Grounds Maintenance at Worcester Polytechnic Institute

An Interactive Qualifying Project Report submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Table of Contents

Table of Figures

Table of Tables

ABSTRACT

This project was designed to improve the grounds maintenance process at WPI by organizing and computerizing the related information. The attractiveness of every campus relies heavily on effective landscaping. To accomplish this goal we mapped out the entire campus on a computer program using a geographic information system. Through an extensive analysis of the current system we were able to create priority levels, while determining the necessary resources, for the proposed method of maintenance.

ACKNOWLEDGEMENTS

We would like to thank project sponsor, WPI Plant Services, for their help and support throughout this project. In particular, Ronald Klocek and his crew for their repeated knowledge of information to help make this project run smoothly and effectively.

The E-grounds team would also like to thank the WPI outside contractors, Bartlett Tree Experts Co., especially Jeff Haimman, and Perennial Planning for working to help us understand and analyze the specific aspects of the grounds maintenance process.

Lastly we would like to thank the project advisors Fabio Carrera, John Miller, and Guillermo Salazar for their support and knowledgeable advice throughout this project.

EXECUTIVE SUMMARY

The need for effective and efficient grounds maintenance is a necessity to enhance the attractiveness of any campus. At Worcester Polytechnic Institute (WPI), grounds maintenance or the landscaping process plays a major role in adding beauty to this small urban campus. There are various ways and many different opinions on effective grounds maintenance; however research done by various landscaping firms, shows that much care is needed in all seasons. WPI has a specific division of labor to handle this maintenance process. WPI Plant Services Grounds Department is responsible for maintaining all of the landscape owned by WPI.

Since the start of the Grounds Services Department, an overall evaluation of the organization has yet to occur. WPI currently needs to have more detailed and better organized information on what types of plants are actually on the campus, where each type is located, and what maintenance tasks each aspect demands. Modern technology now allows landscapes to be mapped onto a computer using Geographic Information Systems (GIS). GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, for example, trees, plants, and flowerbeds identified according to their locations in the world. The system allows groundskeepers to investigate the layout, manage their resources, and effectively come up with a plan of action to maintain the grounds. The new system will ultimately help WPI Plant Services in making better informed decisions regarding its ground maintenance.

Through extensive evaluation of the current system and the new computerized system, Plant Services will be able to effectively maintain the records through a maintenance log. The group used Microsoft Access to keep databases of all information regarding the physical objects

maintained on the campus. These databases are linked to the GIS software which shows the maps of the WPI campus including the various components (lawns, flowerbeds, trees, and hard surfaces) of what the Grounds Maintenance Department must maintain. Below (Figure i) is a smaller picture of the complete map of WPI including the multiple elements of the grounds maintenance process.

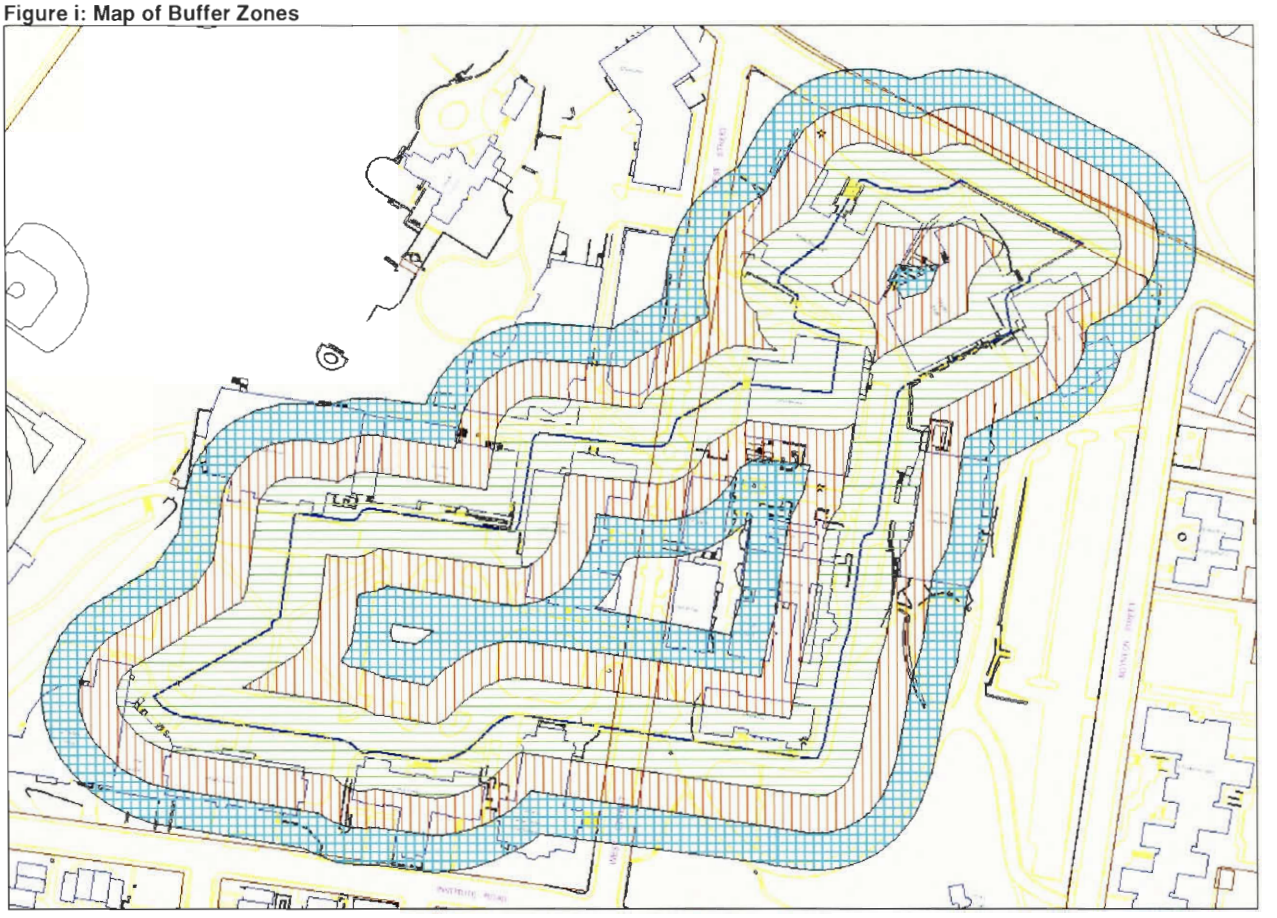
Figure i : Map of Complete GIS Layers

In addition to mapping, the students analyzed the area of each plot of land and calculated the resources needed for each activity based on certain priority levels.

These priority levels are based on different aspects such as the Admissions campus tour, areas seen most by visitors, and areas heavily traveled by motorists. The students calculated the resources needed through formulas assigned by the APPA (The Association of Higher Education Facilities) booklet. This booklet provides references for different maintenance tasks at multiple

priority levels. After mapping the Admissions campus tour, priority levels were established following the tour based on three separate buffer zones: fifty, one hundred, and one hundred and fifty feet deviating from the tour. The closer to the campus tour, the higher the priority level of maintenance was. The campus tour, in blue, and priority levels (50ft – green, 100ft – red, 50ft – blue) are shown below in the reproduced picture of the GIS layer (Figure ii).

Figure i: Map of Buffer Zones



The lawns, flowerbeds, trees, and hard surfaces were divided into their own separate databases and separate GIS layers. From these layers, the total surface area that each entity took up was calculated using the GIS program. After accumulating the data, the group used the formulas from the APPA booklet to calculate the hours each task would take per week. The group then analyzed this information and placed it in pie charts to compare the distribution of

resources. An example of the resource allocation can be seen in the pie charts (Figure iii, iv) for the lawns and the flowerbeds in the fifty foot buffer zone.

