

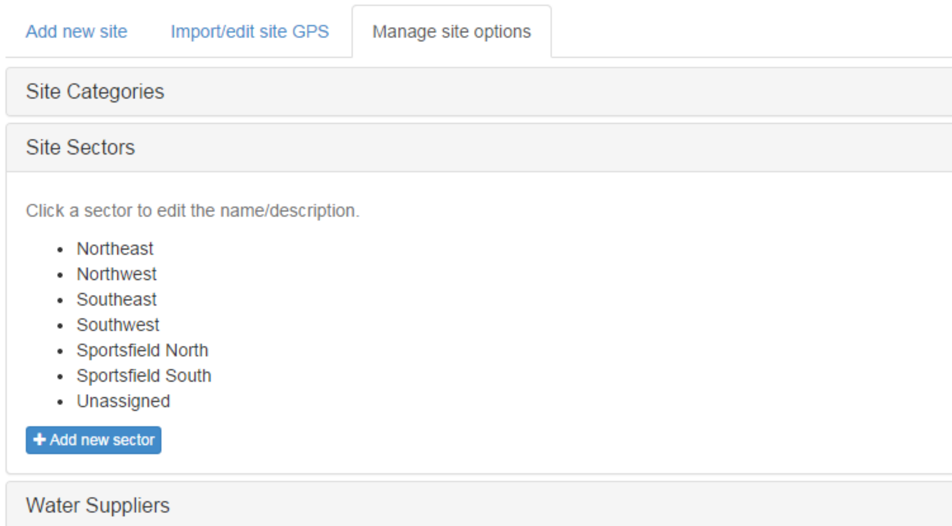


Figure 3.21: Administrative options to edit the different park organization options, with the site sector options tab current displayed.

Figure 3.12. The panel has step-by-step instructions for importing collected GPS data on equipment locations for a park. Administrators can manually add or remove features at a park, and there is a simple 'undo' feature in case an item is accidentally removed. Each item can be selected to edit its details, such as the equipment type, the model information, whether it is associated with an irrigation zone, and any additional comments the administrators wish to include. As well, irrigation zone lines can be automatically added for parks and then manually edited to ensure the correct layout at the park. The map interface uses features of Google Maps to allow drag-and-drop placement of zone lines and equipment at the parks.

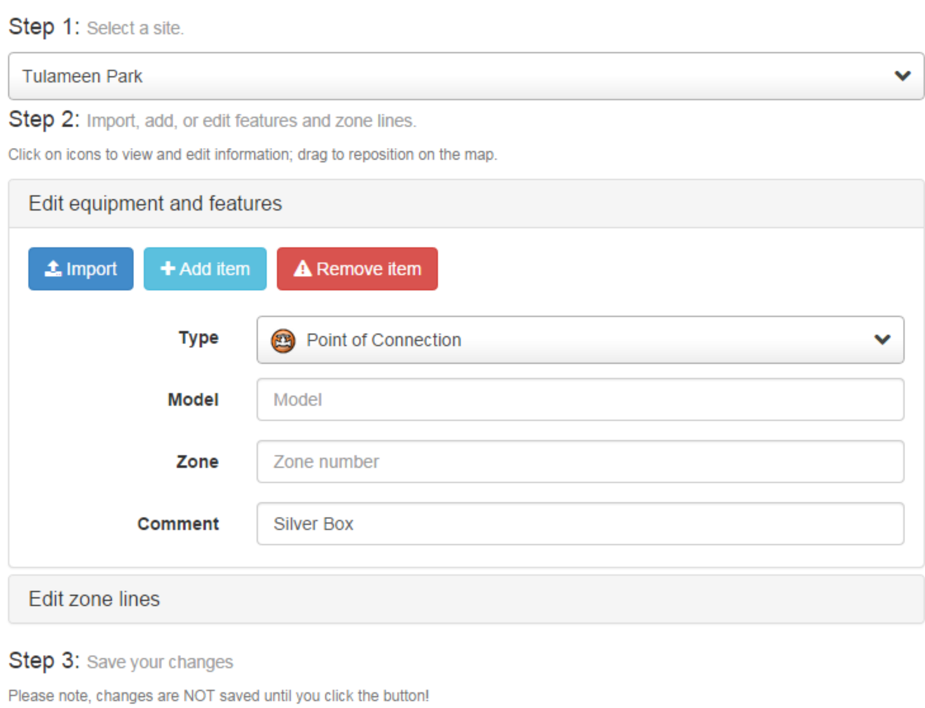


Figure 3.22: Screenshot showing the tool panel for importing new GPS data, manually adding or removing GPS data, and editing the information for equipment and zone lines at Tulameen Park.

Chapter 4

Case Study: City of Kelowna

The primary motivations for developing the irrigation management application were the high water usage by city park irrigation during the summer and the daunting task of maintaining those irrigation systems by irrigation technicians. The hypothesis was that the irrigation practices and maintenance activities at City of Kelowna parks could be significantly improved by providing field employees with information about the parks they manage through the use of a mobile application for the iPad. Having that information available out at the parks, in the form of a mobile application on the iPad, will help irrigation technicians to manage their time and resources better, and that they will be better supported in making decisions regarding sustainable irrigation practices.

This study was performed using a hybrid approach of questionnaires and scenario-based testing to measure the length of time to complete tasks (*efficiency*), number of incorrect actions, incorrect choices, and repeated errors (*effectiveness*), and the perceptions of the participants (*subjective satisfaction*). Efficiency was determined by measuring the length of time to complete the assigned tasks, effectiveness was measured through user observation while performing scenario-based tasks, and subjective satisfaction was measured through formal pre-test and post-test questionnaires, documented think-aloud comments, and unstructured interview responses.

4.1 Study Procedures and Method

4.1.1 Participant Recruitment

The participant pool for this study was the full-time irrigation technicians from the City of Kelowna Parks Services department, whose responsibilities include the regular management and maintenance of irrigation equipment in city parks. After receiving support from the Kelowna Parks Services supervisor (see Appendix A), the irrigation staff who wished to participate were asked to read and sign the consent form (see Appendix B). Four full-time irrigation technicians who were primarily responsible for city parks, two full-time irrigation technicians who were primarily responsible for sports fields, and one temporary irrigation technician were recruited, for a total of seven participants overall. Due to the small sample size and the closed environment of the Parks Services department, no demographics were collected from the participants to ensure their privacy. Additionally, while some of the participants had an opportunity to request features and provide feedback on the appearance of the application, none of them were actively involved in the development process and none of them had any prior experience with the application before the study.

4.1.2 Participant Testing Conditions

For this study, participants were asked to complete a series of tasks at the parks with and without the use of the iPad and irrigation management application. Participants were considered to be an 'expert' for parks which they regularly visited and maintained. For parks outside of their normal responsibilities, participants were considered to be a 'novice'; however, 'novice' participants were still trained irrigation technicians from the Kelowna Parks Services department. Experts were used to provide a baseline of performance for comparison against the two novice conditions during the study: novices with the iPad and application, and novices without. This resulted in three testing conditions which were investigated:

- Expert without the iPad as baseline of performance (E_0)
- Novice without the aid of the iPad and application (N_0)
- Novice with the iPad and application available (N_1)

Due to the small sample size of participants available, each participant was asked to repeat all test scenarios in as many of the testing conditions as possible at the selected parks.

4.1.3 Park Selection

As described previously, the Kelowna Parks Services department has over 300 unique irrigation sites that its employees regularly maintain. For this study, we wanted to use a subset of these parks that were the most representative of the majority of parks in Kelowna. Three criteria were used to select which parks would be most appropriate for this study; sites had to be regularly maintained by irrigation staff, be average in terms of irrigated area and zones, and needed to have recent GPS location data collected. These selections were done before the study was conducted.

The first criterion for selecting appropriate parks for the study was that the parks had to be regularly maintained by irrigation technicians. This was defined to be parks that are visited by an irrigation technician at least three times per month throughout the summer work period, which would indicate that the park is being actively maintained. This was to ensure that there would be at least one participant familiar enough with each park to provide a baseline of expert performance.

The second criterion for selecting parks was that they had to be average sized in terms of irrigated area and number of irrigation zones. The size of the park is important for this study as many of the common tasks that irrigation technicians perform involve finding equipment and irrigation zones. Parks that are quite small make the completion of these tasks trivial, whereas parks that are very large require considerably more time to complete those same tasks. As well, there is significant variation in the layout of equipment and irrigation zones among the different sizes of parks in Kelowna. Irrigated areas range from a minimum of 0.06 acres to a maximum of 31.79 acres, with an average irrigated area of 2.74 acres and standard deviation of 4.98 acres. The number of irrigation zones at parks range from a minimum of a single irrigation zone to upwards of 70 irrigation zones at larger parks. The average number of irrigation zones was 13.17 with a standard deviation of 10.27.

The last criterion for a valid park for the study was that the park needed to have recent GPS location data collected for the irrigation equipment. The Kelowna Parks Services department has undertaken the process of recording the GPS locations of all irrigation equipment for each of their irrigation sites to provide an inventory of the equipment being used at the parks and to allow the generation of maps of the layout of equipment for the parks. At the time of the study, only 70 of the 300 irrigation sites had GPS location data collected for the irrigation equipment within the past six months; however, most of the remaining parks and irrigation sites have since had their location data collected.

While several parks matched the above criteria, only four were deemed suitable for the study by the Kelowna Parks Services management: Birkdale Park, Knowles Heritage Park, Tulameen Park, and Whitman Glen Park. The irrigated areas and number of irrigation zones for each park is shown in Table 4.1. All parks were within one standard deviation of the mean in regards to both irrigated area and number of irrigation zones, had recent GPS location data collected for their equipment, and were considered representative of a typical park in Kelowna by Kelowna Parks Services management.

