Wireless Feasibility Study

Prepared for Ames, Iowa

December 2007

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1. Executive Summary

The City of Ames seeks to use wireless technology to provide free wireless Internet access for residents at public facilities and to enhance internal City communications needs for mobile City users. This report outlines the cost to implement, operate, and maintain selected wireless hot-spots. In addition, the report provides an overview of the range of community wireless options considered and pursued by various municipalities.

1.1 Study Methodology

The City engaged Columbia Telecommunications Corporation (CTC) in fall 2007 to review options for a community WiFi network and to examine the implementation and on-going operational costs for such a network. To conduct this analysis, CTC's staff of engineers and analysts undertook the following tasks:

- Conducted in-person interviews with the City Information Services Department to discuss the role of WiFi within the City.
- Reviewed various business models and their fit to the City's goals and objectives.
- Evaluated experiences of other communities with City-wide WiFi to better understand the potential in Ames.
- Evaluated various public facilities, including City parks, recreation centers, and school facilities for the feasibility of deploying WiFi.
- Prepared a conceptual WiFi design to better understand the potential costs required to deploy a hotspot WiFi network.
- Prepared a bill-of-materials for the recommended hotspot sites.
- Outlined on-going operational and maintenance costs.

These activities were undertaken by CTC in the fall of 2007.

1.2 Summary of Study Recommendations

As a result of the activities summarized above, CTC prepared the analysis, recommendations, and considerations provided below. These recommendations and considerations offer a variety of perspectives on how to meet internal needs and enhance the availability WiFi within the community.

1.2.1 Pursue Deployment of a Public Hot-Spot WiFi Network

CTC recommends that the City deploy WiFi hot-spots at selected public locations in order to meet many of the goals identified during this analysis – both with respect to internal City communications needs and those of the public. This strategy is consistent

with the City's stated goals and parameters, is technically and financially viable, and entails relatively low cost and risk.[1]

The public hot-spot strategy meets many of the City's goals without deployment of a City-wide network, a far more costly and complex proposition. Many of the internal potential uses identified do not require City-wide WiFi coverage. A hot-spot deployment in the identified public areas costs approximately $221,000[2]. This amount is less than 7 percent of the $3.4[3] million estimate for a City-wide deployment. In addition, the 2007 Citizens Satisfaction Survey conducted by the City of Ames almost 50 percent of the respondents supported the concept of selected hot-spots in the City.

CTC does not recommend the City of Ames pursue a City-wide WiFi network to support a retail Internet service. In addition to the implementation cost considerations, the Ames Internet market does not appear conducive for a City-wide WiFi network.

1. The Ames Internet market expects a level of performance greater than what WiFi can deliver to homes. Data and experience in other localities demonstrate that the primary market is likely to be users who currently use dial-up and who would upgrade to WiFi as an entry-level, higher-speed option. In the 2007 Citizens Satisfaction Survey conducted by the City of Ames it was revealed that dial-up likely represents less than 16 percent of current Ames Internet users.
2. Maintaining cash-flow from a City-wide WiFi network is a challenge and is unlikely sustainable in Ames. Our financial analysis conducted for other communities indicate at least 25 to 45 percent of all households would have to subscribe to WiFi for the enterprise to function in a stand-alone manner and maintain cash flow — a penetration rate that is likely to be difficult to obtain given the relatively small (16 percent) market for a WiFi product in Ames.
3. Use of public service and public safety applications that require remote access capabilities are likely to increase- and may start a foundation for City-wide WiFi or similar technology. Public service and public safety application needs can be initially supported by the hot-spot approach. Further the number of wireless access nodes required to support a City-wide WiFi network for public service-safety is substantially lower that a City-wide WiFi network which supports indoor access for Internet access.

In Appendix C of this study, we have provided an overview of the status of the WiFi industry and an overview of business models pursued by various municipalities.

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[1] The public hot-spot option advances the availability of wireless Internet access for residences and visitors – as well as providing a platform to support internal City needs.
[2] Does not include operation and maintenance costs.
[3] Does not include required subscriber hardware and installation, operation, maintenance, marketing, and business management costs.

1.2.2 Deploy a Hotspot WiFi Network Beginning with the "Low-Hanging Fruit" Sites

CTC recommends deploying a public hotspot network in phases beginning with those sites identified in this report with the least cost and greatest feasibility. By beginning with these "low-hanging fruit" sites, the City develops an operations and maintenance approach, minimizes the initial cost of deployment and maximizes availability of community WiFi.

Low-hanging fruit sites include those sites where the City has existing network connectivity and where WiFi access is most beneficial to the public and the City. These first phase sites include the Ames Community Center, the Municipal Pool/Ames High School, and the Ames/ISU Ice Arena.[4] The estimated cost to implement these sites is $59,760.

After deploying the first phase sites, CTC recommends equipping the power plant and water towers to support access to the remaining proposed hot-spot locations. The estimated cost is $27,800 for the power plant and $46,160 for the water towers. The remaining hot-spot locations and estimated cost for each are:

- Campus Town Court at an estimated incremental cost of $3,970
- Brookside Park at an estimated incremental cost of $15,970
- Tom Evans Plaza at an estimated incremental cost of $4,835
- Ada Hayden Memorial Park at an estimated incremental cost of $3,970
- Ames Youth Sports Complex at an estimated incremental cost of $4,835
- Aquatic Center at an estimated incremental cost of $10,875
- County Gables Park at an estimated incremental cost of $11,405
- Bandshell Park at an estimated incremental cost of $4,835
- Emma McCarthy Lee Park at an estimated incremental cost of $8,405
- Moore Memorial Park at an estimated incremental cost of $4,835
- Daley Park and Greenbelt at an estimated incremental cost of $4,835
- Inis Grove Park at an estimated incremental cost of $8,405

Coverage area for the outdoor sites is dependant upon foliage, terrain, and other conditions. Typically a user will be able to obtain Internet service when they are outdoors and within 250 feet to 400 feet of the WiFi access point.

1.2.3 Maximize the Use of the City's Existing Resources in Deploying the Public Hotspot Network

The City has an extensive array of resources that significantly decrease the cost and risk in deploying a public hotspot WiFi network. Within the next six months the City will deploy WiFi at City Hall to meet the City's internal needs. CTC recommends expanding

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[4] A more detailed implementation approach is provided in Section 4 of this Report.

on this experience to bring additional WiFi connectivity to both the public and the City. The City also has fiber optic, copper, and wireless infrastructure that currently support communications between City facilities.

The City of Ames has personnel resources that serve to greatly decrease the cost of implementation and operation of the WiFi network. The City's Information Services Department has personnel with experience monitoring and maintaining an array of communications platforms. It is possible to leverage this experience to manage and maintain the WiFi network. The City's Electric Service Department is a critical component of the cost-efficient installation of both power connections to WiFi equipment and utility poles for mounting radios. Their experience and expertise in running an electric utility and their assistance in similar projects, such as the siren system, lowers the overall cost of implementation and removes barriers to increasing WiFi coverage within the City.

In addition to personnel resources, access to City infrastructure such as the tall backhaul sites including the power plant stack and the water towers, allow installation of WiFi radios in areas where wired connectivity is not available.[5] If access was not available it would greatly increase reoccurring operational costs of the public hotspot WiFi network. These structures also minimize the need for additional wired connectivity.

1.3 Cost Summary

The cost of deploying a hotspot WiFi system to 15 public areas is approximately $220,895. The initial costs include equipment, installation, integration, and engineering. CTC anticipates annual operations and maintenance costs at approximately $71,950. Annual costs include staffing, equipment replacement, service contracts, and leased fees for the Internet connection.

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[5] Backhaul is a method of transporting information from a remote location, such as a WAP, to a central communication point (i.e., central office or internet access point).

2. Public Hotspot WiFi Design

This section examines the engineering considerations and estimates the implementation costs of constructing a public hotspot WiFi network. Additional information regarding technology options is contained in Appendix A.

2.1 Design Methodology

In September and October of 2007, CTC met with City officials to determine the scope and needs of the City's wireless network. From these meetings it was determined that a hotspot WiFi network that provided wireless Internet access to both the public and City personnel most benefits the community. The City provided CTC with a list of 25 potential sites where WiFi access may benefit the public and the City.

In September 2007, CTC initially surveyed each facility to determine the features of each site and to prioritize the sites based on the benefit and usefulness of WiFi at each facility. CTC also reviewed the City's existing assets and the feasibility of deploying WiFi within the City. Section 2.2 outlines our preliminary findings.