Figure ii: Maintenance Tasks for Level of Service 1: Lawns

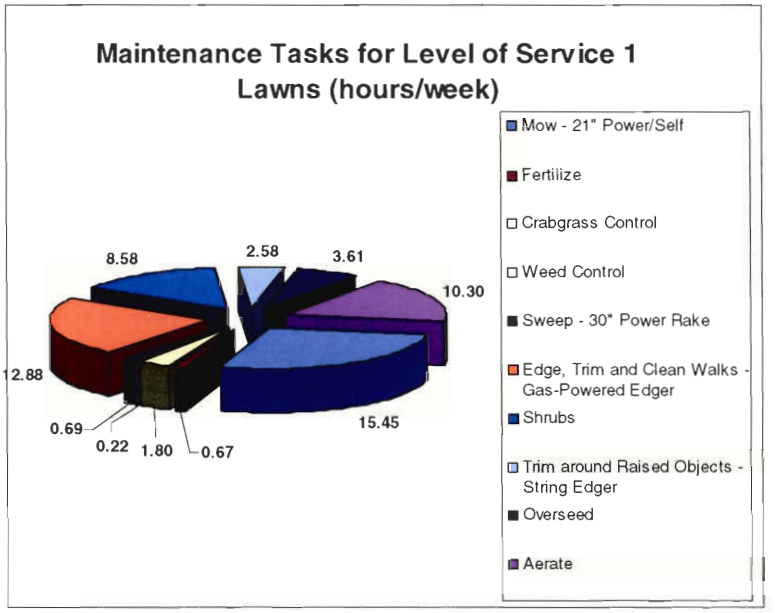
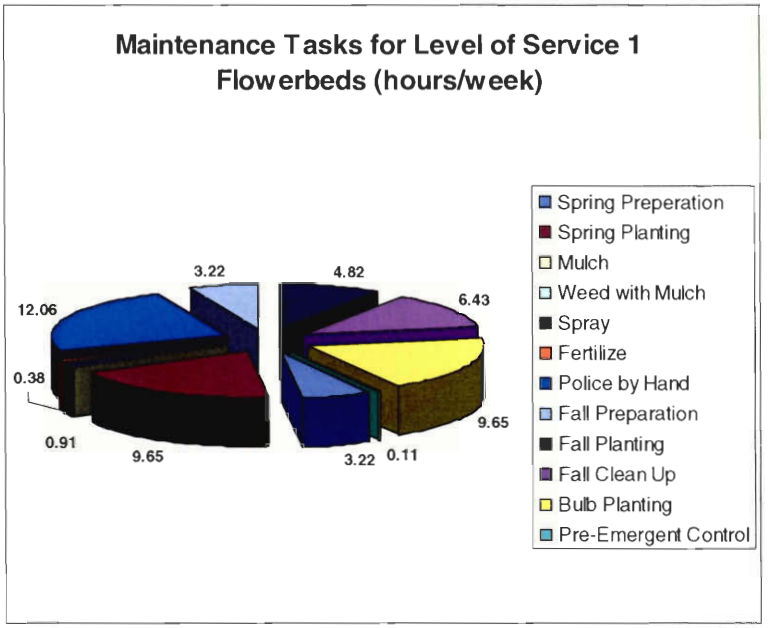
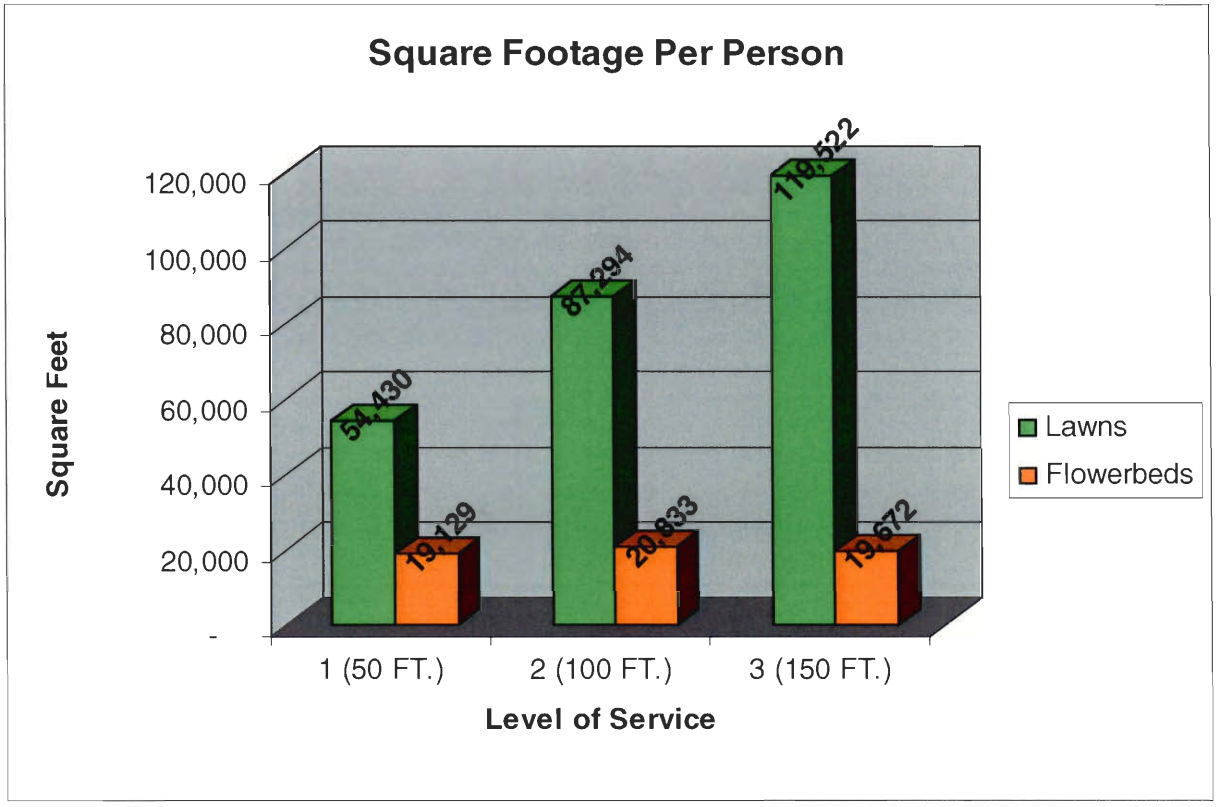


Figure iii: Maintenance Tasks for Level of Service 1: Flowerbeds



In addition to the pie charts, the group analyzed how many hours each worker would contribute to the maintenance process in terms of how much actual square footage they could maintain. Below is a bar graph (Figure v) showing these results.

Figure iv: Square Footage Per Person



After completing the project, the group realized how important an analysis of this measure really is. WPI Plant Services can truly benefit from the created GIS layers and allocation of resources concluded from this Interactive Qualifying Project.

1. INTRODUCTION

The need for effective and efficient grounds maintenance is a necessity to enhance the attractiveness of any campus. Grounds maintenance is the planning, planting, and maintaining of the physical grounds around a given area of land. Horticulture dating back 11,000 years to the development of civilization is the science behind grounds maintenance. Archeologists believe that Egyptians, dating back to 2800 B.C., developed extensive and sophisticated irrigation systems. "The oldest surviving garden plan for the garden of a court official in Thebes dates back to about 1400 B.C. Egyptian tomb paintings depicts gardens situated within the walled enclosures around homes."[1] The value of a home or building is affected tremendously by the actual landscape that surrounds it. As civilization developed the value became more important, improved its maintenance tactics, making the landscapes easier to maintain.

There are various ways and many different opinions on effective grounds maintenance; however research done by various landscaping firms, shows that much care is needed in all seasons. Fertilization is always necessary to keep up with harsh weather conditions and a continuous depreciation of the land. Soil conditions are also very important when planting and maintaining the vegetation. A proper watering technique along with an overall care for plant life is critical to preserving the beauty of each plant.

Worcester Polytechnic Institute (WPI) has a specific division of labor to handle these tasks. WPI Plant Services Grounds Department is responsible for maintaining all of the landscape owned by WPI. Duties performed include trash removal, maintaining flower beds, fertilizing, mowing, pruning, leaf and snow removal. Through the use of environmental friendly

[1] http://artzia.com/Home/Garden/History/

methods of fertilization and pest control the Grounds Services Department strives to promote a healthy campus environment for all members of the WPI community.[2]

The Department currently employs nine grounds keepers that upkeep five estates, eleven residential halls, nineteen academic buildings, and thirty peripheral properties. The organizational structure of the Grounds Services Department is headed by one manager, Ronald Klocek, who is responsible for the two groundskeepers, the six gardeners, and one mechanic. Klocek reports to the Director of Physical Plant, John Miller.

Since the start of the Grounds Services Department, an overall evaluation of the organization has yet to occur. WPI currently needs to have more detailed and better organized information on what types of plants are actually on the campus and where each type is located. There is currently very general documented information on where each of these plants is. Another aspect missing from the current system is the actual care that is needed for each type of plant.

Modern technology now allows landscapes to be mapped onto a computer using Geographic Information Systems (GIS). GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, for example, trees, plants, and flowerbeds identified according to their locations in the world. The system allows groundskeepers to investigate the layout, manage their resources, and effectively come up with a plan of action to maintain the grounds. This new technology will bring the Grounds Services Department to a new level. The new system will ultimately help WPI in making better informed decisions regarding its ground maintenance.

This project is designed to help WPI Plant Services develop an efficient process that will allow the Grounds Services Department to improve its maintenance process of the grounds. The

[2] http://www.wpi.edu/Admin/Plant/Grounds/

team has analyzed flower beds, trees, bushes, grass, and any other plantings to find the best way to upkeep each and still minimize maintenance costs. In doing so, the group has created databases on all the information needed to help the grounds crew easily sustain the grounds. Through extensive research all plants have been labeled or documented in each database and proper care information is available on the GIS system. With the help of the GIS system the team can analyze the time it will take to perform each maintenance task. Through this analytical process the team can show the needed level of service for each aspect of the grounds at any given time.

2. BACKGROUND

2.1 Grounds Maintenance in General

Employment[3]

Grounds maintenance workers held about 1.1 million jobs in 2002 in the US. Employment was distributed as follows:

Table 2.1: U.S. Employment

Landscaping and grounds keeping workers	894,000
First-line supervisors/managers of landscaping, lawn service, and grounds keeping workers	159,000
Tree trimmers and pruners	52,000
Pesticide handlers, sprayers, and applicators, vegetation	27,000

About 42 percent of wage and salary workers in grounds maintenance were employed in companies providing landscape and horticultural services. Others worked for firms operating and building real estate, amusement and recreation facilities such as golf courses and racetracks, and retail nurseries and garden stores. Some were employed by local governments, installing and maintaining landscaping for parks, schools, hospitals, and other public facilities.