Table 4.1: The street addresses, irrigated areas (in acres), and number of irrigation zones for each of the selected parks in the study.

	Street Address	Irrigated area	Zones
Birkdale Park	363 Prestwick Street	1.42	23
Knowles Heritage Park	888 Lawrence Avenue	0.95	22
Tulameen Park	350 Providence Avenue	1.94	15
Whitman Glen Park	308 Whitman Road	1.21	10

4.1.4 Pre-test Survey

Participants were asked to complete a three section pre-test survey. The first section was a series of questions to measure the participant's initial confidence and self-efficacy towards using technology, in particular mobile devices such as iPads or smart phones (see Appendix C.1.1). The second section measured the participant's initial anxiety towards using technology and mobile devices (see Appendix C.1.2). The questions in these two sections of the pre-test survey were adapted from the questionnaire for measuring anxiety and self-efficacy when using computers and the Internet presented in [DH02] and discussed in Chapter 2. The questions were modified to ask about mobile technology and mobile devices in addition to computers and technology in general. The third and final section asked the participant to indicate their familiarity with the selected parks to characterize them as experts or novices for the selected parks (see Appendix C.1.3).

4.1.5 Test Scenarios

To test how the iPad and irrigation management application would be most effectively used at the parks, four test scenarios were developed to replicate the different types of tasks that may be performed by irrigation technicians at city parks. Managers of the Parks Services department were consulted to determine the list of tasks for each scenario, as well as the viability of testing those tasks in a reasonable time-frame given the limited availability of the irrigation staff during the summer season.

The tasks for the test scenarios were designed to be representative of the daily routine at city parks, as well as other less common but still significant activities that may occur at the parks. Several of these tasks asked participants to locate areas of particular interest such as dry brown patches of grass, potential tree planting locations, and damaged sprinkler heads. These areas of interest were indicated in the parks using different coloured flags to mimic the conditions for each task without actually causing any damage to city property or equipment. The exact locations of the areas of interest were different for each park, but the placement of the flags followed the same guidelines:

- Dry brown patches of grass needed to encompass at least two adjacent irrigation zones
- Two potential tree planting locations needed to be placed in different irrigation zones where equipment could be damaged if a tree was planted there, while the other two needed to be placed in locations where no damage would be caused
- Damaged sprinkler heads needed to be placed in an irrigation zone separate from any used in a previous task

Scenario 1: Routine Maintenance

As part of routine maintenance for a park, an irrigation technician needs to be able to locate all of the equipment at the park. Major items of equipment that they need to find include the control cabinet housing the irrigation controller, the points of connection to the main water line, the curb stoppers for shut off and drainage of the main water line, and valve boxes for individual irrigation lines. For this scenario, the participants were asked to complete the following series of tasks:

- Find (1) control cabinet
- Find (1) point of connection
- Find (1) curb stopper
- Find the valve boxes for (2) specific irrigation zones

Scenario 2: Watering Program Alterations

During routine maintenance of a park, an irrigation technician may find that particular areas of the turf grass to be brown and more dried out in comparison to the rest of the park. These dry brown patches of grass are usually the result of inadequate watering time or irrigation coverage from the surrounding sprinklers. Another possible explanation could be that the sprinkler head(s) may be damaged or failing to operate correctly. In either case, the employee must determine which irrigation zones are causing the dry brown patches, and make repairs or watering adjustments. For this scenario, the participants were asked to complete the following tasks:

- Identify in which irrigation zone(s) a dry brown patch of grass is located
- Report or log which irrigation zone(s) had their watering time altered

Scenario 3: Tree Planting

Whenever the city would like to plant new trees at a park or to install new features such as a picnic table, bench, or garbage can, employees from the appropriate departments will go out to the park and indicate where they would like to place the new trees or features. An irrigation technician must then go out to the park to ensure that no existing irrigation equipment or irrigation water lines will be damaged when planting the trees or installing the new features. The two primary tasks the irrigation technicians need to do include identifying which irrigation zones may be affected by the new features or trees, and where it will be safe to actually install the new features or plant the new trees to have minimal impact on the existing irrigation equipment or features. For this scenario, the participants were asked to complete the following tasks, which were repeated four times at each park:

- Identify which irrigation zone(s) may be affected by planting a tree
- Determine where it will be safe to plant a tree with minimal impact to existing irrigation equipment

Scenario 4: Repair Damaged Sprinkler

Whenever sprinkler heads are damaged as a result of vandalism, accident, or general wear and tear, the irrigation technicians must perform a series of tasks to resolve the issue. They must first identify which irrigation zones the damaged sprinklers are located in, determine the replacement parts that will be required, retrieve the replacement parts and make the repairs, and then finally make a report of the damage and repairs to their supervisors and management. For this scenario, the participants were asked to complete the following tasks:

– Identify in which irrigation zone(s) the damaged sprinkler is located

– Identify which type of replacement part(s) are required

– Report or log the repairs that took place and the time spent doing so

4.1.6 Observation and Data Recording

The test scenarios were performed individually by the participants at each of the selected parks throughout July and August of 2014. If a participant had enough familiarity to be considered an expert (E_0 condition) at a selected park, then the participant was asked to complete all the scenarios for that park without the use of the iPad and mobile application, in order to provide a baseline of expected performance at that park. Otherwise, the participants were randomly assigned as either novice with the iPad and mobile application available to use (N_1 condition), or as novice without the iPad and mobile application available (N_0 condition). This led to a distribution of a single expert participant, three novice participants without the iPad or application, and three novice participants using the iPad and application at each of the selected parks.

During all test scenarios, the participants were allowed to use any resources they would normally have available, such as calling another employee for advice. Participants using the iPad and mobile application (N_1 condition) were asked to use the iPad first before resorting to other tactics to complete a task.

The following parameters and observations were monitored during the test scenarios: time to complete task, the types and number of errors or mistakes made, and any indications of frustration, confusion, or other commentary from the participant. The length of time to complete each task for each scenario was recorded using a stop watch, and the observations of behaviour, errors made, and verbal comments from the participant were written in a notebook. Although the option was available, participants did not make any phone calls to other irrigation technicians asking for assistance. Participants were encouraged to speak aloud their thoughts while completing the tasks. At the end of the test scenarios, the task completion times and written observations were then transcribed onto a computer.

4.1.7 Completion Survey

After the participants had successfully completed all of the test scenarios in each of the four parks, they were asked to answer another questionnaire.

The completion survey was divided into five sections. The first asked the participants about their perceptions for each test scenario they completed at parks which they were unfamiliar with (Novice testing conditions N_0 and N_1, see Appendix C.2.1). The second section was only to be completed by participants who had some familiarity with any of the parks during the tests (baseline Expert condition E_0, see Appendix C.2.2). The third section asked the participants about their overall perceptions and experiences while using the mobile application out in the parks (see Appendix C.2.3). The fourth and fifth sections repeated the same questions from the pre-test survey to measure any changes in participant's confidence and self-efficacy (see Appendix C.2.4) and their anxiety towards mobile devices and technology (see Appendix C.2.5) after having used the mobile application in the field. An open feedback section was also included for any additional comments or concerns from the participants (see Appendix C.2.6).

Chapter 5

Results and Discussion

The research hypothesis was that irrigation practices and maintenance activities at City of Kelowna parks could be significantly improved by providing field employees with information about the parks they manage through the use of a mobile application for the iPad. As described in Chapter 4, the results and observations from the test scenarios at the parks, as well as participant perceptions from the pre-test and completion surveys, were collected for analysis. The time to complete tasks for the test scenarios at each park was recorded for each participant as either an Expert without the iPad for baseline performance (E_0 condition), Novice without the aid of the iPad and irrigation management application (N_0 condition), and Novice with the iPad and application available to use (N_1 condition). The distribution of participants among the testing conditions was $E_0 = 1$, $N_0 = 3$, and $N_1 = 3$ for each park (Section 4.1.6). The mean and standard deviation for each of these participant conditions have been calculated at each park and for all parks overall. The mean values were used to measure the average completion times of the tasks, and the standard deviations were used to measure the variability in the completion times, with higher values of standard deviation indicating a greater variability in the time to complete the tasks.

5.1 Test Scenario Results

5.1.1 Scenario 1: Routine Maintenance

In Scenario 1 participants were asked to locate important equipment at each park; an activity irrigation technicians typically perform during the routine maintenance of parks. The first task was to find the control cabinet for the irrigation system at the park (Table 5.1). While the mean completion time is slightly faster for the novices with the iPad and application (N_1) compared to novices without (N_0), there is no significant difference overall. As well, N_0 and N_1 typically did not perform as well as experts (E_0), which was expected since they are more familiar with these parks.

Table 5.1: Means (M) and standard deviations (SD) for time to complete Scenario 1 Task 1: find the control cabinet (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	0.92	N/A	11.41	9.14	16.53	4.38
Knowles Heritage Park	41.75	N/A	82.60	91.30	39.07	33.05
Tulameen Park	2.48	N/A	6.95	6.79	8.53	8.93
Whitman Glen Park	22.90	N/A	58.72	49.59	43.22	22.07
All parks	17.01	19.30	38.21	55.88	30.40	22.82

What is interesting to note, however, is that the length of time required to complete this task varies greatly among the different parks across all participant conditions. This can be attributed to variations in layout at each of these parks. It was observed that at Birkdale Park and Tulameen Park, the control cabinets were located out in the open and were easily seen from any location in the park, whereas the control cabinets at Knowles Heritage Park and Whitman Glen Park were hidden amongst bushes and underneath some trees respectively and required more time to find them, even for the experts who were more familiar with those parks.