In October 2007, CTC performed a detailed site and implementation survey. CTC met with City officials to review the preliminary design and analyze the City's existing communications infrastructure. CTC also surveyed each site that was suitable for WiFi from our preliminary survey to:

- Analyze the locations at each facility needing coverage;
- Review the existing City communications at each site, if available;
- Investigate the use of City structures for providing wireless backhaul;
- Perform line of sight surveys at each location for wireless backhaul; and
- Analyze each facility for implementation requirements, such as power, mounting space, etc.

Section 2.3 outlines the system-level design for providing WiFi access to public facilities.

2.2 Preliminary Findings

The terrain in Ames is fairly flat with gradual elevation changes. The City has a very mature tree line. This poses some difficulty with WiFi coverage because foliage significantly decreases the coverage of wireless signal. In surveying the town, CTC noted that several local businesses offer WiFi service as an incentive to customers. In addition, the presence of Iowa State University attracts a population that is more technologically savvy than other cites of similar size and geography. These factors tend to indicate that the population is generally familiar with WiFi technology and would use additional WiFi coverage if available.

CTC also noted that the City has created a first class system of parks and recreational facilities. The parks are well maintained, equipped with modern amenities, and heavily used by the public. WiFi coverage provides another incentive for residents to use these facilities.

2.2.1 Review of Existing City Network

Prior to the site survey, CTC performed a preliminary review of the City's existing network and assets to determine how to facilitate WiFi deployment using City resources.

The City operates a fiber optic and copper network infrastructure that provides wired connectivity between City facilities. The City uses this infrastructure to provide data connectivity, telephone connectivity, and Internet access. Where the City does not have the necessary wired infrastructure to support a facility, the City has either leased connectivity from a third party telecommunications provider, such as Qwest, or deployed point-to-point wireless communication links.

The City has two point-to-point wireless communication links both originating from the power plant stack and terminating at the Parks and Recreation Administration Building and the Water Pollution Control. The height of the Power Plant stack compared to the terrain and other structures in Ames makes it ideal for establishing wireless connectivity to remote sites. In addition to the power plant stack, the City also owns three water towers in town. These provide excellent mounting locations for wireless equipment.

CTC analyzed the possibility of using the tower structures to create wireless links to the proposed WiFi sites to provide backhaul for the WiFi network. Because the North Dakota Avenue water tower may decommissioned in the future, CTC did not include the tower in its analysis.

2.2.2 Preliminary Site Survey

The City of Ames initially proposed 25 sites that would potentially provide a benefit to the public and City employees by having WiFi coverage. CTC performed an initial site survey of each of the 25 proposed sites to determine the features of each location, whether the sites were suitable for WiFi deployment, and whether the facility type warranted the deployment of WiFi.

While performing the site surveys, CTC prioritized each site based on the amount of use of each facility based on each location's amenities and the amount of park visitors predicted year round. The priorities were then reviewed by the City of Ames. Based on this metric CTC developed the following priority scheme.

Table 1: Preliminary Site Survey Metric

Priority	Description
A	WiFi supports benefits beyond public access
B	Year round traffic, facilities sufficient to allow for laptop use
C	Seasonal traffic, facilities sufficient to allow for laptop use
D	Seasonal Traffic, facilities might be sufficient to allow for laptop use
F	Seasonal traffic, facilities marginal for laptop use
Site NA	Not built at this time or limited access
DUP	Public access already available

After surveying each site, CTC developed the following priority list based on our observations of each site and feedback from the City of Ames.

Table 2: Initial Prioritization of City Sites

UID	Description	Address	Indoor	Outdoor	Both	Priority
			Location Type			
1	Ames Community Center	515 Clark Ave	x			A
2	Campus Town Court	204 Welch Ave		x		A
3	Ames Municipal Pool/ Ames High School	20th & Ridge			x	B
4	Ames/ ISU Ice Arena	1507 Gateway Hills Park Dr	x			B
5	Brookside Park	1325 6th Street		x		B
6	Tom Evans Plaza	340 Main St		x		B
7	Aquatic Center	13th Street & Ridgewood Ave			x	B
8	Country Gables Park	500 Crystal Street		x		B
9	Ada Hayden Heritage Park	5205 Grand Ave		x		C
10	Ames Youth Sports Complex	800 Billy Sunday Rd		x		C
11	Bandshell Park	125 E. 5th Street		x		C
12	Emma McCarthy Lee Park	3400 Ross Road		x		C
13	Moore Memorial Park	3050 Northridge Parkway		x		C
14	Daley Park and Greenbelt	340 Wilder Boulevard		x		D
15	Inis Grove Park	24th & Duff		x		D
16	River Valley Park	725 E. 13th Street				F
17	South River Valley Park	1200 East 13th Street				F
18	Lloyd Kurtz Park	3710 Hyde				F
19	Ames Animal Shelter	325 Billy Sunday Rd				F
20	Carr Pool & Park	1610 Meadowlane				F
21	Hutchinson Park	4517 Hutchinson Street				F
22	Moore Park	1101 Beach Avenue				F
23	Ames Municipal Airport	2508 Airport Dr				DUP
24	Ames Public Library	515 Douglas Ave				DUP
25	Calhoun Park	4320 Dawes Dr				Site NA
		Total	2	11	2	

From our site analysis CTC determined that 13 sites met the A, B, or C priority for the deployment of WiFi. Two sites were considered priority D sites and the City should determine whether they merit the addition of WiFi access to enhance public and City wireless connectivity. Six sites were either not constructed or developed to a point where WiFi would be beneficial or were not suitable for WiFi construction. WiFi coverage is also already available at two sites, the Ames Public Library and the Municipal Airport.

In the 2007 Citizens Satisfaction Survey conducted by the City of Ames, respondents were asked if they support hot-spots at eight locations. The survey results are compared to CTC prioritization is shown in Table 3.

Table 3: Citizen Satisfaction Survey Priority

Description (Site)	Priority	Survey Support Percentage
Tom Evans Plaza	B	71
Brookside Park	B	69
Ada Hayden Heritage Park	C	62
Bandshell Park	C	65
River Valley Park	C	51
Moore Memorial Park	C	48
Emma McCarthy Lee Park	C	44
Ames/ISU Ice Arena	B	31

From the initial list of 25 sites, CTC, in consultation with City staff, narrowed the list of potential sites to 15 locations where WiFi benefits both the public and City personnel. From our preliminary survey and review of the City's existing network and assets, CTC developed a system-level design for providing WiFi access.

2.3 WiFi System Design

CTC proposes the following system-level design that uses point-to-multipoint wireless technology to provide backhaul to the selected WiFi locations. The proposed design maximizes the reuse of the City's existing network infrastructure and is scalable to additional WiFi hot-spots or other network applications in the future.

The generic architecture of the network is WiFi access points (WAPs). These WAPs provide wireless internet at City locations using WiFi standards based technology, which has been incorporated in most laptops and PDAs available on the consumer market. From the WAP, backhaul is needed to get the Internet traffic from the WiFi site back to the WiFi Internet connection at City Hall. At locations where the City has network connectivity, the WiFi design uses the existing connection to connect back to City Hall. Point-to-multipoint wireless equipment is in place at locations where no connectivity is present. Figure 1 depicts the general architecture.

Figure 1: WiFi System Generic Architecture
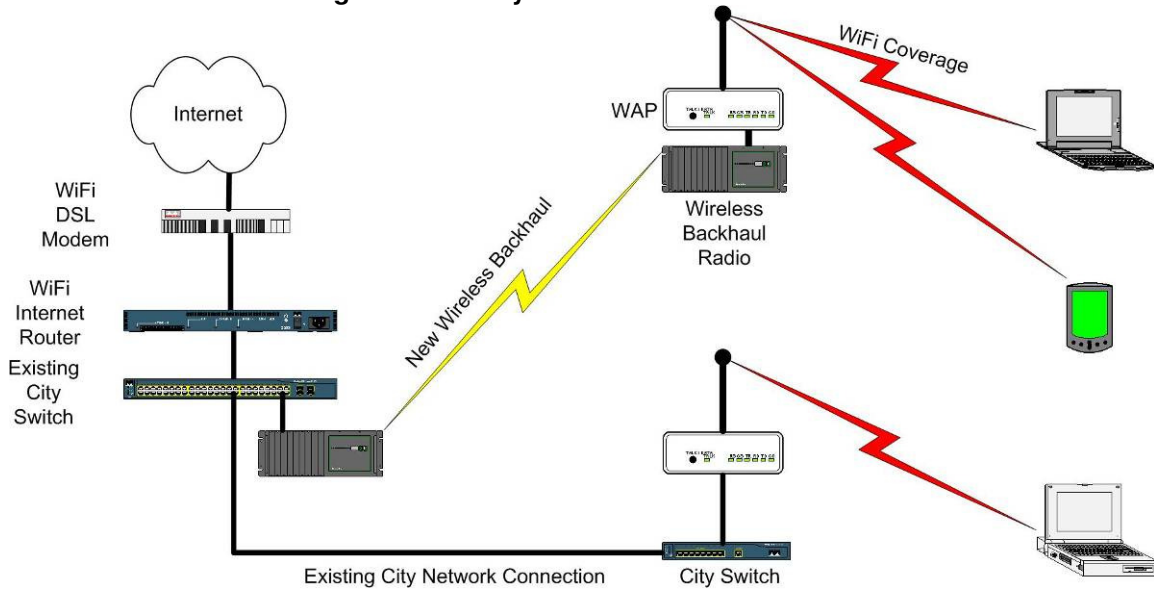
CTC recommends purchasing a business class asymmetrical DSL service from the City's existing internet service provider to provide WiFi Internet access. This DSL service separates WiFi internet traffic from the City's existing Internet connectivity and can also act as a failover Internet connection to the City's bonded T1 internet connection. Asymmetrical DSL service also provides greater downstream bandwidth, which is typical of the traffic patterns associated with public WiFi usage, at a lower cost than symmetrical T1 services. In the event that DSL is not available or cost prohibitive, cable modem service provides an equivalent service at a similar price. CTC also recommends purchasing an additional bonded T1 for Internet access for City personnel.