More than 1 out of every 6 grounds maintenance workers were self-employed, providing landscape maintenance directly to customers on a contract basis. About 1 of every 7 worked part time; many of these were of school age.

[3] Grounds Maintenance Workers, http://www.bls.gov/oco/ocos172.htm

Earnings[4]

Median hourly earnings in 2000 of grounds maintenance workers were as follows:

Table 2.2: U.S. Hourly Earnings

First-line supervisors/managers of landscaping, lawn service, and grounds keeping workers	$14.70
Tree trimmers and pruners	11.41
Pesticide handlers, sprayers, and applicators, vegetation	11.11
Landscaping and grounds keeping workers	8.80

The WPI hourly wages for its employees as of 2004 are as follows:

Table 2.3: WPI Hourly Earnings[5]

Groundskeepers' Helpers	$15.00
Groundskeepers	16.15
Gardener 2	16.75
Gardener 1	17.35
Maintenance Mechanic/Groundskeeper	18.94

In comparison to the average hourly wages in 2000, the WPI grounds crew currently is paid more than average for their line of work. However, the WPI crew performs many more tasks and is asked upon by management to be responsible for more activities then most landscaping workers.

[4] Grounds Maintenance Workers, http://www.bls.gov/oco/ocos172.htm
[5] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.

2.2 Level of Attention

The amount of work that can be done at a certain location depends upon one thing, money. With money, the staff number and supplies are accounted for and basically any project can get done. Plant Services here at WPI has a limited budget to work with in order to keep the grounds presentable. There are certain levels of attention discussed in the APPA (The Association of Higher Education Facilities) booklet; levels 1 through 5 with 1 being a state-of-the-art maintenance and 5 being minimal-level maintenance. Associated with well-developed public areas, malls, government grounds, or college/university campuses, a level of attention 1 or 2 should be upheld. WPI seems to have an average level of attention of 3, but also including some aspects covered in levels 1 or 2. Some specific areas which need more attention due to high traffic areas, are Kaven Hall, Boyton Hill, Higgins House, the four corners of the campus, and any entrance into campus. The following describes the type of area that should be maintained and the tasks associated with that maintenance at level 2 which could be incorporated across campus.

2.3 Level 2 [6]

Turf Care

Grass cut once every five working days. Aeration as required but not less than two times per year. Reseeding or sodding when bare spots are present. Weed control practiced when weeds present a visible problem or when weeds represent 5 percent of the turf surface. Some pre-emergent products may be used at this level.

Fertilizer

Adequate fertilizer level to ensure that all plant materials are healthy and growing vigorously. Amounts depend on species, length of growing season, soils, and rainfall. Rates

[6] APPA, Operational Guidelines for Grounds Maintenance. United States of America, APPA, NRPA, and PGMS, 2001

should correspond to at least the lowest recommended rates. Distribution should ensure an even supply of nutrients for the entire year. Nitrogen, phosphorus, and potassium percentages should follow local recommendations. Trees, shrubs, and flowers should receive fertilizer levels to ensure optimum growth.

Irrigation

Sprinkler irrigation—electric automatic commonly used. Some manual systems could be considered adequate under plentiful rainfall circumstances and with adequate staffing. Frequency of use follows rainfall, temperature, season length, and demands of plant material.

Litter Control

Minimum of once per day, five days per week. Offsite movement of trash depends on size of containers and use by the public. High use may dictate daily or more frequent cleaning.

Pruning

Usually done at least once per season unless species planted dictate more frequent attention. Sculpted hedges or high-growth species may dictate a more frequent requirement than most trees and shrubs in natural-growth plantings.

Disease and Insect Control

Usually done when disease or insects are inflicting noticeable damage, are reducing vigor of plant material, or could be considered a bother to the public. Some preventive measures may be used, such as systemic chemical treatments. Cultural prevention of disease problems can reduce time spent in this category. Some minor problems may be tolerated at this level.

Snow Removal

Snow removed by noon the day following snowfall. Gravel or snowmelt may be used to reduce ice accumulation.

Surfaces

Should be cleaned, repaired, repainted, or replaced when their appearances have noticeably deteriorated.

Repairs

Should be done whenever safety, function, or appearance is in question

Inspections

Inspection should be conducted by some staff member at least once a day when regular staff is scheduled.

Floral Plantings

Normally, no more complex than two rotations of bloom per year. Care cycle is usually at least once per week, but watering may be more frequent. Health and vigor dictate cycle of fertilization and disease control. Beds essentially kept weed free.

Mulching

Mulches used in gardens suppress weeds, reduce soil erosion, modify the soil temperatures, cooler in the summer, and warmer in the winter, and conserve soil moisture. Yard waste compost makes ideal mulch for annual and perennial gardens. All that needs to be done is to apply a three to six inch layer of compost around the base of the plant. Periodically throughout the summer, you may need to add more compost over the old layers to maintain the benefits of the mulch.[7]

Soil pH

It is generally easier to make soils more alkaline than it is to make them more acid. Because different soil types react in different ways to the application of lime you will have to add more lime to clay soils and peaty soils than you will in sandy soils to achieve

[7] Ginsburg, Janet. The City of Chicago Guide to Urban Tree Care. Chicago, IL, City of Chicago Department of Environment, 1994.

the same result.

To increase your pH by *1.0 point* and make your soil more alkaline.

- Add 4 ounces of hydrated lime per square yard in sandy soils
- Add 8 ounces of hydrated lime per square yard in loamy soils
- Add 12 ounces of hydrated lime per square yard in clay soils
- Add 25 ounces of hydrated lime per square yard in peaty soils

If your soil needs to be more acidic, sulfur may be used to lower the pH if it is available. To reduce the soil pH by 1.0 point, mix in 1.2 oz of ground rock sulfur per square yard if the soil is sandy, or 3.6 oz per square yard for all other soils. The sulfur should be thoroughly mixed into the soil before planting. Sawdust, composted leaves, wood chips, cottonseed meal, leaf mold and especially peat moss, will lower the soil pH.[8]

2.4 Current Maintenance at WPI

Management[9]

The manager of the grounds, Mr. Ronald Klocek, heads the current maintenance system at WPI. His official title is Manager of Grounds and Properties. Mr. Klocek reports directly to the Associate Vice President for Business Affairs and the Director of the Physical Plant at WPI. The Associate Vice President for Business Affairs is Stephen J. Hebert. The Director of the Physical Plant at WPI, who is also the Liaison to this project, is John E. Miller. In Mr. Klocek's position description, it states that the basic function of his job is to "manage the maintenance of all campus grounds and properties peripheral to the campus." Meaning anything to do with the maintenance of WPI campus grounds and peripherals is his responsibility.

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[8] Crockett, James Underwood. Flowering Shrubs. New York: Time Life Books, 1972.
[9] Klocek, Ronald. "Manager of Grounds and Properties Position Description." 2000.

In order to become the Manager of Grounds and Properties at WPI, there are some requirements or prerequisites entailed. One must have an Associate Degree in horticulture or a related field desirable. One must also have six to ten years' experience in ground maintenance, with a minimum of three to five years in a supervisory role. Licenses and certifications related to his position are expected as well.

Mr. Klocek has many duties and responsibilities under his job description. He supervises the maintenance of all grounds, athletic fields, and on-site facilities on both the main campus and peripheral properties owned by WPI. He must collaborate with others, usually Mr. John Miller, to hire, and train personnel within his division of Plant Services. When a new project is undertaken to modernize, upgrade or maintain the existing campus grounds and/or peripheral properties he is in charge of managing the endeavor. He is also in charge of acquiring and maintaining new supplies needed to fulfill each operation. Periodically he inspects the current facilities in order to establish a need for maintenance and repair. The records and operations of all Plant Services vehicles are under his supervision. He is to cooperate with Mr. Miller and decide on the maintenance and operation of the peripheral properties on a basis of priority levels. He is responsible for campus functions, i.e. setting up, taking down, and moving of furniture. When required, he shall act as primary negotiator in union contract discussions. When it snows, he is responsible for campus snow removal and the salting of icy walkways. Related to this, he is on-call twenty-four hours for campus emergencies that may arise. He is directly responsible for any expenditure over and above the proposed $800,000 budget. On top of all of these responsibilities he directs nine semi-skilled non-exempt union employees and up to ten student employees. He may however delegate authority to any of the employees to help fulfill his job requirements.