The second task of Scenario 1 was to find the point of connection for the main water line at the park (Table 5.2). Once again, there is quite a bit of variation in time to complete this task between the different parks as a result of the layout of the parks. N_1 were on average a bit slower than N_0, who in turn were very similar to E_0. This is likely due to the fact that points of connection are typically located near to the control cabinets and both the N_0 and E_0 participants simply looked around until they spotted the equipment, whereas N_1 participants used the iPad to navigate towards the equipment which caused them to perform slower in some cases.

Table 5.2: Means (M) and standard deviations (SD) for time to complete Scenario 1 Task 2: find the point of connection (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	0.83	N/A	11.49	9.46	29.80	17.23
Knowles Heritage Park	31.16	N/A	30.16	9.77	27.20	2.43
Tulameen Park	3.71	N/A	3.62	3.71	14.46	10.12
Whitman Glen Park	9.47	N/A	3.39	0.08	7.32	3.65
All parks	11.29	13.72	12.96	13.18	18.74	12.94

The third task of Scenario 1 was to find the curb stopper for the water line at the park (Table 5.3). Again there is not much difference in the overall times to complete the task, as once more the layout of equipment at the parks appeared to be the most significant factor in the time to complete this task.

Table 5.3: Means (M) and standard deviations (SD) for time to complete Scenario 1 Task 3: find the curb stopper (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	12.36	N/A	20.36	14.27	19.39	11.33
Knowles Heritage Park	14.40	N/A	3.95	1.81	6.19	4.25
Tulameen Park	4.85	N/A	9.20	9.51	17.93	16.32
Whitman Glen Park	15.03	N/A	40.93	47.27	27.05	19.28
All parks	11.66	4.68	16.58	21.68	17.64	14.26

The final task of Scenario 1 was to find the valve box for a particular irrigation zone at the park. The task was repeated twice at each park using different irrigation zones (Table 5.4). Here we see more interesting results. Novices using the iPad and application (N_1) were on average faster than novices without (N_0), and in many cases were actually faster than the experts (E_0) who are familiar with the parks. N_0 and E_0 participants on average took over two minutes to find the correct valve box for the indicated irrigation zone, while N_1 participants were typically able to complete the task in under a minute.

Table 5.4: Means (M) and standard deviations (SD) for time to complete Scenario 1 Task 4: find the valve box for a specific zone (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	124.71	53.34	240.18	179.65	77.97	57.01
Knowles Heritage Park	44.34	8.67	118.67	92.01	43.97	27.36
Tulameen Park	18.53	19.55	127.50	65.40	44.00	16.40
Whitman Glen Park	301.83	290.58	114.99	94.34	34.20	29.54
All parks	122.35	162.97	153.55	122.31	48.63	36.85

One reason why this task has very different results in comparison to the previous three is that control cabinets, points of connection, and curb stoppers are typically easy to locate at parks, whereas valve boxes are a different matter. They are physically smaller, buried into the ground, and are often overgrown by turf grass or covered by dirt. As well, there are usually several valve boxes at each park, and each one may connect to one or more irrigation zones. Locating valve boxes for particular irrigation zones is a more labour intensive task than the three previous ones. The irrigation management application greatly aided N_1 participants in locating the valve boxes and correctly identifying the associated irrigation zones.

5.1.2 Scenario 2: Watering Program Alterations

In Scenario 2, participants were asked to identify which irrigation zones may be contributing to dry brown patches of grass, which may indicate that the watering program for the affected irrigation zones may need to be changed. The first task was to identify which irrigation zone(s) were affected by a dry brown patch of the grass, indicated by flags, at each park (Table 5.5). For this task, N_1 consistently, and in most cases dramatically, outperformed N_0. N_1 participants on average were able to complete the task in under 20 seconds, in comparison to over a minute for N_0. Additionally, for most of the parks N_1 performed on par or even better than the baseline of performance E_0. To complete this task, most N_0 participants turned on each irrigation zone one by one until they could confirm which zone(s) were affected by the indicated problem area, which can be quite time consuming. Experts familiar with the park (E_0), on the other hand, simply had to recall the layout of the park if they could, whereas N_1 were able to use the irrigation management application to quickly determine the answer.

Table 5.5: Means (M) and standard deviations (SD) for time to complete Scenario 2 Task 1: identify in which irrigation zone(s) a dry brown patch of grass is located (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	69.91	N/A	115.91	58.15	29.77	4.18
Knowles Heritage Park	3.89	N/A	73.97	59.86	24.35	11.65
Tulameen Park	9.06	N/A	61.10	31.04	11.58	3.80
Whitman Glen Park	15.40	N/A	20.69	13.35	12.98	4.96
All parks	24.57	30.59	72.36	53.12	19.16	9.80

One thing that should be noted, however, is that at Whitman Glen Park both N_0 and E_0 participants made use of a printed as-built map showing the layout of equipment at the park. Only seven of the 200 parks in Kelowna have these as-built maps, and Whitman Glen Park happened to be one that did. While the map was out of date, as several pieces of equipment had been changed or removed entirely, it still provided the general layout of the park and allowed N_0 participants to complete this task (and subsequent ones) much faster at this park than compared to the others.

The second and last task of Scenario 2 was to report which irrigation zones had their watering time altered. During the course of the study, it was discovered that the irrigation technicians typically would not report any changes made to the water programs for the irrigation zones at the parks. Some irrigation technicians claimed they would try to remember which watering programs had been changed with varying success, while others did not track that information at all. This information is something Parks Services managers have expressed interest in keeping, so while no data could be collected for the E_0 or N_0 conditions, the means and standard deviations for N_1 are shown in Table 5.6.

N_1 participants were able to complete the task of creating a maintenance log to record alterations in the watering program for irrigation zones in an average of 45 seconds, which included the time required to take a photo of the problem area using the camera on the iPad, and the time to type the necessary information about which irrigation zones needed to have their watering programs changed.

Table 5.6: Means (M) and standard deviation (SD) for time to complete Scenario 2 Task 2: report or log which irrigation zone(s) had their watering time altered (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	N/A	N/A	N/A	N/A	29.44	16.82
Knowles Heritage Park	N/A	N/A	N/A	N/A	47.09	32.03
Tulameen Park	N/A	N/A	N/A	N/A	46.52	7.49
Whitman Glen Park	N/A	N/A	N/A	N/A	50.57	44.47
All parks	N/A	N/A	N/A	N/A	45.32	28.92

5.1.3 Scenario 3: Tree Planting

In Scenario 3, participants were asked to complete tasks associated with the installation of new features at parks, which were repeated four times. The means and standard deviations of the first task, identifying which irrigation zone(s) could be affected (Table 5.7). Once more, N_1 participants drastically outperformed N_0 participants with an average completion time of 11 seconds for N_1 compared to an average of nearly 100 seconds for N_0. As well, N_1 performed similar to the baseline of expected performance E_0 at 15 seconds on average.

Table 5.7: Means (M) and standard deviations (SD) for time to complete Scenario 3 Task 1: identify which irrigation zone(s) may be affected by planting a tree (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	13.81	9.64	102.66	83.48	13.59	12.75
Knowles Heritage Park	4.26	1.39	227.05	234.13	8.10	5.04
Tulameen Park	34.04	33.21	41.69	29.67	13.27	10.29
Whitman Glen Park	8.11	1.95	15.79	8.36	9.12	7.21
All parks	15.05	19.51	95.17	138.50	10.82	9.10

The last task of Scenario 3 was to determine where installing a new feature such as a tree would have the least impact on existing equipment and features (Table 5.8). Again, N_1 performed better N_0 at each park, completing the task in an average of 6.6 seconds for N_1 in comparison to 13 seconds for N_0. As well, N_1 performed in line with E_0 which completed the task in just under 6 seconds on average.

Table 5.8: Means (M) and Standard Deviation (SD) for time to complete Scenario 3 Task 2: decide where it is safe to plant a new tree (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	2.99	1.34	17.36	21.67	7.69	6.23
Knowles Heritage Park	3.56	2.46	15.11	15.84	5.55	4.73
Tulameen Park	7.90	4.24	11.99	11.48	8.21	10.63
Whitman Glen Park	9.26	0.76	6.23	3.63	5.52	3.52
All parks	5.93	3.62	13.07	15.28	6.56	6.56

5.1.4 Scenario 4: Repair Damaged Sprinkler

In the final test scenario, Scenario 4, participants were asked to perform activities associated with repairing damaged sprinklers. The first task was to identify in which irrigation zone the ‘broken sprinkler’ was located (Table 5.9). N_1 participants dramatically outperformed N_0 participants across all of the parks, and performed on par with, if not better than, E_0 participants for the majority of parks. The identification of the irrigation zones is a time-consuming task for participants not familiar with the layout of the park (N_0) since they have to turn on each irrigation zone manually. In comparison, the irrigation management application on the iPad allows novices with no familiarity of the layout of equipment (N_1) to perform as well as experts (E_0) in those parks.

For the second task of Scenario 4, participants were asked to determine which type of replacement parts would be required for the damaged sprinkler (Table 5.10). Once again, the average time to complete the task for N_1 tends to be faster than for N_0, with 4.5 seconds on average for N_1 compared to 13 seconds on average for N_0. As well, the mean completion time of N_1 is slightly faster than E_0 at 5.5 seconds, and N_1 managed to outperform the experts (E_0) at half of the parks. This slight improvement in performance for N_1 can likely be attributed to fact that E_0 had to remember and recall the different replacement parts needed for the specific sprinkler type compared to N_1 who only needed to look at the application for that answer.