In order to establish point-to-multipoint wireless connectivity in areas where WiFi is required, it is necessary to install microwave radio equipment at high elevations to achieve the required line of sight. CTC selected the power plant stack and two water towers, the Bloomington water tower and the MAC water tower, as locations where line of sight is achievable to many point within the City. Between the water towers and the power plant stack, point-to-point wireless equipment provides network connectivity back into the City's existing network. Point-to-multipoint radio equipment installed at the water towers and power plant stack connects back to the City WiFi sites. A similar point-to-multipoint radio installed at each WiFi site receives network connectivity. The point-to-multipoint radio connects to the WAP, which provides WiFi coverage to the public and City employees. Figure 2 illustrates the wireless connectivity at a park facility.

Figure 2: An Example of Wireless Connectivity to a City Park
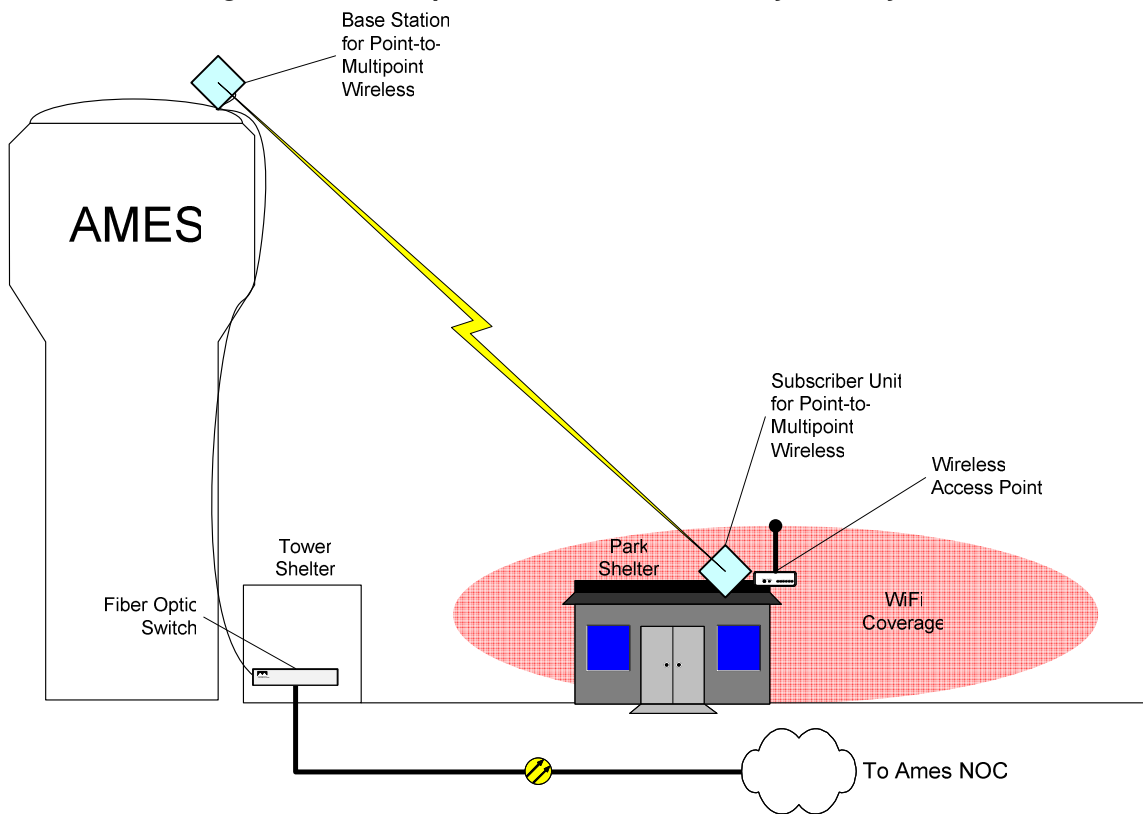
At each WiFi location, the point-to-multipoint radio equipment and WAP can either be installed within an existing structure, such as a park shelter, or mounted in an environmental enclosure on a pole or outside structure. Figure 3 shows an environmental enclosure for a hotspot WiFi application.

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Figure 3: Environmental Enclosure for Outdoor WiFi Hot-spots

Section 3 of this report details CTC's recommended installation procedures for each of the WiFi locations.

DSL lines provide Internet connectivity to those locations where network connectivity is not already available and line of sight to one of the water towers or the power plant smoke stack is not possible. CTC recommends that the City evaluate those locations where DSL is needed to determine whether the monthly recurring cost of the DSL circuit justifies WiFi connectivity at those locations.

2.3.1 WiFi Network Integration

CTC recommends that the City incorporate the proposed WiFi hotspot network into the City's plans for deploying WiFi within City Hall. The Information Services Department informed CTC that within 6 months the City plans to deploy WiFi for public and City use within City Hall. The City Hall system as currently designed can be expanded to include providing WiFi access at other hotspot locations. CTC recommends this approach in order to maximize the use of existing network infrastructure and to leverage the City's existing experience with managing and maintaining wireless access point equipment.

The proposed WiFi network equipment and the City's existing wire line network equipment are manufactured by Cisco. As part of adding WiFi in City Hall, the City plans to purchase a wireless LAN controller to manage and monitor WiFi access points at City Hall. Adding Cisco WAPs at the hotspot locations and connecting them back to the City's network permits use of the same type of controller and one network management platform to control both applications. Further it eliminates the need the need for additional training with another vendor's equipment and management platform.

The Cisco wireless LAN controller is capable of segmenting wireless traffic in order to provide Internet access to the public and limit access to the City's network only to authorized City personnel. This method allows the same network infrastructure to be used to support both types of users.

It is important to note that while the City plans to deploy Cisco access points in City Hall, other manufacturers offer similar products that provide the similar functionality. CTC recommends that the City deploy the same vendor technology at the hotspot locations as the City Hall access point system.

3. WiFi Implementation Plan

CTC conducted a site survey of the proposed hotspot locations to develop an implementation plan for deploying WiFi. The section outlines the steps necessary for deploying WiFi at the 15 sites identified in our preliminary site analysis.

At each potential location line of sight was verified back to one of the water towers or the power plant stack. CTC also determined mounting structures for the WiFi equipment as well as determined if suitable power was available.

Table 4 summarizes the results of our detailed site survey. The following section outlines the steps needed to implement WiFi at each location.