Employees[10]

The employees all belong to a labor union in order to protect their rights and to be able to have their opinions heard amongst the management of the university. The name of the labor union the nine employees belong to is the Service Employee International Union Local 615. Ronald Klocek himself does not currently belong to any labor union; however he represents the employees' voice in that union. Currently there are six gardeners, two groundskeepers and one Groundskeeper/Maintenance Mechanic that specializes in maintenance and fixing equipment around the campus. The six gardeners are divided into two types of gardeners, Gardener I and Gardener II. Gardener I have taken four college level courses in grounds maintenance and operate under a pesticide license. Gardener II has taken only two college level courses in grounds maintenance. (See Appendix B for Organizational Chart)

The two Groundskeepers are George R. Desmarais and Stephen J. Pajka. Donald W. Peterson, John D. Stoever, and Bruce D. Worthington are all Gardener I's. Thomas F. Barter, Thomas H. Bullens, and Robert M. Tupper, Jr. are all Gardener II's. The employee in charge of maintenance is Glen Whitcomb. Whitcomb is also responsible for grounds keeping when there is no maintenance to perform. Mr. Klocek is held directly responsible for the supervision of all nine of these employees. (See Appendix H for Job Descriptions and Qualifications for Gardener I, II, Maintenance Mechanic, and Groundskeeper)

Turf/Lawn Care[11]

There are three separate programs that the groundskeepers follow when maintaining the lawns and turf at WPI. In the spring, they go around and first remove any branches, twigs, papers, stones and any other debris that may have accumulated over the winter season. Next they remove all sand that accumulated over the winter from sanding the walkways and streets

[10] Klocek, Ronald. "Position Descriptions." 2000.
[11] Klocek, Ronald. "Lawn Maintenance (Spring, Summer, Fall)" 2000.

from the curb side lawn area. Then they go around and look for any ruts or large holes in the ground and they repair them by adding soil and leveling off the land. After leveling the land, they go around and look for any thatch, or dead lawn. When there is any thatch, they first remove the dead area and then level it off with fresh soil. When necessary they spot and slice seed in places where the dead lawn has been removed and the ruts have been replaced with new soil.

The next step in the spring process is to aerate the lawns in preparation for seeding and fertilization. Once the lawn regions are aerated, seeding begins. Seeding is necessary to replace and rejuvenate all the grass that has died from a snowy winter. Subsequent to seeding, fertilization takes place. The fertilization process is somewhat complicated and will be talked about in another section. Lime, or calcium oxide, is then put on the grass areas in order to balance out the acidity in the soil and increase the pH level. After all preparation for the lawn is complete, the mowers are checked for functionality and inspected to ensure proper operation. The lawns are then cut to a height of two and half to three inches.

Depending on the area, most of this takes about a week for each zone to complete by each worker(s). As Mr. Klocek explained in the interview, he estimated a total of one hundred and twenty-eight hours to complete the mowing of all the lawns WPI is responsible for. The largest zone is the peripheral properties, taking up to forty-eight hours to complete.[12]

During the summer, like the spring, all braches, twigs, papers, stones, and any other debris accumulated are removed from the lawns. Prior to mowing the lawn mowers are inspected to make sure they are operating properly. The lawns are cut to a height of two and half to three inches. Approximately one inch of water is added to the lawns per week depending on rainfall and other circumstances. The lawns are checked for substantial amounts of insects.

[12] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.

Once a summer the lawns are again aerated and fertilized. According to Mr. Klocek, pesticide and insecticide applications do not exist in the normal maintenance activities.[13]

Again, during the fall, branches, twigs, papers, stones, any other accumulated debris is picked up from the lawns. In the fall, the leaves begin to fall off the trees, which require raking and removing from the campus. Prior to mowing the machines are checked for proper operation and again the lawns are mowed to approximately two and a half to three inches. Again, the lawns are aerated and fertilized. To reach the proper pH level the lime is added to the soil.

In all seasons, the lawn is mowed accordingly. During certain weeks, rainfall may be heavier than others, requiring the lawn to be mowed sooner than usual. After meeting with Mr. Klocek, he described that the activities and maintenance tasks that have been described are not usually completed to their fullest. The biggest reason behind this is the budget, which is well below what it should be. (Maintenance Schedules found in Appendix G)

Flowerbed Maintenance & Planting[14]

Bed maintenance occurs in all seasons, but the actual planting occurs in the summer and fall seasons. In the springtime, Gardener's begin by raking out all the debris in the flowerbeds and cut back all the flowers that have grown to unnatural shapes. All the dead wood is cut from the shrubbery along with any weeds that have sprouted up. The beds are then edged for a natural clean look. After being cleaned and edged, the flowerbeds are then fertilized and fresh mulch is added to the flowerbed. Watering takes place through irrigation when available, yet manual watering takes place in most flowerbeds.

The summer process is similar to the springtime, watering, weeding, and cutting back any dead plant life where necessary. Plants are checked for any insect damage that occurred during

[13] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.
[14] Klocek, Ronald. "Bed Maintenance (Spring, Summer, Fall)" 2000.

the change of seasons. The mulch is fluffed to look presentable. In the summer time annuals and perennials are planted in the beds where desired along with the replacement of any dead shrubs. During the fall season the same maintenance occurs, however new plant bulbs and perennials are planted for the new season. During the past six years, approximately 20,000 perennial bulbs have been planted.[15] All dead plant life is removed and the flower beds are prepared for the winter season.

The bed maintenance usually takes approximately a week to complete. As explained by Mr. Klocek, the crew works on beds in the spare time, while walking around the campus performing everyday tasks, they weed the gardens when necessary. As far as scheduling set dates on when each garden is to be maintenanced or weeded, he explained that no such schedule exists. There is no distinct process or set times for each garden or activity.[16] (Maintenance Activities found in Appendix G)

The flowerbeds around Higgins House receive the best attention. They are subcontracted to a local company, Perennial Planning, which on a weekly basis comes and performs the basic maintenance tasks to all of the flowerbeds surrounding the Higgins House. Since the Higgins House is one of the most prestigious aspects of the WPI campus, it must receive the best attention. Perennial Planning also is responsible for the President's house located on 1 Drury Lane, and the Vice President's house located on 15 Regent Street. Again these properties are highly respected by WPI, therefore receiving the best care.[17]

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[15] Miller, John. "WPI Alumni: The Bridge" <http://www.wpi.edu/Admin/Alumni/Bridge/0703.html> July 2003.
[16] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.
[17] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.

Fertilization[18]

Fertilization is the process in which fertilizer is applied to the lawns and flowerbeds. Fertilizer is a combination of natural and synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread on or worked into soil to increase its capacity to support plant growth. The fertilization program at WPI, as Mr. Klocek has explained, does not exactly happen the way that it should. The lawn is supposed to be fertilized in the springtime, during the summer, and before the snow begins to fall in the fall. However, the budget allows for the fertilization to take place a maximum of two times a year. The total budget for the fertilization program is approximately $4600; however, most of that money is allocated to other areas of the Grounds Services division because the budget for the entire division is not suitable.

Currently there are forty different zones that need fertilization, each having a fixed cost per square foot of area needed to be fertilized. The zones are broken into two classifications: Classification 1 – high maintenance areas, and Classification 2 – low maintenance areas. The high maintenance areas include Morgan Hall, the Quad, the Beech tree rotary, Higgins house, Atwater Kent, Kaven Hall, the area on Institute road, and the West Street area. These areas are all high maintenance areas because they are areas that are most seen by visitors and potential students. Therefore, these areas need to have a higher per square foot cost, since more fertilization is necessary. The high maintenance areas have a cost approximately three times that of a low maintenance area. The complete chart of all of the fertilization areas can be seen in Appendix C.

The high maintenance areas are supposed to be fertilized six times a year, during April, May, July, August, and October. The low maintenance areas are only fertilized twice a year, once in April and once in September. The high maintenance areas are fertilized in April to

[18] Klocek, Ronald. "Fertilization Program." 2000.

control remerging crab grass. In May, Confront Fertilizer with weed control is used to stop the growth of unnecessary weeds. In the month of July, the lawns are treated with Merit Preventive® grub control. These special fertilizers and care are reasons why the cost for the high maintenance area is more than the low maintenance areas. However, both times the low maintenance areas are fertilized they use special types of fertilizers. In the April fertilization application, the crews use fertilizer with Dimension® additives. In the September fertilization, application groundskeepers use fertilizer with Confront® additives.

Mulching[19]

Mulching is the process of covering an area of land with mulch. Mulch is a protective covering, usually of organic matter such as leaves, straw, or peat, placed around plants to prevent the evaporation of moisture, the freezing of roots, and the growth of weeds. Mulch can also be in the form of small pieces of tree bark. WPI currently uses mulch in all of the flowerbeds around the campus and on its multiple peripheral properties. All beds are raked, edged and fertilized annually in the current mulching plan. However, each area of land that needs mulch has a separate plan for mulching and when each bed gets new mulch. WPI Grounds Services use approximately three hundred cubic yards of mulch each year.[20] Each area is on a different cycle and can be seen in Appendix D.

Each spring the gardeners are instructed to mulch the flowerbeds around campus after all debris is cleared out, flowers and shrubs are cut back, and all the beds are edged and fertilized. Then in the summer time, they are instructed to fluff up the mulch around the flowerbeds to make it look attractive. The beds that are most attractive and have the most appeal to visitors are the beds that get the most attention and care. For example, the quad and the West Street area get

[19] Klocek, Ronald. "Mulching Plan" 2000.
[20] Miller, John. "WPI Alumni: The Bridge" <http://www.wpi.edu/Admin/Alumni/Bridge/0703.html> July 2003.

the most attention since students, visitors and potential students see these areas daily. The warm campus atmosphere is enhanced through proper mulching.