Table 5.9: Means (M) and standard deviations (SD) for time to complete Scenario 4 Task 1: identify in which irrigation zone(s) the damaged sprinkler is located (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	3.76	N/A	99.97	97.03	3.14	1.14
Knowles Heritage Park	4.53	N/A	58.21	33.65	2.58	0.52
Tulameen Park	18.49	N/A	48.01	25.37	13.26	5.19
Whitman Glen Park	3.31	N/A	8.34	2.75	4.21	2.90
All parks	7.52	7.33	57.75	57.36	5.68	5.09

Table 5.10: Means (M) and standard deviations (SD) for time to complete Scenario 4 Task 2: identify which type of replacement part(s) are required (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	3.26	N/A	12.34	7.37	9.49	4.99
Knowles Heritage Park	1.10	N/A	21.93	24.02	3.14	2.28
Tulameen Park	9.16	N/A	9.13	7.43	2.27	1.53
Whitman Glen Park	8.40	N/A	6.90	7.04	3.37	1.98
All parks	5.48	3.92	13.03	12.92	4.48	3.84

The last task of Scenario 4 was to record the repairs made at the park. As with the second task of Scenario 2, irrigation technicians do not actively report their maintenance activities at the parks, so data for E_0 and N_0 could not be collected (Table 5.11). Participants created maintenance logs with pictures and text in an average of 30 seconds. The decrease in time compared to the similar task from Scenario 2 (Table 5.6) could be attributed to the participants becoming more comfortable using the iPad and irrigation management application to create maintenance logs. Another potential explanation for the decrease in time could be that participants took fewer photos when creating the maintenance logs for this task in comparison to the previous task.

Table 5.11: Means (M) and standard deviations (SD) for time to complete Scenario 4 Task 3: report or log the repairs that took place and the time spent doing so (in seconds).

	E_0		N_0		N_1	
	M	SD	M	SD	M	SD
Birkdale Park	N/A	N/A	N/A	N/A	43.79	20.00
Knowles Heritage Park	N/A	N/A	N/A	N/A	35.93	1.72
Tulameen Park	N/A	N/A	N/A	N/A	33.33	18.71
Whitman Glen Park	N/A	N/A	N/A	N/A	13.92	5.92
All parks	N/A	N/A	N/A	N/A	30.12	16.44

5.1.5 Summary of Task Performance

To summarise the differences in performance across each task between the novice conditions (N_0 and N_1) in comparison to the baseline of performance from the experts (E_0), percent changes were calculated using the mean values from the all parks for each task (Table 5.12). A positive percentage in the table indicates that the task took longer to complete in comparison to the baseline of performance, while a negative percentage indicates the task took less time to complete. The conditions that performed the best in each task have been emphasized in the table. It should be noted that the percent changes for Scenario 2 Task 2 and Scenario 4 Task 3 could not be calculated as no data were collected for the novices without the iPad (N_0) or for baselines of performance (E_0) to compare against.

As seen in Table 5.12, novices using the iPad and irrigation management application (N_1) performed better than those without the iPad (N_0) for the majority of tasks. The only tasks where N_0 on average completed the tasks faster than N_1 were for Scenario 1 Tasks 2 and 3 (locating the point of connection and curb stopper respectively). These tasks involved locating equipment that is large and typically easy to find at the parks by simply looking around. For these tasks, N_1 participants used the GPS of the iPad and the interactive map of the irrigation management application to navigate around the park until they found the equipment, which slowed them down in comparison to N_0 who simply looked around until they had spotted the equipment.

Table 5.12: The percent change in mean performance between the respective novice conditions in comparison to the baseline of performance from experts at all parks for each task.

	N_0	N_1
Scenario 1 Task 1: find control cabinet	+125%	**+65%**
Scenario 1 Task 2: find point of connection	**+15%**	+66%
Scenario 1 Task 3: find curb stopper	**+42%**	+51%
Scenario 1 Task 4: find valve boxes	+26%	**-60%**
Scenario 2 Task 1: identify zone with dry patch	+195%	**-22%**
Scenario 2 Task 2: report watering time changes	N/A	N/A
Scenario 3 Task 1: identify zones to plant trees	+532%	**-28%**
Scenario 3 Task 2: determine if safe to install	+120%	**+11%**
Scenario 4 Task 1: identify zone with damage	+668%	**-24%**
Scenario 4 Task 2: determine replacement parts	+138%	**-18%**
Scenario 4 Task 3: report on repairs	N/A	N/A

Across all tasks, N_0 participants were slower than baseline performance by experts, which was expected as the novices were unfamiliar with the parks; however, not only did N_1 participants outperform N_0 on the majority of tasks, but they were actually able to complete half of the tasks even faster than the baseline of performance from experts. Furthermore, those same tasks also showed the greatest differences in performance between N_0 and N_1. The most dramatic example of this is for Scenario 4 Task 1, where participants were asked to identify in which irrigation zone a 'broken sprinkler' was located. Novices using the iPad and irrigation management application (N_1) were on average 24% faster than the expert performance for that task across all the parks, in comparison to novices without the iPad or application (N_0) which were on average 668% slower than experts in completing that task.

The results from the test scenarios emphasize the significant improvement in maintenance efficiency that can be achieved when using the irrigation management application for novice irrigation technicians unfamiliar with the parks, as well as the potential benefit for expert technicians that are knowledgeable of the parks with many of the maintenance activities covered by the test scenarios.

5.2 Survey Results

The results from the pre-test and completion surveys were analysed to see if there were any changes in the anxiety and confidence of the participants, as well as to gather their perceptions of the test scenarios and of using the irrigation management application.

5.2.1 Participant Confidence

The means and standard deviations of participant confidence and self-efficacy for using mobile technology and devices were calculated from the pre-test survey and completion survey (labelled as post-test) (Table 5.13).

Table 5.13: Means (M) and standard deviations (SD) of participant confidence and self-efficacy for using mobile technology and devices (1 = strongly disagree and 5 = strongly agree).

		Pre-test		Post-test	
I feel confident when ...		M	SD	M	SD
1.	Working on a mobile device (e.g. iPad, iPhone, Tablet, Smart Phone)	3.43	0.79	4.00	0.58
2.	Opening apps and using them	3.43	0.98	3.86	0.69
3.	Using the users guide when help is needed	3.00	1.00	3.43	1.13
4.	Learning to use a variety of apps	3.14	0.90	3.86	0.69
5.	Learning advanced skills within an app	2.86	1.07	3.29	1.11
6.	Writing simple apps for mobile devices	1.29	0.49	1.43	0.53
7.	Using mobile devices to write an email or take a picture	4.14	0.90	4.86	0.38
8.	Describing the function of mobile device interactions (e.g. touch, swipe, pinch, double-tap)	3.57	0.53	4.29	0.49
9.	Getting help when encountering problems in apps	2.86	0.69	3.14	1.21
10.	Explaining why an app will or will not run on a given mobile device (e.g. iPad vs. Android)	2.14	0.69	2.71	1.25
11.	Troubleshooting mobile device problems	2.57	0.98	2.57	1.40

The mean value of each of the responses increased by an average of 0.5 in the post-test (completion) survey compared to the initial responses from the pre-test survey, with the exception of the last question which remained the same. The average response from the pre-test survey was 2.99 (neither strongly disagree nor strongly agree), while the average response from the post-test (completion) survey was 3.49 (closer to strongly agree). While the small sample size of participants prevents us from drawing too many conclusions from these results, we can at least see that participants felt fairly confident about using mobile devices. Furthermore, the iPad and irrigation management application does not appear to have had a negative impact on the participants' confidence for using mobile technology.

5.2.2 Participant Anxiety

The means and standard deviations of participant anxiety towards using mobile technology and devices were calculated from the pre-test survey and completion survey (labelled as post-test) (Table 5.14). When comparing the post-test responses to the pre-test responses, we expect to see a decrease in the mean values for negatively-framed questions (1, 6, 9, 10, 11, 12, 13, 15, and 16) and an increase in the mean values for positively-framed questions (2, 3, 4, 5, 7, 8, 14, and 17), which would indicate a decrease in participant anxiety.

As we can see from the results in Table 5.14, the mean values for questions 1, 6, 10, 13, 15, and 16 have decreased as expected (by an overall average of 0.17), the mean values for questions 2, 4, 5, 7, 14, and 17 have increased as expected (by an overall average of 0.40), and the mean values for questions 3, 8, and 12 have remained the same. There were two responses which did not remain the same or change as anticipated. Question 9, "I would dislike working with machines that are smarter than I am", saw its mean value increase by 0.29, while question 11, "I have difficulty in understanding the technical aspects of computers or mobile devices", saw a 0.14 increase in its mean value. As with participant confidence in the previous section, the small sample size of participants limits the conclusions which can be drawn from these results; however, they still indicate that overall participants rated their anxiety towards mobile technology as being lower after using the iPad and irrigation management application.

Table 5.14: Means (M) and standard deviations (SD) of participant anxiety for using mobile technology and devices (1 = strongly disagree and 5 = strongly agree).