Table 4: Detailed Site Survey Summary

UID	Description	Address	Location Type			WAP Type (Quantity)				Priority	Add Public WiFi (Yes/No)	Existing City Network Site	LOS to Power Plant	LOS to North Water Tower	LOS to West Water Tower
			Indoor	Outdoor	Both	Indoor	External, AC Power, Mount on Existing Structure	External, AC Power, Install New Pole	External Solar Power						
1	Ames Community Center	515 Clark Ave	x			2				A	Yes		Y		
2	Campus Town Court	204 Welch Ave		x			1			A	Yes		Y		
3	Ames Municipal Pool/ Ames High School	20th & Ridge			x	1				B	Yes		Y		
4	Ames/ ISU Ice Arena	1507 Gateway Hills Park Dr	x			1				B	Yes		Y	Y	
5	Brookside Park	1325 6th Street		x			2			B	Yes				Y
6	Tom Evans Plaza	340 Main St		x			1			B	Yes				Y
7	Aquatic Center	13th Street & Ridgewood Ave			x	2	1			B	Yes		Y		
8	Country Gables Park	500 Crystal Street		x					1	B	Yes				
9	Ada Hayden Heritage Park	5205 Grand Ave		x			1			C	Yes				
10	Ames Youth Sports Complex	800 Billy Sunday Rd		x			1			C	Yes		Y		
11	Bandshell Park	125 E. 5th Street		x			1			C	Yes		Y		
12	Emma McCarthy Lee Park	3400 Ross Road		x				1		C	Yes				Y
13	Moore Memorial Park	3050 Northridge Parkway		x			1			C	Yes		Y	Y	
14	Daley Park and Greenbelt	340 Wilder Boulevard		x			1			D	Yes				Y
15	Inis Grove Park	24th & Duff		x					1	D	Yes		Y		
16	River Valley Park	725 E. 13th Street								F	No		Y		
17	South River Valley Park	1200 East 13th Street								F	No		Y		
18	Lloyd Kurtz Park	3710 Hyde								F	No			Y	
19	Ames Animal Shelter	325 Billy Sunday Rd								F	No				
20	Carr Pool & Park	1610 Meadowlane								F	No				
21	Hutchinson Park	4517 Hutchinson Street								F	No				
22	Moore Park	1101 Beach Avenue								F	No				
23	Ames Municipal Airport	2508 Airport Dr								DUP	No				
24	Ames Public Library	515 Douglas Ave								DUP	No				
25	Calhoun Park	4320 Dawes Dr								Site NA	No				
		Total	2	11	2	6	10	2	1						

3.1 Site-by-Site Implementation Plan

3.1.1 Ames Power Plant

The Ames Power Plant, located at 200 East 5th Street, is one of the tallest structures in Ames and houses some of the City's existing wireless equipment. The City has network connectivity at the top of the power plant stack through a fiber optic run. From the top of the power plant stack the three City water towers are visible and line of sight can be established. In addition to the water towers the following sites are clearly visible:

- Ames Youth Sports Complex
- Bandshell Park
- Community Center
- Tom Evans Plaza

CTC recommends installing two point-to-point microwave radios that aim toward the Bloomington and MAC water towers. CTC recommends using a 2.4 GHz unlicensed point-to-point wireless such as the Proxim Tsunami Quickbridge or equivalent hardware. CTC recommends installing the point-to-point radio equipment on the 9th floor of the

power plant stack. The point-to-point radio equipment can either be mounted to the parapet wall or on poles mounted to the parapet. From the radios, waterproof Category 5 Ethernet cables should be run through conduit back to the network switch on the 9th floor. At the existing Ethernet switch, the power injectors for the point-to-point wireless radios will provide power to the radios and connect the radios to the existing City network. Figure 4 depicts the point-to-point radio installation.

Figure 4: Power Plant Point-to-Point Wireless Link Installation Diagram
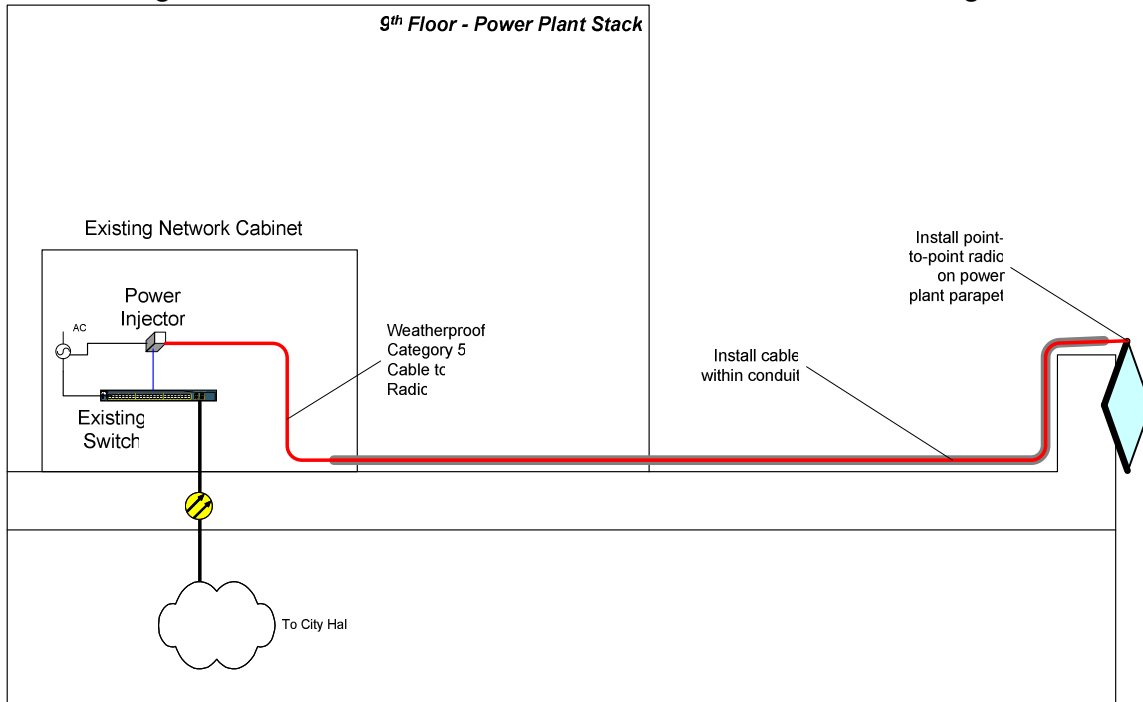
CTC recommends installing the point-to-multipoint wireless radios in the same manner as the point-to-point system. CTC recommends installing three 5.3 GHz point-to-multipoint base stations on the 9th floor of the power plant stack such as the Proxim Tsunami MP.11 5054 or equivalent hardware. Each base station supports multiple WiFi hot-spots within a sector providing near 360 degree coverage.

 All cables running to the point-to-multipoint base stations are run in conduit.

3.1.2 Bloomington and MAC Water Towers
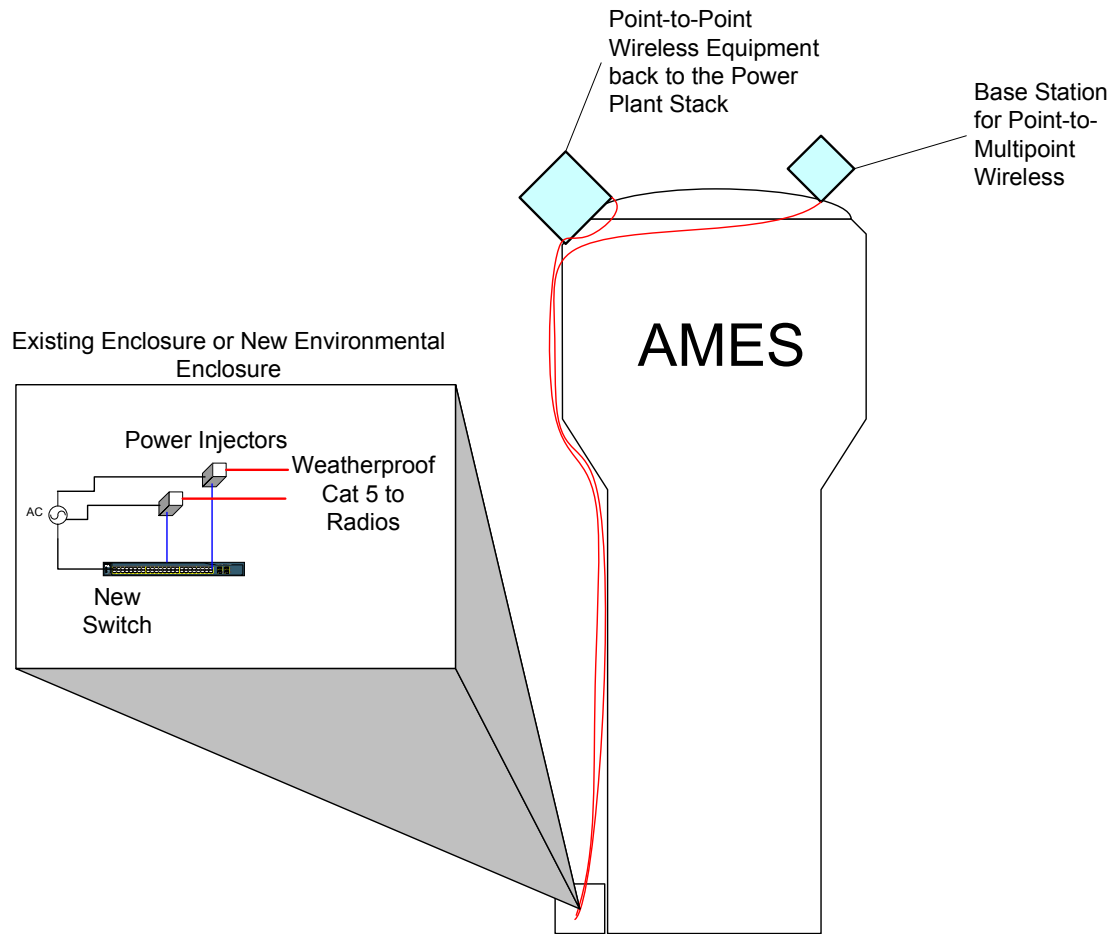
The Bloomington and MAC water towers are located at 2521 Bloomington Road and 900 South 500th Street respectively, and provide additional wireless connectivity to sites not in line-of-sight of the power plant stack.