Irrigation[21]

The maintenance of plant life is impossible without the presence of water. The most efficient and effective way to water plant life is through an irrigation system. Through proper water management and irrigation, water and soil conservation is possible. In most facilities and universities, an elaborate automatic irrigation system is present. Irrigation systems are essential to efficient grounds maintenance. However, currently at WPI, there are only four automatic irrigation systems on the main campus.

Currently an irrigation system waters the rotary at the West Street entrance to WPI. This systems main function is to keep the Beech tree, its roots, and the grass covering the rotary constantly watered. Another irrigation system is located around the campus center area. The main function of this system is to keep the flowerbeds located in and around the walkways of the campus center constantly watered. The third irrigation system on campus is located on the walkway known as West Street. This area is defined as the walkway from Olin Hall, located on the corner of Salisbury Street and a private entrance to WPI, to Stratton Hall, located at the West Street entrance to WPI. The main function of this system is to keep the flowerbeds and small grass areas constantly wet. The fourth and final system is located on the Athletic fields. The system is brand new and was just installed over the 2003 summer. This irrigation system's main function is to keep both the softball and baseball fields watered during the green season.

These systems are currently in place not only to keep the area watered, but also to make it more efficient for the Grounds Services department at WPI. The current maintenance process at WPI does not allow for time for each gardener to sit for hours and manually water the

[21] Klocek, Ronald. "Interview with Ronald Klocek." Recorded by T.J. McLaughlin. December 11, 2003

flowerbeds and lawns around campus. This process would take weeks and WPI does not have the money to implement this manual process. Therefore, automatic irrigation systems are necessary in every area that needs constant water.

The irrigation systems are very expensive to be installed. The estimated cost of the athletic field irrigation system (seen in Appendix J), was approximately $30,000. The cost of the Beech Tree system was approximately $4500. The two other systems, both very large, was the West Street system with an estimated cost of $30,000, and the Campus Center system, estimated at $25,000. Mr. Klocek explained that each year he has someone come and service the systems in the spring to start it up and in the fall to blow the lines out and shut them down. He explained that for each season the estimated cost to maintain the systems in $300 per season.[22]

In comparison to an irrigation system, the estimated cost of manually watering these areas would be phenomenal. In order to manually water each area, the set up and take down of the sprinklers and hoses would take an hour at least each time. On top of that periodically throughout the day the sprinklers would need to be moved, in order to cover the entire area that an irrigation system would account for. Granted the irrigation systems are very expensive, the system is a fixed cost and is incurred only once. To manually water the lawns and beds, the labor and water costs would begin to add up substantially after some years. In conclusion the irrigation systems are more cost effective.[23]

The current systems are in place at the various locations because they are the areas of campus most frequently seen by visitors and people from admissions tours. The area around the campus center is most seen by visitors and potential students taking tours around the campus. The same philosophy is behind the West Street walkway. These areas are irrigated currently

[22] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.
[23] Idem.

because of the attractiveness and beauty the campus needs to have in the eyes of visitors and potential students. The rotary is irrigated for the same reasons, but also since the Beech tree located directly in the center of the rotary is a historic tree that needs to be preserved. That beech tree has been a symbol of WPI since its planting some sixty years ago.[24] Along with the historical value, the beech tree is also one of the first objects someone will see when entering the main entrance to WPI. The final system amongst the WPI ball fields needs the most watering. This area is always used during anytime the fields are not covered in snow. Having an irrigated field is necessary for proper maintenance of a baseball/softball field. Previously to the installation of the system the grass area was always destroyed from the wear and tear of every activity that utilized the area. With an irrigation system in place, the maintenance of the outfields and infields will be much easier and will attract more athletes looking for decent playing fields. As for the current teams, the play will improve greatly, since the grass has always been destroyed during the winter season and through extensive use without constant watering and rejuvenation. To properly irrigate any area of the grounds irrigation is required.

Soil[25]

The soil is maintained by taking pH levels of the various sections of the campus. Currently WPI Grounds Services measures forty-two separate locations around the campus. Every year the pH level is taken and measured. In order to maintain the proper pH levels, lime is added to raise the pH level to the proper acidity level. This is necessary for the grass to grow properly. Fertilization is also necessary and is described in length in the 'Fertilization' section. See Appendix E for a complete pH level chart.

[24] Miller, John. "WPI Alumni: The Bridge" <http://www.wpi.edu/Admin/Alumni/Bridge/0703.html> July 2003.
[25] Klocek, Ronald. "Soil PH Levels." 2000.

Disease and Insect Control

Disease and Insect control is not a big concern at WPI. The only process that the groundskeepers perform related to insects is during the summer lawn-care program. The groundskeepers are instructed to check the lawn for abnormal amounts of insects. In the bed maintenance program, groundskeepers are instructed to check plants for insect damage during the summer months. These programs are inadequate and need to be revised. Nowhere in the maintenance programs does it state that the lawn or flowerbeds be sprayed with pesticides, herbicides, or insecticides. Herbicides are necessary for proper disease prevention, without them the grass will die if infected with certain diseases. Mr. Klocek explained that no such spraying was involved in any of the maintenance activities. He did however explain that when there are bee hive problems, he contracts the work out to Brahman Chemical company.[26]

Pruning

Pruning is a process that involves removing branches from trees that are unnecessary, dead, or in the way of power lines, lights, buildings, etc. WPI Grounds Services currently budgets for about $20,000 a year for pruning and tree care. For the most part, WPI out sources its pruning to Bartlett Tree Company, which is a global leader in scientific tree care. Their local office is located in Worcester on Grove Street; however, they have multiple locations across twenty-seven different states, Canada, Ireland and the UK.[27]

The campus as of now is divided into ten different pruning zones. Each year one zone is worked on and the trees in that zone are pruned, trimmed and cared for. In the interview with Mr. Klocek, he described that the current process is insufficient and should be modified. He explained that six zones would be optimal. This change is necessary because the trees need to be pruned more often then they presently do. Not only did Mr. Klocek mention the zoning needed

[26] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.
[27] Bartlett Tree Company. http://www.bartlett.com/au400.cfm 2003.

to be changed, but like the rest of the budget, the tree care budget should be doubled to $40,000 a year. This would help pay for trees that actually need to be pruned each year.

During windstorms and ice storms severe damage to trees is expected. After a storm as such, the crew is instructed by Mr. Klocek to do a run through of the campus to look for any potential damage done by the storm. Bartlett Tree Experts are also called to come in and give professional opinions about the status of the trees after a storm. For the most part they are on an 'on-call' basis. Mr. Klocek explained that this process accounts for approximately forty hours per year.[28]

Snow Removal

Every member of the Grounds Services Department takes part in the snow removal process at WPI. As explained in the "Employees" section, the crew is on-call twenty-four hours a day. The groundskeepers are responsible to participate in snow removal from all walks, steps, hydrants, roads and parking lots owned and managed by WPI. In addition to the snow removal, they must undertake such tasks as salting and sanding of all the areas mentioned previously. WPI currently owns numerous snow shovels along with a Toro Snow Thrower and an Arien's Snow Thrower.[29] Most of the parking lots are cleared by plows that are attached to a couple of the pick-up trucks owned by WPI. At night when the snow falls, the WPI Grounds Services works through the night to make sure all the paths leading to campus, all the sidewalks, and all parking lots are cleared of the snow. Then once all the snow is removed they make sure all walkways are salted and sanded to ensure the safety of the students and faculty of WPI.

The snow removal process is usually on an overtime schedule, therefore extra costs are incurred. The overtime is recorded by Mr. Klocek every year and is tallied up at the end of the

[28] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.
[29] Klocek, Ronald. "Plant Services Vehicles Data" 2000.

year in order to keep tract of how much it costs in overtime wages to remove the snow from the campus and make it safe for students, visitors, and professors. In 2002, there was a total of 658.5 overtime hours, in 2003, there was 1,353 hours, and in 2004 there was 674 overtime hours. The complete overtime charts can be seen in Appendix I. The breakdown between plowing and salting overtime hours can be seen in Figure 2.4 below:[30]

Table 2.4: WPI Overtime Hours

Figure 5	2002	2003	2004
Salting	346.5	247	137
Plowing	312	1106	537
Total (hrs.)	658.5	1353	674

Litter Control[31]

As explained previously in the turf and lawn care section, each time the groundskeepers begin to treat the lawn they begin by picking up branches, twigs, papers, stones, and any other debris from the lawns. Controlling the litter in an inner-urban school is very difficult, especially in the city of Worcester. Every groundskeeper and gardeners' duty is to make sure the campus looks the best it possibly can. Litter is a problem that occurs from a person's laziness to not throw something in the trash. With this in mind, they must make sure there is nothing on the ground that should not be there. Mr. Klocek explained that litter control is a big issue on campus and is done on a daily basis by each member of his crew. He explained that each day each worker goes around the campus for approximately two hours a day picking up litter and trash. The only way this problem can be controlled is by making sure there are adequate trash disposal barrels located all over the campus.