		Pre-test		Post-test	
		M	SD	M	SD
1.	I do not think I would be able to learn a computer programming language	2.71	0.49	2.57	0.98
2.	The idea of learning about computers and mobile devices is exciting	3.29	0.76	3.86	0.69
3.	I am confident that I can learn skills for computers and mobile devices	4.00	0.82	4.00	0.58
4.	Anyone can learn to use a computer or mobile device if they are patient and motivated	4.00	0.58	4.14	1.46
5.	Learning to operate computers or mobile devices is like learning any new skill, the more you practice, the better you become	4.14	0.69	4.86	0.38
6.	I am afraid that if I begin to use computers and mobile devices more I will become more dependent upon them and lose some reasoning skills	2.29	0.76	2.00	1.15
7.	I am sure that with time and practice I will be as comfortable working with computers or mobile devices as I am in working by hand	3.57	0.79	4.00	0.82
8.	I feel that I will be able to keep up with the advances happening in the computer field	3.57	0.98	3.57	0.79
9.	I would dislike working with machines that are smarter than I am	1.57	0.79	1.86	0.90
10.	I feel apprehensive about using computers or mobile devices	1.86	0.90	1.71	0.95
11.	I have difficulty in understanding the technical aspects of computers or mobile devices	2.43	0.98	2.57	0.79
12.	It scares me to think that I could cause the computer or mobile device to destroy a large amount of information by hitting the wrong key	1.86	0.90	1.86	1.21
13.	I hesitate to use a computer or mobile device for fear of making a mistake that I cannot correct	2.00	0.82	1.86	0.90
14.	If given the opportunity, I would like to learn more about and use computers and mobile devices more	3.86	0.69	4.00	0.82
15.	You have to be a genius to understand all the special keys contained on most computer terminals or mobile devices	1.57	0.79	1.43	0.53
16.	I have avoided computers and mobile devices because they are unfamiliar and somewhat intimidating to me	1.57	0.98	1.43	0.79
17.	I feel computers and mobile devices are necessary tools in both educational and work settings	4.29	0.76	4.71	0.49

5.2.3 Perceptions of Test Scenarios

The completion survey asked participants about their perceptions for each test scenario at parks they were unfamiliar with as Novices (conditions N_0 and N_1), and then asked the same questions for participants who had completed at least one test scenario as an Expert at a park (condition E_0). The first question of this section asked participants about their experiences during Scenario 1 where they had to locate major pieces of equipment at a park (e.g. control cabinet, curb stoppers, points of connection, and valve boxes), and the second question asked about Scenario 2 where participants had to determine which irrigation zones needed their watering time adjusted due to a dry patch in the grass. The third question asked participants about Scenario 3 where they had to determine if no irrigation equipment would be damaged if a new feature like a tree was planted at indicated areas, and then the fourth question asked about Scenario 4 which asked participants to identify which irrigation zone a damaged sprinkler was in and what replacement parts would be required. The means and standard deviations of the responses to questions 1 and 2 have been calculated and are shown in Table 5.15, and the means and standard deviations for question 3 and 4 are shown in Table 5.16, where 1 = significantly more time and 5 = significantly less time.

As seen in the results, when comparing the mean values across questions (a), (b), and (c) for each of the test scenarios (1, 2, 3, and 4), participants consistently rated their experiences when using the iPad and irrigation management application as being faster and taking less time in the parks when they did not have the application available. This pattern can be seen across both expert and novice experiences. Furthermore, when comparing the mean values between participants whom had expert and novice experiences versus only novice experiences, again participants consistently rated their experiences when using the irrigation management application as being faster and taking less time as novices in comparison to experts.

Question (d) for Scenarios 2 and 4 was used to determine how participants perceived the length of time spent creating maintenance logs as novices (since as described previously, data could not be collected for E_0 and N_0 conditions). Although participants did not have any previous experiences to compare against, the average mean response between the two scenarios was still 3.38 (standard deviation of 0.26), which places it between 3 = no noticeable difference and 4 = slightly less time on the 5 point scale used.

Additionally, when asked if there was any equipment that was easier to

Table 5.15: Means (M) and standard deviations (SD) for participant perceptions as Experts and Novices for test Scenarios 1 and 2 (1 = significantly more time and 5 = significantly less time).

		As Expert		As Novice	
		M	SD	M	SD
1.a	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks without the iPad?	2.75	0.50	1.86	0.69
1.b	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks when using the iPad and irrigation management app?	3.25	1.26	4.29	0.95
1.c	How would you rate the time spent completing these tasks when using the iPad and irrigation management app in comparison to when you completed these same tasks without the use of the iPad?	3.50	1.00	4.57	0.53
2.a	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks without the iPad?	2.50	0.58	2.14	0.69
2.b	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks when using the iPad and irrigation management app?	3.75	0.96	4.43	0.79
2.c	How would you rate the time spent completing these tasks when using the iPad and irrigation management app in comparison to when you completed these same tasks without the use of the iPad?	3.75	0.96	4.71	0.49
2.d	When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting which irrigation zone(s) required more watering. In comparison to how you would normally track or report which zones needed more water, how would you rate the overall time spent taking creating the maintenance logs using the iPad and app?	N/A	N/A	3.57	1.27

Table 5.16: Means (M) and standard deviations (SD) for participant perceptions as Experts and Novices for test Scenarios 3 and 4 (1 = significantly more time and 5 = significantly less time).

		As Expert		As Novice	
		M	SD	M	SD
3.a	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks without the iPad?	2.50	0.58	2.14	0.69
3.b	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks when using the iPad and irrigation management app?	3.75	0.96	4.57	0.76
3.c	How would you rate the time spent completing these tasks when using the iPad and irrigation management app in comparison to when you completed these same tasks without the use of the iPad?	3.75	0.96	4.71	0.79
4.a	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks without the iPad?	2.50	0.58	2.14	0.69
4.b	Compared to the time normally spent in parks that you maintain, how would you rate the time spent completing these tasks when using the iPad and irrigation management app?	3.75	0.96	4.43	0.79
4.c	How would you rate the time spent completing these tasks when using the iPad and irrigation management app in comparison to when you completed these same tasks without the use of the iPad?	3.75	0.96	4.43	0.79
4.d	When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting that the damaged sprinkler had been replaced. In comparison to how you would normally track or report which sprinklers had been replaced, how would you rate the overall time spent taking creating the maintenance logs using the iPad and app?	N/A	N/A	3.20	1.30

find in the parks when using the iPad and irrigation management application, the feedback from the participants was nearly unanimous: points of connection, valve boxes, curb stoppers, irrigation zones, and individual sprinkler head locations. This perception is supported by the results (for finding valve boxes and irrigation zones) seen in Tables 5.4, 5.5, 5.7, and 5.9. It is interesting to note that while the participants felt it was easier to find the points of connection and curb stoppers when using the iPad and irrigation management application, the results from Tables 5.2 and 5.3 show otherwise; the average times when using the iPad and irrigation management application (N_1) were not significantly faster than without the application (N_0) or compared to baseline expert performance (E_0). When asked the opposite question, if there was any equipment that was easier to find without the iPad and application, the only response was control cabinets (from two of the participants).

5.2.4 Perceptions of Overall Experiences

The completion survey asked participants about their overall experiences during the test scenarios. The first question in this section asked participants if they felt like they spent more time or less time overall in the parks when using the iPad and irrigation management application (1 = significantly more time and 5 = significantly less time). The mean was 4.57 with a standard deviation 0.53, which indicates that overall participants felt the iPad and irrigation management application helped them spend less time at the parks.

The second question asked participants how useful (if at all) it was to have the interactive map showing the locations and descriptions of the equipment in parks (1 = not useful at all and 5 = very useful). The mean was 4.86 with a standard deviation of 0.38, strongly indicating that they found this feature to be very useful. The third question asked participants how useful it was to have access to the park details. The mean of the responses was 4.29 with a standard deviation of 0.49, once again indicating that participants found this feature to be very useful.

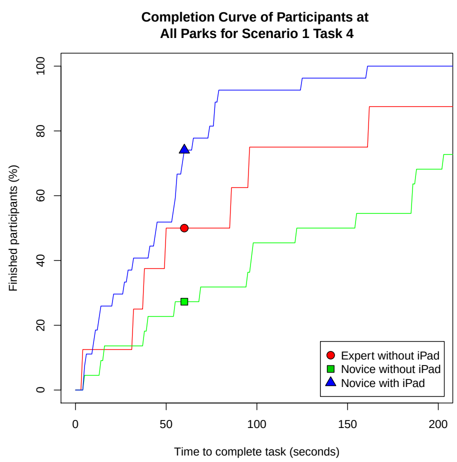
The fourth question asked participants how likely it was that they would continue to use the feature that allowed them to create maintenance logs of activities performed at parks (1 = highly unlikely and 5 = highly likely). The mean was 3.71 with standard deviation 1.38, which indicates that while participants may continue using this feature in the future, they are not as enthusiastic about it as the others in the irrigation management application.

When asked how useful it was to have the iPad out in the parks (fifth question with 1 = not useful at all and 5 = very useful), the mean response of participants was 4.86 with a standard deviation of 0.38. The sixth question asked participants how difficult was it to carry the iPad around in the parks (1 = significant difficulty and 5 = significantly easy). The mean for this question was 3.86 with standard deviation 0.90. The responses from these questions indicate that participants found the iPad to be a useful tool out in the parks and that it was relatively easy to carry it around with them.

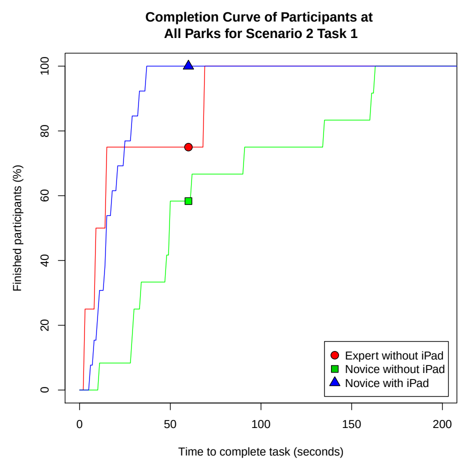
Finally, when participants were asked the seventh and last question of how likely are they to use the iPad and irrigation management application again in the future (1 = highly unlikely and 5 = highly likely), the mean response was 4.86 with a standard deviation of 0.38. This provides further indications that participants found the iPad and irrigation management application to be useful and will likely use it again in the future.