The project requires installing point-to-point radios at the top of the two towers and pointed back toward the power plant stack. This radio provides network connectivity

with the City network.   Figure 5 shows an overview of the installations at the water towers.

Figure 5: Water Tower Installation Diagram

Point-to-Point Wireless Equipment back to the Power Plant Stack

Base Station for Point-to-Multipoint Wireless

AMES

Existing Enclosure or New Environmental Enclosure

Power Injectors

Weatherproof Cat 5 to Radios

AC

New Switch

At the Bloomington Water Tower two point-to-multipoint base stations in 180 degree sectors provide near 360 degree coverage from the tower. At the MAC water tower one base station provides 180 degrees of coverage as the water tower sits at the edge of the City limits, where 360 degree coverage is not necessary.

3.1.3 Ames City Hall

The City Hall is located at 515 Clark Avenue. City Hall serves as the center of the City's IT network and houses the majority of its network users. At City Hall, wireless access points within the Police Department provide wireless access to users. To provide outdoor wireless coverage for police vehicles an access point was added to the garage. The City currently has deployed Cisco 1230 access points, and plans to expand the current system in City to cover the conference rooms, Council Chambers, and other areas to provide wireless access to City employees and the public. The City also plans to deploy a Cisco

wireless LAN controller to better manage and maintain the access points within City Hall.

In order to accommodate the additional access points deployed for the WiFi hotspot system, CTC recommends purchasing an additional 25 access point wireless LAN controller to support the hotspot system and any future hotspot deployments. Each WAP communicates back to the wireless LAN controller for network configuration and management.

3.1.4 Ames Community Center

The Ames Community Center is part of the City Hall complex. The Community Center consists of a gymnasium, fitness center, multipurpose rooms, and an auditorium. Existing Category 5 data drop cables run to the gymnasium and auditorium from a City Hall wiring closet. Two access points, one located in the corner of the gymnasium by the fitness center and one located in the stage area or control room of the auditorium would provide coverage for the gymnasium, fitness center, auditorium, and likely the multipurpose rooms. Figures 6 and 7 denote the proposed locations for access point installation.

Figure 6: Gymnasium Access Point Location

Figure 7: Auditorium Access Point Location

The City may choose to modify the locations of the access points within the Community Center for aesthetic or power considerations. Relatively short changes in locations should not affect the overall WiFi coverage.

3.1.5 Campus Town Court

Campus Town Court is located at 204 Welch Avenue, adjacent to Fire Station 2. The location is located near the center of the Iowa State University (ISU) campus. The Information Services Department has unsuccessfully attempted to create a wireless link from the Power Plant to Fire Station 2. The Fire Station is surrounded by high rise buildings and line of sight cannot be achieved. Upon performing a site survey at Campus Town Court, we determined that line of sight is not achievable from the Power Plant or either water tower.

In order to install a wireless access point at Campus Town Court, it is necessary to either increase the capacity of the existing Fire Station T1 or add a DSL connection. Due to capacity restrictions on the existing T1 line to Fire Station 2, we do not recommend using the T1 connection to provide connectivity to the wireless access point without increasing the capacity of the circuit. A bonded T1 provides access to a WAP installed on the outside of the Fire Station, while also increasing the network capacity to the Fire Station. This increased capacity may benefit Fire Station personnel especially during ISU events occurring in Campus Town.

Installing a separate DSL connection enables Internet access to the WAP from Fire Station 2. The DSL connection is separate from the Fire Station T1, and does not affect Fire Station traffic.

Figure 8 shows the potential WAP mounting location on Fire Station 2.

Figure 8: Campus Town Antenna Mounting Location

3.1.6 Ames Municipal Pool/Ames High School

The Ames Municipal Pool is connected to Ames High School, 1921 Ames High Drive. The pool offers aquatic recreation to the public when not in use by the school. The City has fiber optics to the school, but has not activated the fiber. CTC recommends activating the fiber and using the network connectivity to provide backhaul for the wireless access point. Currently the City is using a DSL connection to provide connectivity to the municipal pool. One access point provides coverage for the entire pool area. CTC recommends placing the wireless networking equipment within the pool office and running cables to the wireless antenna to prevent damage to the equipment from the high level of humidity at the pool.

If the City desires expansion of wireless coverage beyond the pool, additional access points are needed. For example, the football stadium may be a location where WiFi would be beneficial. The City needs to work with the School District to install WiFi at other locations at the high school as the School District may have network access and security considerations with providing WiFi access on school grounds.

3.1.7 Ames/ISU Ice Arena

The Ames/ISU Ice Arena is located at 1507 Gateway Hills Park Drive, adjacent to the City Parks and Recreation Administration Building. The Parks Administration building is serviced by a 5.8 GHz point-to-point wireless link from the Power Plant. The Ice Arena is serviced by a point-to-point copper link from the Administration building. Within the Ice Arena, Category 5 network drops provide network connectivity throughout the building. We recommend using existing Category 5 wiring or new wiring to connect a wireless access point to the existing City network. One access point provides adequate coverage for the entire Ice Arena. The access point is mounted in the Ice Arena where power and aesthetics dictate.

3.1.8 Brookside Park

Brookside Park is located at 1325 6th Street and is one of the larger parks in Ames with three shelters, a skateboard park, three little leaguer baseball diamonds, and a lighted baseball diamond. The park has a relatively low elevation and a mature tree line. Line of sight is not feasible from ground level to any of the backhaul sites. CTC recommends using the rooftop of the CyRide building as a point-to-multipoint base station. From the rooftop of the CyRide line of sight is achieved to the light posts at the skateboard park and the baseball diamond. CTC recommends attaching the point-to-point wireless antenna to the light posts. The antennas connect to an environmental enclosure on the poles that house the point-to-point wireless radio and the wireless access point. The antenna for the wireless access point is mounted to the side of the enclosure to provide WiFi coverage for the skateboard park and the parking lot, and the baseball diamond and possibly for the little league fields. Figure 9 shows the point-to-multipoint connectivity from the CyRide building.

Figure 9: Brookside Park Connectivity Overview

Due to the mature trees within Brookside Park, it may be difficult to establish wireless connectivity to the shelters and other areas of interest within the park. One option is to construct fiber optics or copper lines from the Skateboard Park or baseball diamond wireless access point to the areas where WiFi is desired. With wired connectivity, WiFi access points are set up in areas where wireless connectivity cannot reach.

3.1.9 Tom Evans Plaza

Tom Evans Plaza is located at 340 Main Street within the Ames Business District. The site is a small park area that contains benches and seating areas. The northern part of the park has line of sight to the Power Plant stack. We recommend mounting the point-to-point wireless antenna to the light pole in the parking lot behind Main Street. The antenna can connect to an environmental enclosure mounted to the light pole that houses the point-to-point wireless radio and the wireless access point. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the park and possibly the surrounding businesses. Figure 10 shows the lamp post proposed for equipment mounting.

Figure 10: Proposed Pole for WiFi Mounting at Tom Evans Park
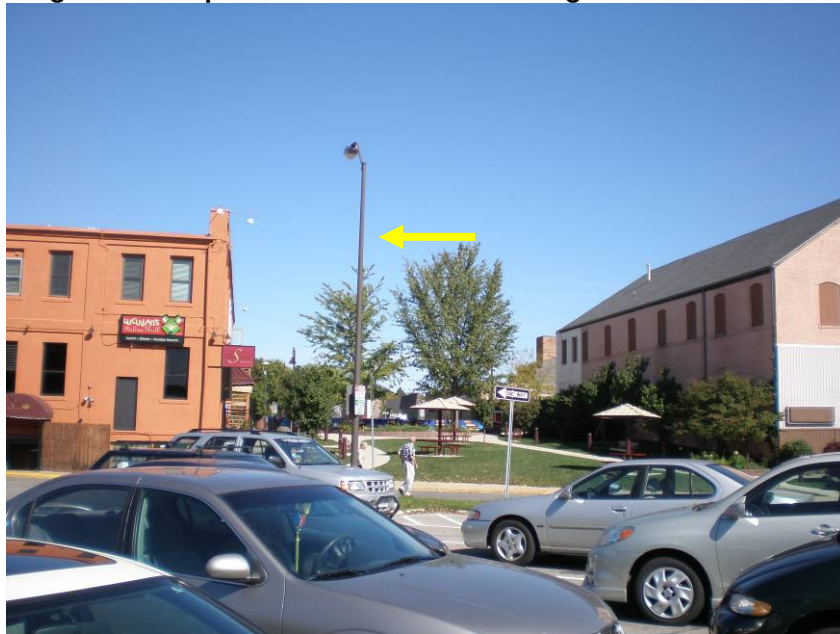
3.1.10   Aquatic Center