[30] Snow Removal Overtime Hour Information. Ron Klocek. 2002, 2003, 2004.
[31] Klocek, Ron. Interview with Ron Klocek. Recorded by T.J. McLaughlin. April 1, 2004.

3. METHODOLOGY

3.1 Problem Identification

Currently at WPI, the Plant Services Grounds Maintenance Department manages and maintains all aspects of WPI grounds on campus and for its peripheral properties. As we move into the computerized age, technology is advancing and processes are becoming computerized. The objective of this project is to make a computerized system for the Grounds Maintenance Department in an attempt to make it easier and more cost efficient to maintain the grounds of WPI. The group used Microsoft Access to keep databases of all information regarding the physical objects maintained on the campus. These databases are linked to computer mapping software which shows the maps of the WPI campus including the various components of what the Grounds Maintenance Department must maintain.

Through extensive evaluation of the current system and the new computerized system, Plant Services will be able to effectively maintain the records through a maintenance log. This will cut down on unnecessary maintenance that has previously been performed recently and also encompass new activities that need to be completed. If maintenance workers have questions regarding their jobs during the workday, they will be able to access proper specifications as to what exactly has to be done and when. This will reduce maintenance time, for example when questions arise and a worker needs to find the specific amount of fertilizer to place in a flower bed, he/she will no longer need to look the information up in a book, he/she can go to the Access database and find the specifications under the proper database. The new process will ultimately save time and money.

In addition to this, the students analyzed the area of each plot of land and calculated the resources needed for each activity based on certain priority levels previously established. These

priority levels are based on different aspects such as the Admissions campus tour, areas seen most by visitors, and areas heavily traveled by motorists. The maintenance for each priority level must be different since different amounts of resources are needed at different levels of service. The students calculated the resources needed through formulas assigned by the APPA (The Association of Higher Education Facilities) booklet. This booklet provides references for different maintenance tasks at multiple priority levels.

3.2 Elements of WPI Campus

The first major objective of this project is to inventory the elements of the campus subject to grounds maintenance at WPI. In order to complete this objective, data must be collected on all elements of the campus. Data was collected in the field with the help of Bartlett Tree Experts and Perennial Planning Inc. Specific information about the needed maintenance tactics needed was given by interviews with Ronald Klocek. To prepare for the interviews, the group developed multiple specific questions regarding the various objectives the project addressed. The students recorded all data into Microsoft Access databases into which information could be stored according to general information, dimensions, maintenance needed, and condition. To make the collection process easier, Access spreadsheets were printed out in order to record the data more simply.

The first element of the grounds, also being the largest area to maintain, is the lawns. With the help of a computer generated map of the campus, the students were able to identify an approximate location for most of the lawns found on campus. The specific details of where the lawns end and where sidewalks, curbs, and gardens began had to be filled in from actual in-the-field collection. By printing out maps of each section of the campus, the group was able to identify the specific dimensions for each lawn area. Then by using the computer program

MapInfo, the students were able to plot the lawns on a GIS (Geographic Information System) map, where the coordinates are real, and based on their world location. The information about the lawns were then recorded in the Access databases. The general information database included the code given to each specific lawn area, the zone, the species names, the optimal grass height, and identified if there was any irrigation present. The condition database includes the pH level, the type of soil, texture, and if there are any disease or insect problems. Again the maintenance database for the lawns included all maintenance activities, including: seeding, thatching, watering, mowing, raking, etc. Like the rest of the databases the grounds crew will be able to see exactly what tasks need to be completed each day.

The next aspect of the grounds are the trees. With the help of Bartlett Tree Experts the team was able to accurately identify all of the species and proper maintenance techniques needed to maintain the trees on a regular basis. The trees were then mapped based on their location on the campus, and in the world, through the GIS program, MapInfo. All information regarding the trees including the general information, dimensions, maintenance and disease information was stored in the Access databases. The general information includes the code assigned to the individual tree, what zone it is in, and the English and Latin species names. This information for the most part is permanent. The dimensions which vary from year to year include the DBH (diameter breast height), measured approximately four feet from the ground, and the canopy radius. Maintenance information include such activities as planting, pruning, and mulching. The condition of the tree as far as diseases, insect or even physical damage were included in a separate database.

After talking with Perennial Planning, information about the flower beds were accumulated. The actual dimensions of the beds were taken from the GIS print-outs and

measured to scale through field calculations. In the flowerbed databases, similar to the tree databases, the general information included where the bed is located and what code it is given. The dimension database contained the surface area of the garden. All maintenance information such as planting, pruning, watering, weeding, fertilizing, etc. is kept in another database. The disease information is again kept in the condition database, which can be updated every time the gardener checks it. The flowerbed databases are very helpful in knowing exactly what flowers are actually planted in the gardens and the proper techniques and specifications to consider when maintaining them.

The final aspect of the grounds are the hard surfaces. The surface dimensions were found by using the GIS print-outs and identifying the exact dimensions in the field. In the databases information was stored about the hard surfaces which require shoveling, plowing (in some cases), sanding, and salting in the winter, and weeding and sweeping in the rest of the seasons. These maintenance activities are located in the maintenance database. The general information database for hard surfaces included the length and width of the walkway/driveway, therefore proper calculations of manpower and time can be calculated.

A maintenance log database was also established in order to keep tract of all maintenance activities on a regular basis. The purpose is for the crew to know exactly the last time a lawn was mowed, a garden was watered, flowers were planted, an icy walkway was salted, and so on. The date, time and activity can all easily be stored in the databases for easy access in the future. This process reduces many questions crew members may have about the last time a task was completed or when the next time it should be performed.

All elements of the campus were mapped onto the MapInfo program on GIS layers. Priority levels were established on the basis of many factors. One important factor was the

campus tour given to potential students by the Admissions Department. Since this is where the potential students will be seeing most of the campus, then it has to look very respectable. To accommodate the campus tour into the planning of the priority levels, buffer zones of fifty, one hundred, and one hundred and fifty feet were set up along the same route as the campus tour. The closer to the campus tour, the higher the priority level of maintenance was. Higher maintenance requires more resources, therefore each aspect of the priority 'zone' needs to be accounted for.

Other parts of the campus also need specific attention. For example, the four corners of the campus: the intersection of Park and Institute, the corner in front Atwater Kent, Skull Tomb, and the West Street entrance, all are heavily seen by visitors, motorists, and people passing by the campus. A priority buffer zone was set up around these areas to encompass proper maintenance activities. Like the campus tour buffer zone, a higher level of maintenance is needed in these areas therefore requiring more resources.

3.3 Resources Necessary

The resources necessary to maintain these elements of the campus are based on the level of service desired. The level of service desired for the most part by WPI, is the 2nd level of attention according to the APPA booklet.[32] "Level 2: high-level maintenance; associated with well-developed public areas, malls, government grounds, or college/university campuses; recommended level for most organizations."[33] The growing season is assumed to be thirty weeks from the first planting or from the start of spring. Analytically the students determined the size of each aspect of the grounds, and then through formulas given in the APPA booklet, determined the time and resources needed to maintain the grounds.

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[32] APPA, Operational Guidelines for Grounds Maintenance. United States of America, APPA, NRPA, and PGMS, 2001
[33] APPA, Operational Guidelines for Grounds Maintenance. United States of America, APPA, NRPA, and PGMS, 2001

The lawns, flowerbeds, trees, and hard surfaces were divided into their own separate databases. In each database, the ID, identifies the element of the grounds with the MapInfo ID and the relational databases. The number corresponding to the actual number of the element within each zone of the campus was also located in these databases. The other piece of the pie is the actual surface area each element of campus takes up. Calculating this figure by using the tools in MapInfo gave the students the necessary information to plug into the formulas of the APPA booklet, therefore allowing them to calculate the total time needed to maintain each aspect of the grounds.

3.4 Asses Level of Service Achievable

After accumulating all of the surface areas and times necessary to maintain each aspect, a certain level of service was established that was attainable using the available resources and scheduling. The team analyzed the various possible levels of service in the APPA booklet realizing that the Level 2 service level was the best fit for WPI. The resources available to the grounds services department and the available man hours per week, limits the level of service attainable. However, "Level 2" is very respectable and all of the necessary maintenance activities can be accomplished using this level of service.

The group then decided that since the buffer zones would be the main focus of the grounds maintenance process, separate priority levels should be established for each zone. "Level 2" maintenance is respectable for the campus as a whole; however each priority zone should have an individual priority level. "Level 1" maintenance is described as "state-of-the-art maintenance applied to a high-quality diverse landscape. Associated with high-traffic urban areas, such as public squares, malls, government grounds, or college/university campuses."[34]

[34] APPA, Operational Guidelines for Grounds Maintenance. United States of America, APPA, NRPA, and PGMS, 2001.

The group decided that "Level 1" maintenance would be more feasible for the fifty foot buffer zone, since this is the area that will be seen the most by visitors touring the campus.

The one hundred foot buffer zone was then established as the "Level 2" maintenance level. The one hundred and fifty foot buffer zone was created as the "Level 3" maintenance level. "Level 3" maintenance is described as "moderate-level maintenance. Associated with locations that have moderate to low levels of development or visitation, or with operations that, because of budget restrictions, cannot afford a higher level of maintenance."[35] This level of service is not necessarily true for the WPI campus, because affordability was not an issue when determining these levels. The main determinant for each priority zone was the APPA booklet and setting up separate levels for each buffer zone.