5.3 Further Discussion

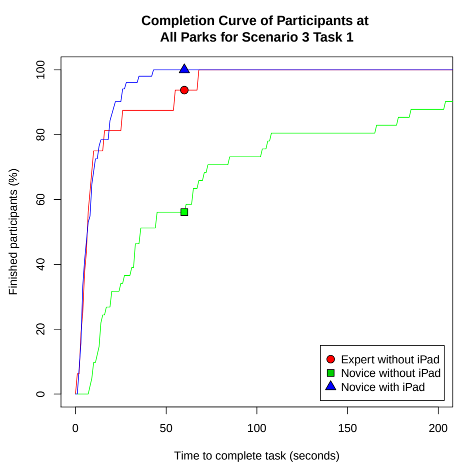
Looking at the data from a different perspective by focusing on the variations in completion times revealed additional insights into how the behaviour of the participants was changed by using the iPad and irrigation management application. As experts (E_0 condition) are more familiar with the parks than novices (N_0 and N_1 conditions), it was expected that they would have the fastest time to complete the tasks in each scenario. For some of the simpler tasks (for example, the first three tasks in Scenario 1), that was the case; however, for every other task from each of the scenarios, the novices with the iPad and irrigation management application (N_1) not only performed as well as or faster than novices without the iPad available (N_0), but in many cases actually outperformed experts (E_0) as well. This is demonstrated by the completion curves that have been generated for sample tasks from each scenario, which show the percentage of participants that have completed the task versus the length of time to complete the task (see Figure 5.1). For example, by one minute (60 seconds), 74% of N_1 participants had completed Task 4 of Scenario 1, compared to 50% of E_0 and 27% of N_0 respectively, shown in Figure 5.1(a). These results demonstrate that the irrigation management application allows irrigation technicians who are not familiar with the parks (novices) to perform as well as, or even better than, the irrigation technicians who have spent years of regular maintenance at those parks to become familiar with them (experts). This highlights the benefit of having the irrigation management application out in the parks, particularly for new irrigation technicians who are not yet familiar with the parks they are supposed to maintain.



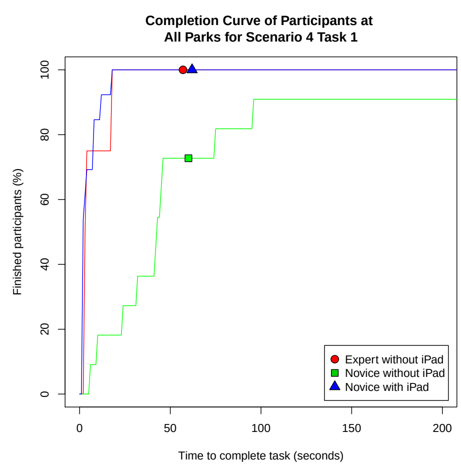
(a) Scenario 1 Task 4.



(b) Scenario 2 Task 1.



(c) Scenario 3 Task 1.



(d) Scenario 4 Task 1.

Figure 5.1: Sample completion curves for test scenarios, showing the percentage of participants finished versus the time to complete tasks in seconds. The percent finished at 60 seconds for each participant condition is highlighted by the respective symbols.

During the test scenarios, novices using the iPad and irrigation management application (N_1) made no mistakes or errors while completing the tasks, novices without the iPad (N_0) made on average one to two mistakes, and the baseline of performance from experts (E_0) only made a single mistake on average. All of the mistakes occurred during Scenario 1 Task 4 when they were asked to locate the valve box for a specified irrigation zone. For every other task, the length of time to complete the task varied but the participants made no errors otherwise.

To illustrate further the benefit of using the irrigation management application in the parks, the potential daily time savings can be calculated. As discussed previously in Section 2.5, irrigation technicians can be responsible for upwards of 80 individual parks, and since each park can have upwards of 70 unique irrigation zones, it is unrealistic to expect them to be able to memorise all the details and layouts for each of their parks. The following tasks are activities which irrigation technicians are most likely to perform on a daily basis:

– Locate valve boxes for particular irrigation zones (Scenario 1 Task 4)

– Identify irrigation zones within a dry or wet patch (Scenario 2 Task 1)

– Identify irrigation zones with damaged sprinklers (Scenario 4 Task 1)

Tasks which are unlikely to occur on a daily basis, such as those from Scenario 1 Tasks 1, 2, and 3 and Scenario 3, are excluded from the potential time savings calculation. Using the average percent change of novices using the irrigation management application (N_1) from Table 5.12 and the average baseline performance (E_0) from Tables 5.4, 5.5, and 5.9, the average time saved for each task is calculated at 73.41 seconds for Scenario 1 Task 1, 5.41 seconds for Scenario 2 Task 1, and 1.80 seconds for Scenario 4 Task 1, for a total average savings of 80.62 seconds. Based on discussions with the irrigation technicians, it can be reasonably assumed that they perform these tasks an average of five times per park and that they visit an average of 10 parks in a single day. Using these assumptions, the total time savings can be calculated at 4,031 seconds or just over one hour each day. This time savings is in comparison to the baseline expert performance (E_0) of irrigation technicians that are very familiar with their parks. If instead we compare the time spent using the irrigation management application (N_1) against new irrigation technicians unfamiliar with their parks (N_0), and we use the same numbers for times the tasks are performed and parks are visited, then the potential savings becomes 10,497 seconds or nearly three hours each day.

These time savings are only an estimate as irrigation technicians can visit up to 20 or more parks each day during their regular maintenance duties. However they still serve to demonstrate the potential benefit from using the irrigation management application in city parks.

An interesting observation that was noted during the test scenarios, and through the feedback from the completion survey, was the difference in attitudes of the irrigation technicians who had been working at the Kelowna Parks Services for several years compared to those of the newer staff. The long-term employees commented that while the irrigation management application was helpful and would be beneficial for new staff, they probably would not use it very much themselves. In comparison, newer employees repeatedly stated that they loved the application and looked forward to using the irrigation management application in their own parks. This difference in attitude is likely a result of the years of experience. The long-term irrigation technicians have been doing their jobs for several years and are very familiar with the layouts at their parks, so they do not see as much benefit from the application, whereas newer irrigation technicians, who are still learning the layouts of their parks, are excited for a tool that can help them become familiar with their parks faster and aid them in their maintenance activities.

Participants felt that the iPad and irrigation management application reduced the amount of time they spent in the parks, particularly for parks which participants were not familiar with and had no additional resources to aid them in their duties such as the as-built map at Whitman Glen Park. As well, the comments and feedback from the participants was overwhelmingly positive. Every participant stated that they recognized the potential of the irrigation management application to improve their irrigation practices out in the parks. Overall, participants found the application to be very useful and would likely use it again in the future.

Chapter 6

Conclusion

This thesis sought to demonstrate that providing real time mobile access to park data for irrigation technicians out in the field would improve maintenance efficiency in city parks. An overview of the commercial irrigation systems and of existing research into irrigation sustainability was explored in Section 2.1. While commercial systems offer a range of irrigation options from simple automated timers to more sophisticated weather-based controllers and sensor-based shut-off systems, they often have issues with deployment, high costs, low interoperability, and maintenance. Research efforts have seen success with automated irrigation systems that collect and monitor data for irrigated areas, automate the process of calculating watering requirements, and run the irrigation; however, these research efforts have focused more on agriculture and residential water users. There has been little research towards municipal irrigation in city parks, and the few projects which do again focus on automation to reduce water usage.

Irrigation sustainability in city parks requires more than just efficient water usage. Irrigation equipment needs continual maintenance and proper layout; the soil, plants, landscape, and climate at the parks needs to be considered; and most importantly, there needs to be a commitment from the people who manage and maintain the parks. Irrigation technicians are crucial for any improvements in efficiency and continued sustainability of the irrigation systems in city parks. However, they need to have the resources and tools available to them in order to make those decisions.

As discussed in Section 2.2, advances in mobile technology and the ubiquity of mobile devices provide new opportunities for irrigation technicians to manage their time and resources better out in the parks and help them improve their irrigation practices. Research efforts to develop mobile applications that aid field workers with management and maintenance activities have been quite successful, but they often fail to take into account usability concerns for mobile applications. Further research in Section 2.3 suggested using a hybrid approach of heuristic evaluation, scenario-based testing, and questionnaires as the best means for ensuring the usability of any developed mobile application. After considering the mobile development options in

Section 2.4, I developed a mobile-friendly web application for the employees of the Kelowna Parks Services department.

Described in Chapter 3, the irrigation management application provides irrigation technicians from the Parks Services department with real time mobile access to information on the parks that they maintain. That information included irrigated areas, categories and organizational classifications, and current, historic, and expected water usage for each park. As well, the descriptions, layouts, and GPS locations of all equipment in the parks was collected by myself and Kelowna Parks Services staff, and integrated into the irrigation management application to provide interactive maps of each park and allow GPS navigation with the mobile device to position the user in relation to the displayed equipment. Finally, the application provided users with the ability to create, view, and edit maintenance notes for each park using text and images.

To evaluate the effectiveness of the irrigation management application in aiding irrigation technicians with their maintenance activities and irrigation decisions in city parks, a user study was developed and performed with the Kelowna Parks Services department. Presented in Chapter 4, the study used a hybrid approach of questionnaires measuring participant confidence, anxiety, and perceptions (see Appendix C) and scenario-based tests which mimicked regular maintenance activities (see Section 4.1.5) to measure the length of time to complete tasks, the number of incorrect choices or errors, and the perceptions of the participants.

As highlighted by the analysis of results in Chapter 5, the irrigation management application allowed irrigation technicians unfamiliar with the parks to complete non-trivial tasks from the test scenarios much faster when using the iPad and application (N_1 condition) than without (N_0 condition). Furthermore, the irrigation management application allowed N_1 participants to perform as well as irrigation technicians with years of expertise at those parks (E_0 condition, without the iPad and application as baseline of performance), and in many cases actually outperform them. Participants had the perception that the irrigation management application helped them to spend a lot less time in the parks, even for some cases where the time results showed otherwise. The feedback from the participants was overall quite positive, and they believe that the irrigation management application will be a great tool to help new employees become knowledgeable about their parks in a lot less time, as well as to help existing staff when they have to maintain other parks outside of their regular responsibilities. The irrigation technicians of the Kelowna Parks Services department are excited to use this application in the future.