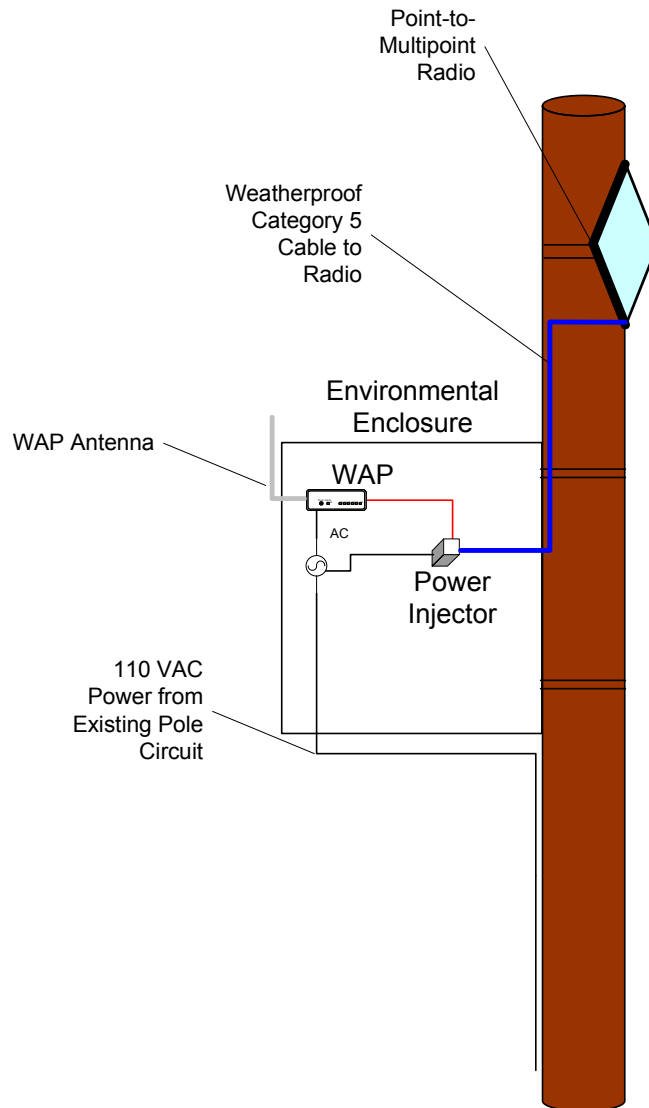The City is constructing a new outdoor Aquatic Center on 13th Street to provide aquatic recreational facilities to residents.   Based on the preliminary design of the Aquatic Center, WiFi hotspots would be beneficial to the Aquatic Center. CTC envisions three WiFi access points providing coverage to the Aquatic Center. For budgetary purposes, we envision two of the hotspots being installed within buildings and shelters at the aquatic center and one access point providing outdoor coverage.   Access point connectivity can be provided through the City's planned network connection at the Aquatic Center. CTC recommends performing a detailed WiFi design once final plans for the Aquatic Center have been completed.

3.1.11   Country Gables Park

Country Gables Park is small recreational facility in the southern part of the City. WiFi coverage would be beneficial at the Country Gables as the recreational facility becomes increasing used and developed. CTC recommends installing a 40-foot pole and placing the point-to-point wireless antenna at the top of the pole.[6] The antenna can connect to an environmental enclosure on the pole that houses the point-to-point wireless radio and the wireless access point. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the park. Figure 11 shows a typical pole mount application for a hot-spot network.

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[6] CTC was unable to verify line of sight to the power plant stack.

Figure 11: Typical Pole Mounted Hotspot Installation

Point-to-Multipoint Radio

Weatherproof Category 5 Cable to Radio

Environmental Enclosure

WAP Antenna

WAP

AC

Power Injector

110 VAC Power from Existing Pole Circuit

Solar panels may be attached to the pole to provide electrical power to the wireless access point depending on the availability of commercial power.   For budgetary purposes, CTC included the cost of solar panels for Country Gables Park.

3.1.12   Ada Hayden Heritage Park

Ada Hayden Heritage Park is a large park facility located at 5205 Grand Avenue. The park is mostly a nature preserve and lake with a shelter located near the park entrance. From the shelter, the tree line blocks the view of the Bloomington Water Tower. Line of sight can be achieved from the western side of the parking lot, but the range of the WiFi coverage may not be great enough to cover the shelter from this area.

If WiFi coverage is desired at the park shelter, a DSL connection would be needed to provide internet connectivity to the WAP.

3.1.13   Ames Youth Sports Complex

The Ames Youth Sports Complex is a large athletic facility located at 800 Billy Sunday Road. The facility contains nine baseball and softball diamonds, multiple soccer fields, a concession stand, and a facilities building. There is line of sight from the facilities building to the Power Plant stack. CTC recommends installing the point-to-multipoint wireless antenna at the top of the facilities building. Figure 12 shows the proposed location for the antenna placement.

Figure 12: Proposed Antenna Mounting Location at Ames Youth Sports Complex

The antenna connects to either an environmental enclosure mounted to the side of the facilities building or to equipment housed in the facilities building. The wireless access point antenna is mounted to the side of the enclosure or the top of the facilities building depending on the equipment location chosen. The WiFi access point will likely provide coverage for the stands at the baseball diamond and the area around the concession stand. If additional coverage is needed more units may be deployed.

3.1.14   Bandshell Park

Bandshell Park is located at 125 East 5th Street, adjacent to the Power Plant. The park contains a playground and an amphitheater. There is clear line of sight from the amphitheater to the power plant stack. CTC recommends mounting the point-to-point wireless antenna on the back of the roof of the amphitheater. The antenna can connect to either an environmental enclosure mounted to the roof of the amphitheater or the

equipment can be housed within the amphitheater. The wireless access point antenna is mounted to the front of the amphitheater. The WiFi access point will likely provide coverage for amphitheater and seating area around the amphitheater.
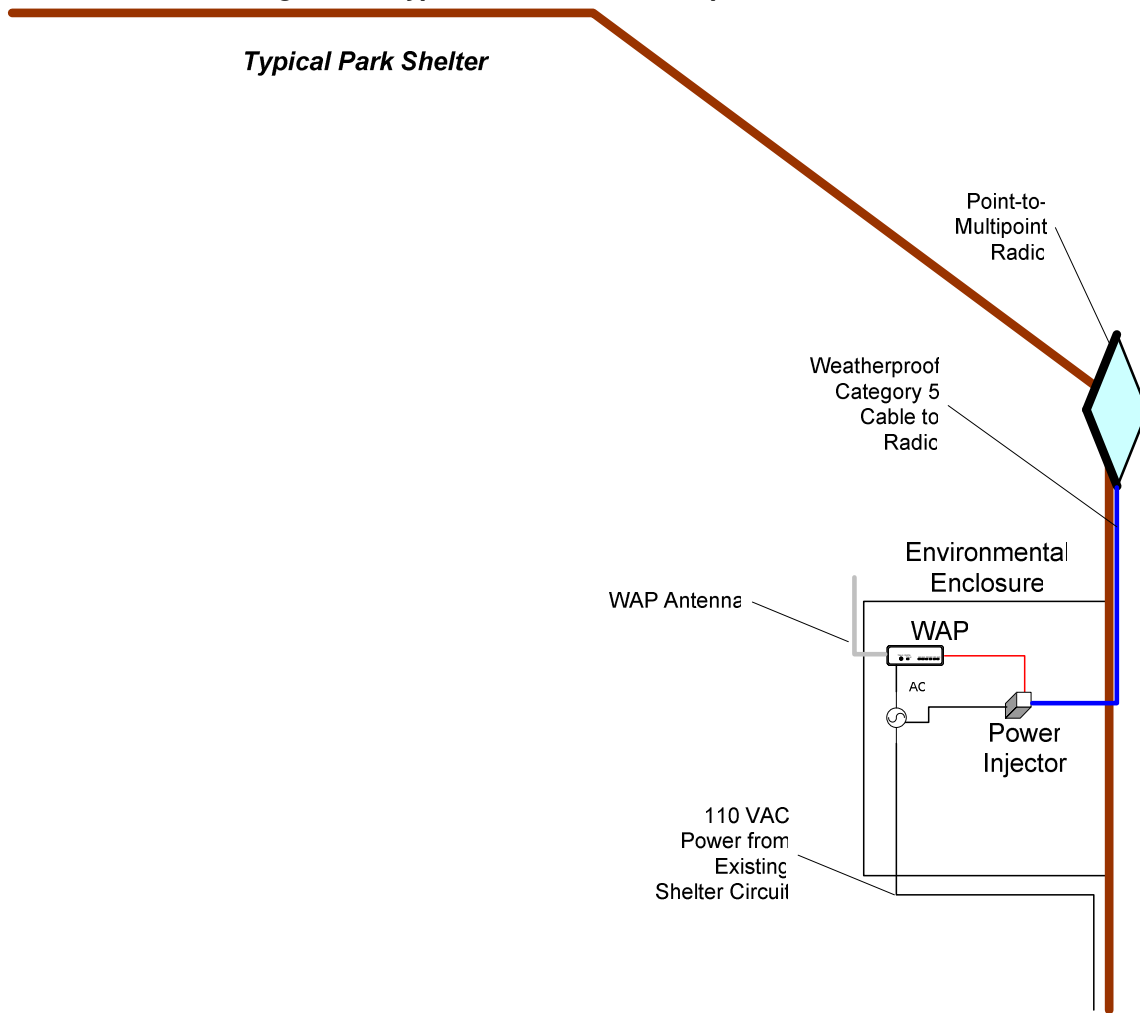
3.1.15   Emma McCarthy Lee Park