3.5 Asses Resources and Scheduling

After concluding that three priority levels needed to be established, the resources were planned using the APPA booklets formulas for each priority zone. The total man hours were calculated for each priority zone and compared. Through analysis of each zone and the various resources needed, including how many men per activity, and how much time each task would take, the group created graphs and charts to display the results.

[35] APPA, Operational Guidelines for Grounds Maintenance. United States of America, APPA, NRPA, and PGMS, 2001.

4. RESULTS

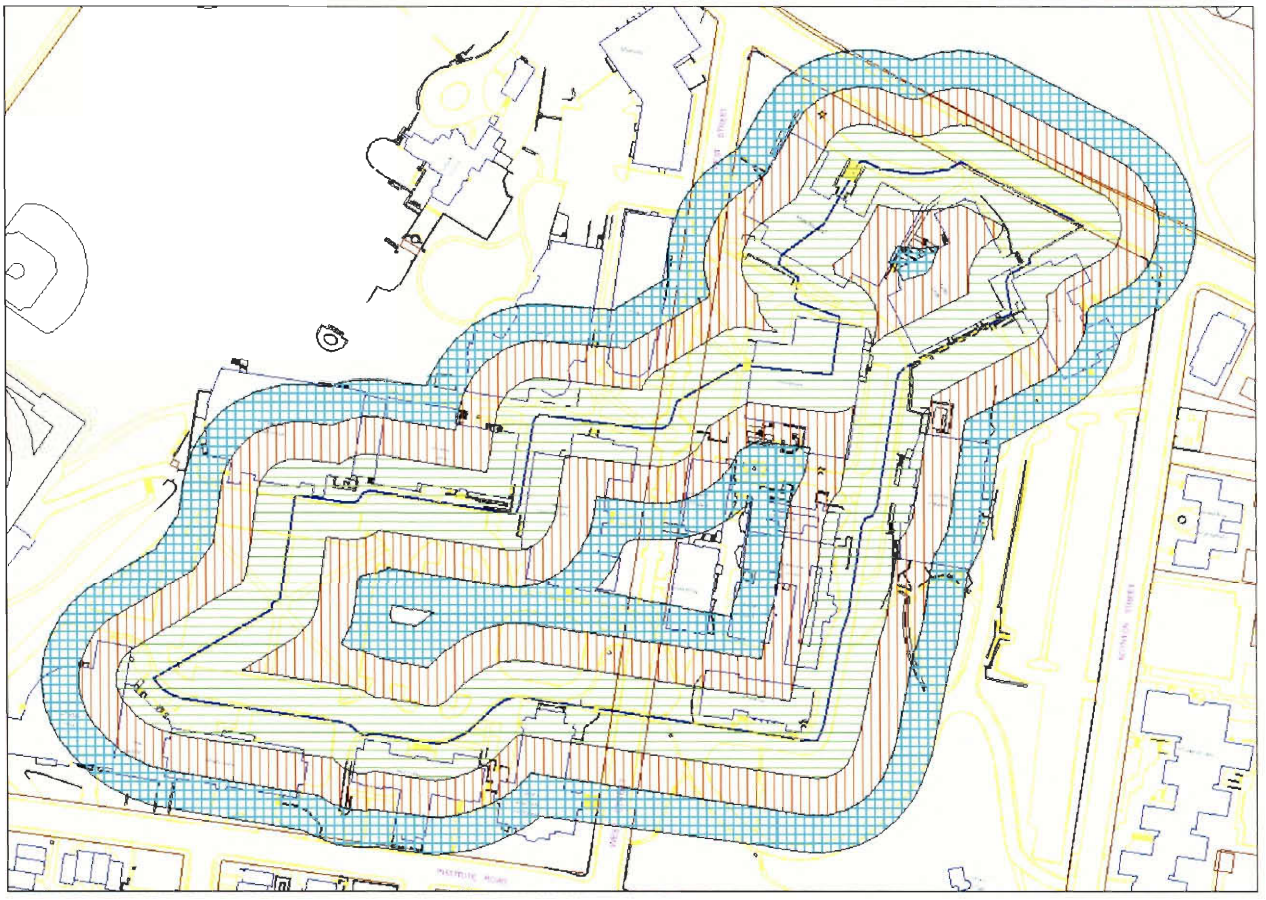
4.1 Buffer Zones

The amount of space that needs to be maintained by the small WPI grounds crew is just unattainable without setting up some sort of priority system. Priority levels were discussed with Mr. Ronald Klocek, manager of the grounds crew, and established on the basis of visibility and high traffic of cars and/or visitors to the campus. After talking with the Admissions Department at WPI, the group mapped out the campus tour given by the Admissions Department to incoming freshmen and/or potential students. The tour can be seen by the dark blue line running through the campus map in Figure 4.1. After mapping the campus tour throughout the campus, the group had to establish the buffer zones, or the areas to which the admissions visitors would see.

These buffer zones were set up in three tiers: a fifty foot, one hundred foot, and a one hundred and fifty foot buffer zone. In Figure 4.1 below, the fifty foot buffer zone can be seen in green horizontal stripes outlining the campus tour as explained previously is blue. The one hundred foot buffer zone can be seen outside of the fifty foot zone in the vertical red region. The one hundred and fifty foot buffer zone outlining the other two zones can be seen in the checkered light blue pattern.

Using these buffer zones the group was able to map out the elements of the campus of most importance to attracting new students to WPI. Each aspect of the grounds maintenance process was taken into consideration throughout each buffer zone. The following elements: lawns, trees, flowerbeds, and hard surfaces, were all taken into consideration when mapping and figuring out the proper maintenance techniques.

Figure 4.1: Map of Buffer Zones

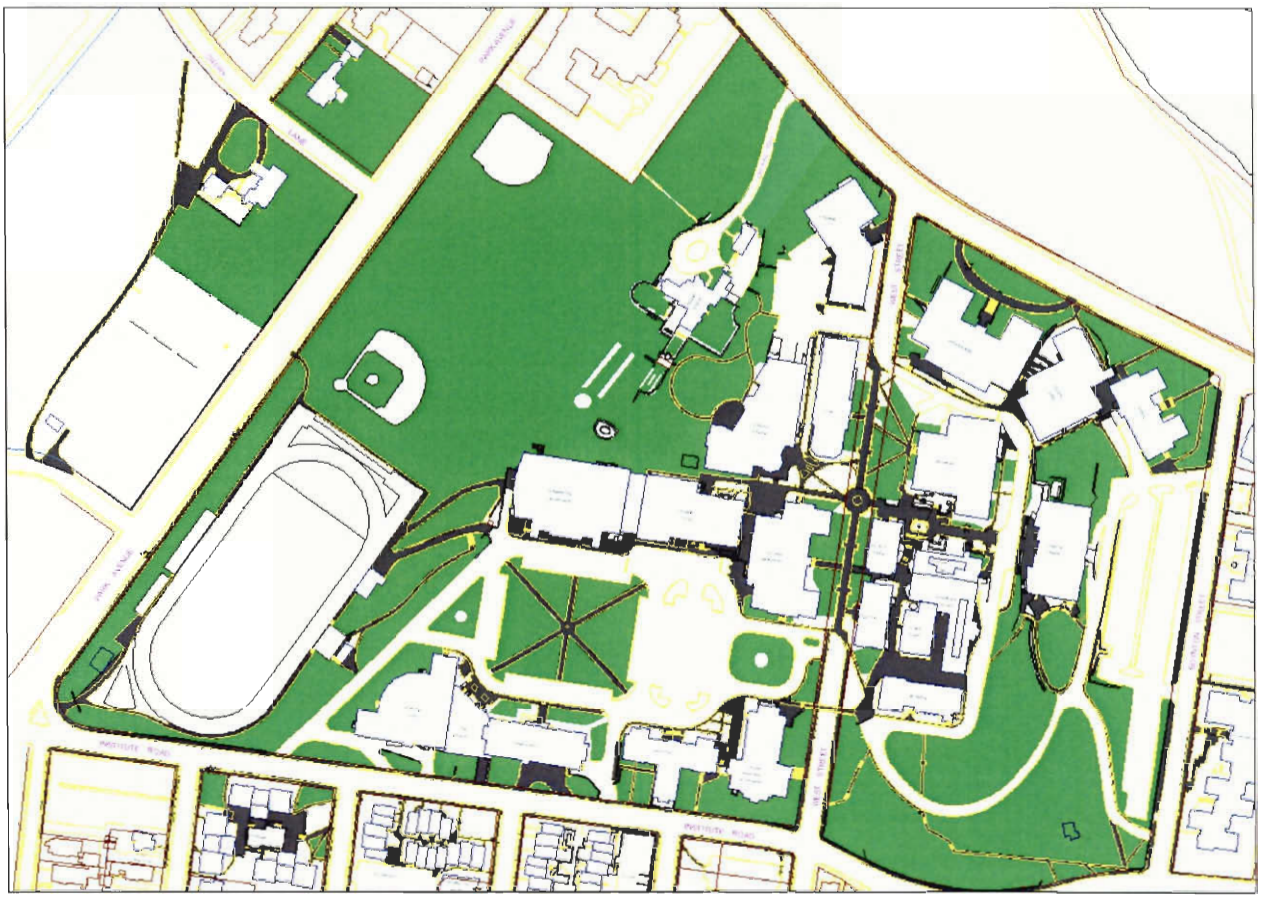


4.2 Lawns

The lawns on WPI account for most of the area that is maintained by the WPI grounds crew. After mapping almost all of the lawns on the WPI campus, without taking into consideration peripheral properties and student residence halls off the main section of the campus, the lawns account for approximately one million, forty thousand square feet of area or twenty-four acres. As you can see in Figure 4.2, the lawns, located on the map in bright green, account for most of the maintenance area at WPI. The lawn area encompasses more than half of the campus area. The lawns vary in size and have many flowerbeds and trees surrounded by mulch throughout the lawn areas. These mulch areas do not require much maintenance other than weeding every few weeks and new mulch application each spring.