Future work and development of the irrigation management application will offer more support with generating different reports for water usage, park costs, and water use efficiency (see Section 3.3.5), explore the potential to adapt the application to work with mobile wearable technology such as Google Glass [Goo14], and examine the possibility of working with other cities to implement a version of the irrigation management application for their parks. As well, the study could be repeated with additional participants or adapted to perform the test scenarios at other parks in Kelowna.

In summary, the main contributions from this thesis include: the collection and integration of park and irrigation data, including the GPS locations of equipment at each park in Kelowna; the development and testing of a mobile application for park maintenance and irrigation management; and the development and implementation of a user study to evaluate the effectiveness of that application. In conclusion, by providing irrigation technicians with real time mobile access to information on the parks they maintain, as demonstrated by this thesis, they can improve the efficiency of their maintenance activities in city parks and simplify decisions regarding park irrigation and practices.

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Appendices

Appendix A

Letter of Support

City of Kelowna

December 5, 2013

Dr. Ramon Lawrence and Robert Ryan Trenholm,

I have reviewed your proposal, consent form, questionnaire and procedures for your study to see if a mobile iPad application can help irrigation employees improve their efficiency and sustainability in managing our parks.

I believe that there will be minimal risk to our employees or city parks by participating in this study. The study has my full support and that of the City of Kelowna and the Kelowna Parks Department.

All six of our full-time irrigation employees may participate in the study. In addition, the four parks which you can use for the tests are: *Whitman Glen Park*, *Knowles Heritage Park*, *Birkdale Park*, and *Tulameen Park*. These parks match your criteria for study (regularly maintained, average irrigated area, recent GPS information), and are representative of a typical park in the City of Kelowna. Other parks may also be substituted if required.

Looking forward to working with you,

[redacted]

Ted Sophonow

Park Services
1359 K.L.O. Road
Kelowna, BC V1W 3N8
TEL 250 469-8503
FAX 250-862-3335
Kelowna.ca

Appendix B

Consent Form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Participant Consent Form

Improving sustainability and efficiency in City of Kelowna parks using a mobile application

Who is conducting the study?

Principal Investigator:
Dr. Ramon Lawrence
Associate Professor - Computer Science
University of British Columbia Okanagan
Phone: (250) 807-9390
Email: ramon.lawrence@ubc.ca

Co-Investigator:
Robert Ryan Trenholm
Graduate Student - Computer Science
University of British Columbia Okanagan
Phone: (250) 515-1332
Email: ryan.trenholm@alumni.ubc.ca

Why are we doing this study?

We want to know if irrigation practices and maintenance efficiency can be improved in city parks by providing you (the field employees) with information about the parks that you maintain on an interactive mobile application on the iPad. The goal of the study is to see if by providing you with the application, can you be more efficient with some maintenance tasks and simplify decisions for the park irrigation.

How is the study done?

If you say 'Yes' to participate, you will be asked to complete a series of tasks related to your work. These tasks will mimic scenarios that you might encounter during your regular work at a park; finding equipment for regular maintenance, determining which irrigation zones may need additional water, whether it is safe for some trees to be planted in locations at the park, and repairing a damaged sprinkler head.

You will be asked to repeat these scenarios at up two parks which you regularly maintain, and at two parks which you do not. At one of each of those pairs of parks, you will be encouraged to use a mobile application on an iPad that was developed to provide you with information about the irrigation at the parks you maintain. The co-investigator will accompany you during these scenarios to record notes, observations, and the length of time to complete the scenarios. The goal of the study is evaluate the effectiveness of having information about the parks (via the application on the iPad): **we are not evaluating you or your ability to do your job**.

Initially you will be asked to complete a short survey to measure your comfort and confidence with using mobile devices. Then you will be given two hours to complete the scenarios at each park. After all of the scenarios have been completed at all four parks, you will be asked to complete a second short survey. The tests may be spread across multiple days based on your availability. The total time requirements will be a maximum of eight and three-quarter hours, not including travel time between parks.

What is done with the results?

Please note that this research is being completed as part of a graduate degree thesis. As such, the results will be reported in a graduate thesis (which is a public document) and may also be published in journal articles and books. However, only aggregated data will be included in the results, and no information which could potentially identify you will be included.

Are there any potential risks in participating?

We do not think there is anything in this study that could harm you or be bad for you. You will not be asked to perform any tasks or activities, or to use any equipment, that you would not normally encounter at your work and in your daily life. Additionally, we do not believe that any of the questions from the survey will upset you, but if you have any concerns, please let one of the staff know right away.

Are there any potential benefits in participating?

Taking part in this study may not directly benefit you, but the findings from this study may help Kelowna and other cities to improve their irrigation practices.

Will you get paid for taking part in this study?

To acknowledge the time you have taken out of your normal schedule to support this project, you will receive a $25 gift card for Tim Hortons.

How will we maintain your privacy?

All documents will be identified only by a code number (research ID) and kept in a locked filing cabinet. Participants will not be identified by name in any reports of the completed study. Additionally, no personal information will be collected during the study that could potentially identify you or connect you to the data that was gathered.

Who to contact if you have questions about the study?

If you have any questions or concerns about what we are asking of you, please contact the primary investigator or the co-investigator. The names, emails, and telephone numbers are listed at the top of the first page of this form.

Complaints or concerns about the study?

If you have any complaints about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 1-877-822-8598 or the UBC Okanagan Research Services Office at 250-807-8832.

Participant Consent and Signature

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason.

- Your signature below indicates that you have received a copy of this consent form for your own records.
- Your signature indicates that you consent to participate in this study.

____

Participant Signature   Date

____

Printed Name of the Participant Signature

____

Research ID

Appendix C

Questionnaires

C.1 Pre-test Survey

This survey is to be completed before you begin any of the test scenarios in the parks. There are **three sections** to this survey. Please answer each of the following questions honestly and to the best of your ability.

C.1.1 Confidence using Mobile Devices and Apps

Please indicate the extent to which you agree or disagree with the statements listed below using the following 5 point scale, where 1 = strongly disagree and 5 = strongly agree.

I feel confident when . . .		Strongly disagree				Strongly agree
1.	Working on a mobile device (e.g. iPad, iPhone, Tablet, Smart Phone)	1	2	3	4	5
2.	Opening apps and using them	1	2	3	4	5
3.	Using the users guide when help is needed	1	2	3	4	5
4.	Learning to use a variety of apps	1	2	3	4	5
5.	Learning advanced skills within a specific app	1	2	3	4	5
6.	Writing simple apps for mobile devices	1	2	3	4	5
7.	Using mobile devices to write an email or take a picture	1	2	3	4	5
8.	Describing the function of mobile device interactions (e.g. touch, swipe, pinch, double-tap)	1	2	3	4	5
9.	Getting help when encountering problems in apps	1	2	3	4	5
10.	Explaining why an app will or will not run on a given mobile device (e.g. iPad vs. Android)	1	2	3	4	5
11.	Troubleshooting mobile device problems	1	2	3	4	5

C.1.2 Anxiety using Mobile Devices and Apps

Please indicate the extent to which you agree or disagree with the statements listed below using the following 5 point scale, where 1 = strongly disagree and 5 = strongly agree.

		Strongly disagree				Strongly agree
1.	I do not think I would be able to learn a computer programming language	1	2	3	4	5
2.	The idea of learning about computers and mobile devices is exciting	1	2	3	4	5
3.	I am confident that I can learn skills for computers and mobile devices	1	2	3	4	5
4.	Anyone can learn to use a computer or mobile device if they are patient and motivated	1	2	3	4	5
5.	Learning to operate computers or mobile devices is like learning any new skill, the more you practice, the better you become	1	2	3	4	5
6.	I am afraid that if I begin to use computers and mobile devices more I will become more dependent upon them and lose some reasoning skills	1	2	3	4	5
7.	I am sure that with time and practice I will be as comfortable working with computers or mobile devices as I am in working by hand	1	2	3	4	5
8.	I feel that I will be able to keep up with the advances happening in the computer field	1	2	3	4	5
9.	I would dislike working with machines that are smarter than I am	1	2	3	4	5
10.	I feel apprehensive about using computers or mobile devices	1	2	3	4	5
11.	I have difficulty in understanding the technical aspects of computers or mobile devices	1	2	3	4	5

12.	It scares me to think that I could cause the computer or mobile device to destroy a large amount of information by hitting the wrong key	1	2	3	4	5
13.	I hesitate to use a computer or mobile device for fear of making a mistake that I cannot correct	1	2	3	4	5
14.	If given the opportunity, I would like to learn more about and use computers and mobile devices more	1	2	3	4	5
15.	You have to be a genius to understand all the special keys contained on most computer terminals or mobile devices	1	2	3	4	5
16.	I have avoided computers and mobile devices because they are unfamiliar and somewhat intimidating to me	1	2	3	4	5
17.	I feel computers and mobile devices are necessary tools in both educational and work settings	1	2	3	4	5

C.1.3 Familiarity with Selected Parks

Please note that this information is only being used to aid in the analysis of the collected data; it will not be used to identify you or to connect you to any collected results.

Please indicate if you have any familiarity with the following parks. Specifically, are you currently responsible for any of these parks, have you had any past responsibilities at any of these parks, or have you visited any of these parks outside of your regular work. Check all that apply.