Emma McCarthy Lee Park is located at 3400 Ross Road and contains two shelters and lighted tennis courts. The park contains one shelter at the top of the hill and the tennis courts and other shelter at the bottom. The lower shelter and tennis courts do not have line of sight to the Power Plant stack of the water towers due to their elevation and the mature tree line. There is also no line of sight from the upper shelter to the lower shelter and tennis courts. From approximately 40 feet above ground elevation at the upper shelter and parking lot, line of sight can be achieved to the MAC water tower. CTC recommends that if WiFi coverage of the park is required that the City install a 60-foot pole and install the point-to-point wireless antenna at approximately 50 feet. The antenna can connect to an environmental enclosure on the pole that houses the point-to-point wireless radio and the wireless access point. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the both the upper parking lot and upper shelter.

If WiFi connectivity is needed at the bottom shelter or tennis courts, an option is to construct fiber optics or copper lines from the upper shelter wireless access point to the areas where WiFi is desired. With wired connectivity, WiFi access points can be set up in areas where wireless connectivity cannot reach.

3.1.16   Moore Memorial Park

Moore Memorial Park is located at 3050 Northridge Parkway and contains a large shelter. From the shelter, both the Bloomington water tower and the Power Plant stack are clearly visible. CTC recommends placing the antenna for the point-to-point link on the roof of the shelter. From the antenna it is possible to run cable to an environmental enclosure mounted to the rafters of the shelter. The wireless access point and point-to-point wireless radio are stored in the enclosure. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the shelter and surrounding areas of the park. Figure 13 shows a typical installation at a park shelter for providing WiFi access.

Figure 13: Typical Park Shelter Hotspot Installation

Typical Park Shelter

Point-to-Multipoint Radio

Weatherproof Category 5 Cable to Radio

Environmental Enclosure

WAP Antenna

WAP

AC

Power Injector

110 VAC Power from Existing Shelter Circuit

3.1.17   Daley Park and Greenbelt

Daley Park and Greenbelt is located at 340 Wilder Boulevard and has a playground and shelter on the western side of the park. The shelter has line of sight to the MAC Water Tower. CTC recommends mounting the point-to-point wireless antenna at the corner of the shelter roof facing the water tower. Figure 14 shows our recommended mounting location.

Figure 14: Proposed Antenna Mounting Location at Daley Park and Greenbelt

The antenna can connect to an environmental enclosure mounted to the rafters of the shelter that houses the point-to-point wireless radio and the wireless access point. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the shelter and playground.

3.1.18   Inis Grove Park

Inis Grove Park is located at 24th Street and Duff Avenue and is a large park containing three shelters, lighted tennis and basketball courts, soccer fields, and playgrounds. Due to the elevation and mature tree line surrounding the park, none of the water towers or the Power Plant stacks are visible from ground level. At the parking lot on Duff Avenue at approximately 40 feet above ground elevation, line of sight is achievable to the Power Plant stack. If WiFi connectivity is desired, CTC recommends installing a 60-foot pole near the shelter to achieve line of sight. Near the top of the pole, CTC recommends installing a point-to-point wireless antenna. The antenna connects to an environmental enclosure on the pole that houses the point-to-point wireless radio and the wireless access point. The wireless access point antenna is mounted to the side of the enclosure to provide WiFi coverage for the parking lot, shelter and possibly for the soccer fields.

At the lighted tennis and basketball courts, line of sight is not achievable to any of the water towers or the Power Plant. To provide connectivity, a DSL connection is needed.

3.2 Implementation Phasing

The modular design of the WiFi hotspot system allows the City to look at a phased approach for the deployment of hot-spots within the City. CTC recommends the following phased deployment approach based on the priority of sites and the technical feasibility of deploying WiFi at each location.

3.2.1 Perform Central WiFi Network Configuration and Installation

Prior to network deployment, CTC recommends installing the business class asymmetrical DSL service and a separate WiFi router at the City Hall Data Center. The WiFi router connects to one of the City's existing router or firewalls in order to receive traffic from the WiFi VLAN and to act as a redundant Internet connection to the City's network.

As part of the initial network deployment, CTC recommends testing and configuring the wireless LAN controller to ensure that the hotspot WiFi access points are properly configured and communicating with the controller. CTC recommends setting up a pilot access point at City Hall or the Community Center and testing the configuration and security settings to ensure that traffic and user access are properly configured.

3.2.2 Add WiFi Hot-spots at Existing Network Sites

CTC recommends prioritizing the connection of the WiFi access points at those locations where the City already has network connectivity. This approach eliminates potential network connectivity issues associated with WiFi deployment and can be performed while preparations are being made for deploying the wireless connectivity between tower locations.

CTC recommends beginning with the Community Center, Ames Municipal Pool, and the Ice Arena. During deployment CTC recommends monitoring the WiFi traffic over the network to ensure that the WiFi traffic does not interfere with City network traffic and to adjust the WiFi traffic bandwidth accordingly.

CTC recommends constructing the Aquatic Center once it is constructed and the City's network connection is in place.

3.2.3 Install Point-to-Multipoint Radio Equipment at the Power Plant

It is necessary to install point-to-multipoint radio equipment at the Power Plant in order to connect sites that have line of site back to the Power Plant. Of the seven sites were line

of sight is achievable, four of the sites go back to the Power Plant stack. These sites include:

- Tom Evans Park;
- Ames Youth Sports Complex;
- Country Gables Park;[7]
- Bandshell Park; and
- Inis Grove.

Adding the point-to-multipoint radios allows for the deployment of WiFi hot-spots at these locations without installing equipment at the other two water towers.

3.2.4 Install Point-to-Multipoint Radio Equipment at Cyride to Connect Brookside Park

Installing a point-to-multipoint radio system at Cyride provides connectivity to Brookside Park. Once the point-to-multipoint system is operational, CTC recommends installing WiFi at the baseball diamond and skateboard park to provide WiFi access for the park. Our site surveys indicate that Brookside is a heavily used park facility that benefits from WiFi coverage.

3.2.5 Establish Wireless Connectivity to Water Towers and Install Point-to-Multipoint Equipment

Once the priority sites are installed, CTC recommends installing point-to-point microwave links from the Power Plant stack to the Bloomington and MAC water towers. While installing the point-to-point links at the water towers, the City should also install the point-to-multipoint base stations in order to connect the remaining priority sites. From the Bloomington Road tower, this is Moore Memorial Park. From the MAC tower, these include Emma McCarthy Lee Memorial Park, and Daley Park and Greenbelt.

3.2.6 Deploy DSL Circuits at those Sites where Connectivity is Unavailable.

The City should investigate deploying DSL at those sites where connectivity is unavailable and park traffic dictates that WiFi is a desired park feature. These sites include Campus Town Court and Ada Hayden Heritage Park. DSL service is not available in all areas so the City needs to verify availability. An alternative is to use cable modem service.

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[7] CTC was unable to verify the line of sight to the Power Plant from Country Gables Park.

3.2.7 Monitor WiFi Traffic and Network Performance and Evaluate Further WiFi Deployment Sites

CTC recommends the City monitor network traffic and performance once WiFi sites become available to the public and the public is informed that WiFi is available in these areas. If there is a large demand for WiFi at given areas, the City may consider expanding WiFi in those areas. Conversely, if WiFi has limited use, the City can move the equipment from one area to another that has a greater demand for WiFi connectivity. The modular design allows the City to add and move sites as need dictates with minimal additional costs.