	Currently responsibile?	Had past responsibility?	Have visited outside of work?
Birkdale Park	☐ Yes	☐ Yes	☐ Yes
Knowles Heritage Park	☐ Yes	☐ Yes	☐ Yes
Tulameen Park	☐ Yes	☐ Yes	☐ Yes
Whitman Glen Park	☐ Yes	☐ Yes	☐ Yes

If you answered yes to any of the parks above, please answer the additional questions where appropriate for those parks. Answer as best you can (e.g. last week, one month ago, a year ago, daily, weekly, or never).

	How recently have you been responsible?	What was the duration your responsibility?	How often have you visited?	When was the last time you visited?
Birkdale Park				
Knowles Heritage Park				
Tulameen Park				
Whitman Glen Park				

C.2 Completion Survey

This survey is to be completed after you have finished performing all the scenarios for each of the test conditions. There are *five sections* to this survey, in addition to an open feedback section at the end. Please answer each of the following questions honestly and to the best of your ability.

C.2.1 Unfamiliar parks

This set of questions will be about your experiences during the test scenarios at the parks which you are not familiar with and have not regularly maintained. Please indicate your perception of the time spent completing the tasks using the following 5 point scale, where *1 = significantly more time*, *2 = slightly more time*, *3 = no noticeable difference*, *4 = slightly less time*, and *5 = significantly less time*.

Question 1:

Recall the first scenario for locating the major pieces of equipment at a park (e.g. control cabinet, curb stoppers, points of connection, and valve boxes).

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) Were there any specific pieces of equipment which were easier to find in the parks **when using the iPad and irrigation management app?** If so, please list them.

e.) Were there any specific pieces of equipment which were easier to find in the parks **without the iPad?** If so, please list them and indicate why.

Question 2:

Recall the second scenario for determining which irrigation zones needed to have their watering time adjusted due to a dry patch in the grass.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting which irrigation zone(s) required more watering. In comparison to how you would normally track or report which zones needed more water, **how would you rate the overall time spent taking creating the maintenance logs *using the iPad and app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

Question 3:

Recall the third scenario for determining if it was safe (i.e. no equipment would be potentially damaged) to plant trees where indicated in the parks.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

Question 4:

Recall the fourth scenario for identifying which irrigation zone the 'damaged' sprinkler was in and which replacement part(s) would be required for repairs.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting that the 'damaged' sprinkler had been replaced. In comparison to how you would normally track or report which sprinklers had been replaced, **how would you rate the overall time spent taking creating the maintenance logs *using the iPad and app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

C.2.2 Familiar parks

This set of questions will be about your experiences during the test scenarios at the parks which you are not familiar with and have not regularly maintained. Please indicate your perception of the time spent completing the tasks using the following 5 point scale, where *1 = significantly more time*, *2 = slightly more time*, *3 = no noticeable difference*, *4 = slightly less time*, and *5 = significantly less time*.

If you were not familiar with any of the parks (Birkdale, Knowles Heritage, Tulameen, and Whitman Glen) used in the test scenarios, then you may skip this section.

Question 1:

Recall the first scenario for locating the major pieces of equipment at a park (e.g. control cabinet, curb stoppers, points of connection, and valve boxes).

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) Were there any specific pieces of equipment which were easier to find in the parks **when using the iPad and irrigation management app?** If so, please list them.

____

____

____

e.) Were there any specific pieces of equipment which were easier to find in the parks **without the iPad?** If so, please list them and indicate why.

____

____

____

Question 2:

Recall the second scenario for determining which irrigation zones needed to have their watering time adjusted due to a dry patch in the grass.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting which irrigation zone(s) required more watering. In comparison to how you would normally track or report which zones needed more water, **how would you rate the overall time spent taking creating the maintenance logs *using the iPad and app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

Question 3:

Recall the third scenario for determining if it was safe (i.e. no equipment would be potentially damaged) to plant trees where indicated in the parks.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

Question 4:

Recall the fourth scenario for identifying which irrigation zone the 'damaged' sprinkler was in and which replacement part(s) would be required for repairs.

a.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *without the iPad*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

b.) Compared to the time normally spent in parks that you maintain, **how would you rate the time spent completing these tasks *when using the iPad and irrigation management app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

c.) How would you rate the time spent completing these tasks *when using the iPad and irrigation management app* in comparison to when you completed these same tasks *without the use of the iPad*?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

d.) When using the iPad and irrigation management app, you were asked to create a maintenance log for reporting that the 'damaged' sprinkler had been replaced. In comparison to how you would normally track or report which sprinklers had been replaced, **how would you rate the overall time spent taking creating the maintenance logs *using the iPad and app*?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

C.2.3 Overall Experience

These questions will be about your overall experiences at the parks during the test scenarios.

Question 1:

Consider the overall amount of time spent at the parks to complete the scenarios. **Did you feel like you spent more time or less time at the parks when using the iPad and irrigation management app** in comparison to *without the iPad* at the parks?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significantly more time	*Slightly more time*	*No noticeable time difference*	*Slightly less time*	*Significantly less time*

Question 2:

Recall the interactive map available on the iPad and irrigation management app showing the locations and descriptions of all the equipment at the parks. **In your opinion, how useful (if at all) was it to have access to this information?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Not useful at all	*Slightly not useful*	*No opinion either way*	*Slightly useful*	*Very useful*

Question 3:

Recall the additional irrigation information available through the iPad and irrigation management app, which included the address, number of irrigation zones, irrigated and total area, and the current and historic water usage for each park. **In your opinion, how useful (if at all) was it to have access to this information?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Not useful at all	*Slightly not useful*	*No opinion either way*	*Slightly useful*	*Very useful*

Question 4:

Recall the ability to create maintenance logs using the iPad and irrigation management app to report which irrigation zone(s) required more watering and which 'damaged' sprinklers were replaced. **How likely are you to continue using this feature of the app?**

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Highly unlikely	*Slightly unlikely*	*No opinion either way*	*Slightly likely*	*Highly likely*

Question 5:

In your opinion, how useful (if at all) was it using the iPad out in the parks?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Not useful at all	*Slightly not useful*	*No opinion either way*	*Slightly useful*	*Very useful*

Question 6:

In your opinion, how difficult or easy was it to carry the iPad around with you while out in the parks?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Significant difficulty	*Slightly difficult*	*No opinion either way*	*Slightly easy*	*Significantly easy*

Question 7:

How likely are you to use the iPad and this irrigation management application again in the future?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Highly unlikely	*Slightly unlikely*	*No opinion either way*	*Slightly likely*	*Highly likely*

C.2.4 Confidence using Mobile Devices and Apps

Now that you have used the irrigation management application on the iPad at the parks, please indicate once more the extent to which you agree or disagree with the statements listed below using the following 5 point scale, where *1 = strongly disagree* and *5 = strongly agree*.

	I feel confident when ...	Strongly disagree				Strongly agree
1.	Working on a mobile device (e.g. iPad, iPhone, Tablet, Smart Phone)	1	2	3	4	5
2.	Opening apps and using them	1	2	3	4	5
3.	Using the users guide when help is needed	1	2	3	4	5
4.	Learning to use a variety of apps	1	2	3	4	5
5.	Learning advanced skills within a specific app	1	2	3	4	5
6.	Writing simple apps for mobile devices	1	2	3	4	5
7.	Using mobile devices to write an email or take a picture	1	2	3	4	5
8.	Describing the function of mobile device interactions (e.g. touch, swipe, pinch, double-tap)	1	2	3	4	5
9.	Getting help when encountering problems in apps	1	2	3	4	5
10.	Explaining why an app will or will not run on a given mobile device (e.g. iPad vs. Android)	1	2	3	4	5
11.	Troubleshooting mobile device problems	1	2	3	4	5

C.2.5 Anxiety using Mobile Devices and Apps

Now that you have used the irrigation management application on the iPad at the parks, please indicate once more the extent to which you agree or disagree with the statements listed below using the following 5 point scale, where *1 = strongly disagree* and *5 = strongly agree*.

		Strongly disagree				Strongly agree
1.	I do not think I would be able to learn a computer programming language	1	2	3	4	5
2.	The idea of learning about computers and mobile devices is exciting	1	2	3	4	5
3.	I am confident that I can learn skills for computers and mobile devices	1	2	3	4	5
4.	Anyone can learn to use a computer or mobile device if they are patient and motivated	1	2	3	4	5
5.	Learning to operate computers or mobile devices is like learning any new skill, the more you practice, the better you become	1	2	3	4	5
6.	I am afraid that if I begin to use computers and mobile devices more I will become more dependent upon them and lose some reasoning skills	1	2	3	4	5
7.	I am sure that with time and practice I will be as comfortable working with computers or mobile devices as I am in working by hand	1	2	3	4	5
8.	I feel that I will be able to keep up with the advances happening in the computer field	1	2	3	4	5
9.	I would dislike working with machines that are smarter than I am	1	2	3	4	5
10.	I feel apprehensive about using computers or mobile devices	1	2	3	4	5

11.	I have difficulty in understanding the technical aspects of computers or mobile devices	1	2	3	4	5
12.	It scares me to think that I could cause the computer or mobile device to destroy a large amount of information by hitting the wrong key	1	2	3	4	5
13.	I hesitate to use a computer or mobile device for fear of making a mistake that I cannot correct	1	2	3	4	5
14.	If given the opportunity, I would like to learn more about and use computers and mobile devices more	1	2	3	4	5
15.	You have to be a genius to understand all the special keys contained on most computer terminals or mobile devices	1	2	3	4	5
16.	I have avoided computers and mobile devices because they are unfamiliar and somewhat intimidating to me	1	2	3	4	5
17.	I feel computers and mobile devices are necessary tools in both educational and work settings	1	2	3	4	5

C.2.6 Open feedback

If you have any additional comments, concerns or feedback you would like to give, please feel free to use the space provided below.