As the public becomes aware of the availability of WiFi in public areas, there may be a demand for additional sites. CTC recommends following the design methodology of this report in determining whether WiFi is beneficial and technically feasible in future deployment areas.

3.2.8 Evaluate other Potential Wireless Applications

The City may find other wireless applications that benefit City personnel and the public once the point-to-multipoint system is installed. The point-to-multipoint system may have benefits beyond public WiFi including:

- Establishing video surveillance cameras for traffic monitoring and public safety;
- Providing wireless connectivity to mobile city vehicles; and
- Network connectivity for a mobile command vehicle or incident command post.

By establishing point-to-multipoint base stations on the water towers and power plant stack, the City creates a large coverage area where wireless connectivity to the City's network is achieved.

4. Initial and Ongoing WiFi Deployment Costs

The initial cost estimate is approximately $220,895 to deploy a WiFi hotspot network at the 15 priority A through D sites. This cost includes equipment, site work, and integration of the network. CTC estimates that the ongoing costs of operating and maintaining the WiFi network at $71,950 annually.

The following section details the initial and ongoing costs associated with the WiFi hotspot network.

4.1 Initial WiFi Deployment Costs

By leveraging the City's existing infrastructure and resources, the initial cost of the hotspot deployment is significantly reduced compared to a "green field" WiFi deployment. Table 5 outlines the cost of the initial WiFi deployment.

Table 5: Initial WiFi Cost Estimate
City of Ames
Public Hotspot Wireless Access Point Approach
Cost Estimate
All Sites (A through D)

Total number of Hotspots	15	
Total number of WAPs	19	
Total number of point to point wireless links	2	
Total number of Base Stations (sectors)	7	3 @ PP, 1 @ BRET, 2 @ MAC, 1 @ CyRide
Total number of Ethernet Switches	1	1 @ Ames Pool

Network Equipment

	Unit Price	Qty.	Total Price
2.4 GHz Wireless Access Point (WAP) Radio	$ 1,000	19	$ 19,000
2.4 GHz Antenna for WAPs	$ 150	19	2,850
NEMA Enclosure	$ 300	15	4,500
Base Station Radio and Antenna	$ 3,000	7	21,000
Subscriber Radio & Antenna	$ 900	10	9,000
Point to Point Wireless Equipment (per link)	$ 3,000	2	6,000
Wireless LAN Controller	$ 10,000	1	10,000
Fiber Optic Ethernet Switch	$ 6,000	1	6,000
WAP Pole	$ 2,700	3	8,100
WAP Solar Kit	$ 3,000	1	3,000
Server for Network Management Software	$ 3,000	1	3,000
Total Network Equipment		**$**	**92,450**

Spare Network Equipment

10% of network quantity

	Unit Price	Qty.	Total Price
2.4 GHz Wireless Access Point (WAP) Radio	$ 1,000	2	$ 2,000
2.4 GHz Antenna for WAPs	$ 150	2	300
Subscriber Radio & Antenna	$ 900	1	900
Base Station Radio and Antenna	$ 3,000	1	3,000
Total Spare Network Equipment		**$**	**6,200**

Software/Installation/Contingency/Engineering Costs

	Unit Price	Qty.	Total Price
Installation WAP's	$ 400	19	$ 7,600
Installation of Base Station (Includes antenna installation)	$ 3,000	7	21,000
Installation of Point to Point Links	$ 7,000	2	14,000
Installation Servers & Switches	$ 2,500	2	5,000
Installation of Pole for WAP	$ 600	3	1,800
Installation of Power for WAP	$ 500	18	9,000
Installation of Solar for WAP	$ 200	1	200
Installation of Fiber at the Municipal Pool	$ 3,500	1	3,500
Installation of DSL Circuits	$ 125	2	250
Integration (per AP)	$ 100	19	1,900
Network Management System (NMS) software and installation	$ 7,000	1	7,000
Engineering (Core Network)	$ 5,000	1	5,000
Engineering (Power Plant)	$ 3,000	1	3,000
Engineering (Water Towers)	$ 4,000	1	4,000
Engineering (Per WAP)	$ 750	19	14,250
Project Management (Core Network)	$ 2,000	1	2,000
Project Management (Power Plant)	$ 2,000	1	2,000
Project Management (Water Towers)	$ 2,000	1	2,000
Project Management (Per WAP)	$ 500	19	9,500
Contingency	10.00%		9,245
Total Installation/Contingency/Engineering Costs		**$**	**122,245**

Total Cost Estimate	**$**	**220,895**
Average Cost per WAP	**$**	**11,627**

Equipment, integration, and engineering cost estimates are based on pricing from similar WiFi hotspot deployments. Pole installation cost estimates were provided by the City's Electric Distribution Department. The cost estimates assumes that a Wireless LAN controller for 25 access points is purchased for this project. Cost estimates may be reduced through competitive bidding or performing WiFi installation and integration in house.

Appendix B contains a bill-of-materials for the major WiFi equipment components required to complete this network design. Other minor hardware materials should be supplied by the integrator as part of their contract with the City.

4.2 Ongoing Maintenance and Operational Costs

Several of the key ongoing and operational costs of the WiFi hotspot network include:
- Network staffing for monitoring, management, and troubleshooting;
- Equipment maintenance and replacement;
- Leased network services; and
- Network marketing.

CTC estimates that the cost of maintaining the network is approximately $71,950 annually. Table 6 outlines the ongoing costs of the WiFi network.

Table 6: Ongoing WiFi Costs

Network Staffing	Unit	Unit Price	QTY	Total Price
Troubleshooting Network	FTE	$ 75,000	0.25	$ 18,750
Monitoring, Maintaining, and Configuring Network	FTE	$ 75,000	0.25	$ 18,750
			Total Network Staffing	**$ 37,500**
Network Maintenance	Unit	Unit Price	QTY	Total Price
Service Contracts	Total Equipment Cost	$ 92,450	10%	$ 9,245
Replacement Schedule	Total Equipment Cost	$ 92,450	10%	$ 9,245
Equipment Fees and Rentals	Annual	$ 5,000	1	$ 5,000
			Total Network Maintenance	**$ 23,490**
Leased Services	Unit	Unit Price	QTY	Total Price
Business DSL for Internet Acess	per Month	$ 100	12	$ 1,200
Campus Town Court DSL	per Month	$ 65	12	$ 780
Ada Hayden Heritage Park DSL	per Month	$ 65	12	$ 780
Redundant Internet connection T1	per Month	$ 475	12	$ 5,700
			Total Leased Services	**$ 8,460**
WiFi Network Marketing	Unit	Unit Price	QTY	Total Price
WiFi Placards	Annual	$ 1,000	1	$ 1,000
Newsletter Ads, Mailings	Annual	$ 1,500	1	$ 1,500
			Total Network Marketing	**$ 2,500**
			Total Ongoing Cost Estimate	**$ 71,950**
			Average Cost Per WAP	$ 3,787

The ongoing cost estimates assumes that the equivalent of one full time network employee will spend half of their work time managing and maintaining the WiFi network. This time assumes that the City takes a very proactive role in the management and use of the network. Several of the tasks included in network staffing include:
- Answering and resolving WiFi network access issues from the public and City employees;
- Monitoring network traffic and network availability;
- Diagnosing and troubleshooting network issues;
- Swapping or replacing failed equipment;
- Monitoring and changing WiFi access configurations; and
- Maintaining and updating network documentation and configuration records.

If the City were to take a more "best effort" approach to the WiFi network and try to minimize the amount of troubleshooting that network staff had to perform for the public, the City can likely reduce the number of staffing hours allotted to the WiFi network.

Network maintenance includes the cost of service contracts on the initial equipment purchased for the WiFi system as well as funds to replace equipment as it reaches the end of its useful life period. The replacement schedule is estimated at 5 years, although these numbers may vary, and CTC recommends allotting funds for replacement equipment as needed. The equipment service contracts allow the City to have equipment replaced or repaired that is defective as well as provide additional technical support when needed. These costs combined represent approximately 30% of the total equipment cost annually.

Leased services provide Internet connectivity to the WiFi network and connect those sites that are unable to receive wire line or wireless connectivity. CTC estimated the City's leased costs based on available industry pricing and similar leased costs already incurred by the City.[8]

Network monitoring costs are included to promote the availability of the WiFi network to the public to increase use and to alert users of its presence. Marketing costs include placards stating that WiFi is available and potentially a number to call for troubleshooting. There may also be incremental costs for marketing the network in City mailings, Parks and Recreation newsletters, and other avenues.

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[8] CTC did not include electrical service fees within the leased services category as each site already has metered electrical service, and each access point uses less than 100 watts of power.