The largest lawn area is by far the baseball and softball field lawn area (BSBL-LW-1), covering 232,519 square feet. This area includes the outfields for both the baseball and softball teams, which require the same type of turf maintenance. The second biggest lawn area is the area behind Higgins House (HH-LW-1), in which the surface area is 87,015 square feet. Following the Higgins House lawn, is the lawn area on the President's property (REG-LW-1), covering 58,416 square feet. The lawn areas on Boynton Hill (BH-LW-8, BH-LW-3) are 48,384 square feet and 40,262 square feet respectively. The rest of the lawn areas are smaller than 40,000 square feet. They range all the way from the smallest lawn area at 277 square feet (HH-LW-7).

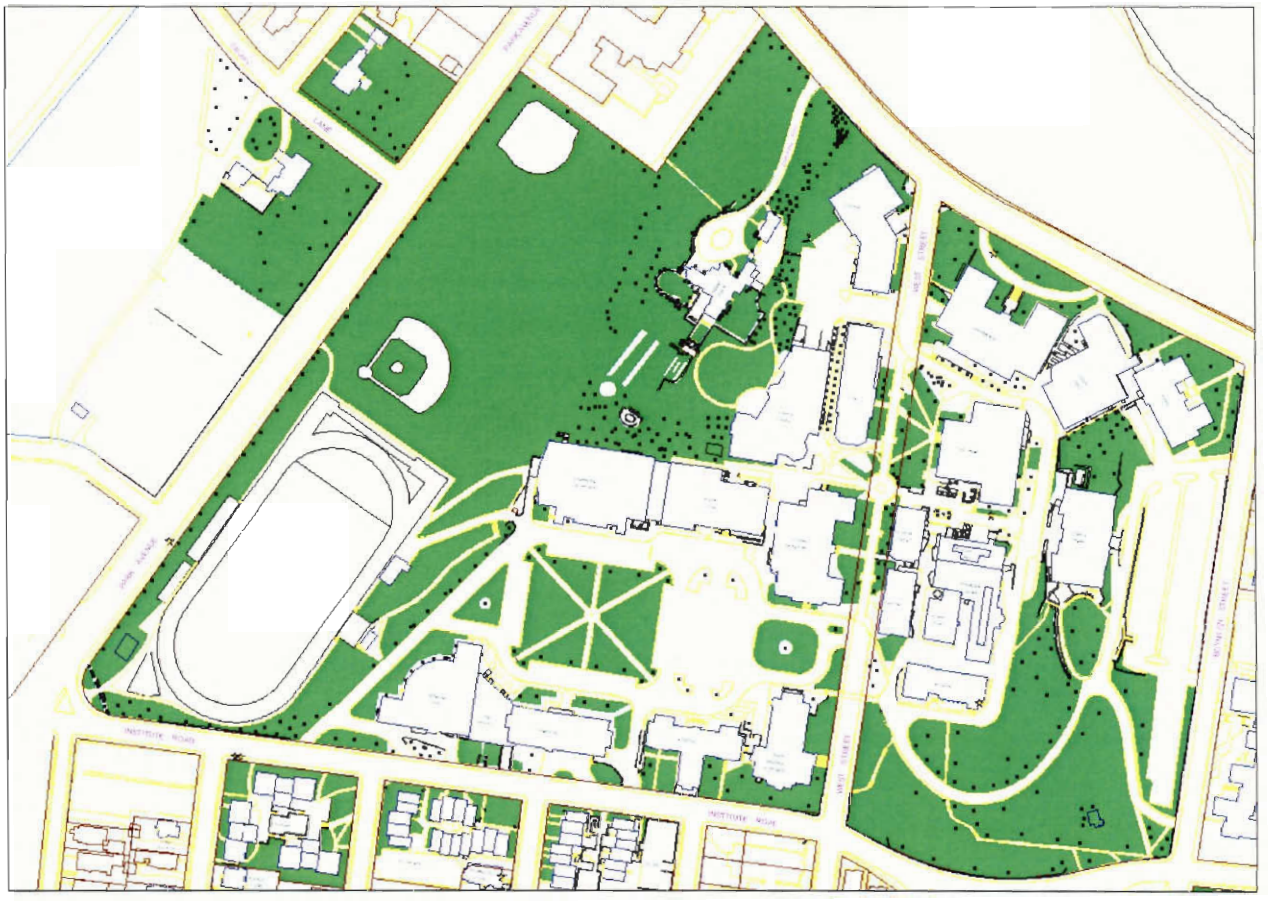
Figure 4.2: Map of Lawns



4.3 Trees

After accumulating the data from The F.A. Bartlett Tree Expert Co. on a study done in August 1993, we mapped all of the trees around the Higgins House area, a total of one hundred and ninety trees. The data included species names, English and Latin, diameter breast heights (DBH), the condition of the tree determined by the plant pathologists from the company, and whether or not a cable was used for the stability of the tree. The group was also able to map various trees around the admissions campus tour area and along the top of Boynton Hill. In total an additional four hundred and ninety-three trees were added to the GIS (Geographic Information Systems) maps.

Figure 4.3: Map of Trees



In Figure 4.3 above, the trees that the group was able to map are indicated by small black dots around the campus. The area to the top of the picture where most of the trees (black dots) are located is the area surrounding the Higgins House. This area encompassed most of the information available to the group regarding the trees aspect of the grounds maintenance process. There is obviously more trees on campus then the total of six hundred and eighty-three trees that were mapped, however, the time constraints on this project limited the group to mapping only the ones present in Figure 4.3.

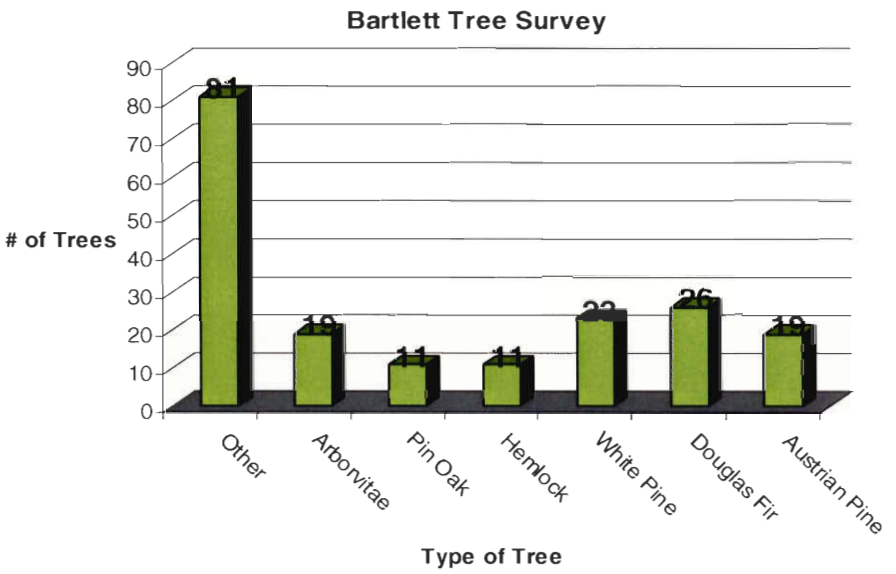
As previously stated, due to time constraints, only information on species and DBH's were retained in the Higgins House project. From the one hundred and ninety plantings there were a total of thirty-five species and varieties. The largest amount of one species was of the Douglas Fir, formally known as Pseudotsuga menziesii. There was a total of twenty-six Douglas Fir's, out of the one hundred and ninety (14%). Coming in a close second was the Eastern White Pine (Pinus Strobus), with twenty-three trees (12%). Followed by the Shagback Hickory (Carya ovata) with twenty-two trees (12%). Species having more than ten trees in the Higgin's Report were Arborvitae (Thuja occidentalis; 19 trees), Austrian Pine (Pinus nigra; 19 trees), Rhododendron (12 trees), Hemlock (Tsuga spp.; 11 trees), and Pin Oak (Quercus palustris; 11 trees).[36]

There were many of the species that only appeared once in the Higgins House area, however some of the trees were very rare for this part of the world. For example tree number 141, was a European Beech (Fagus sylvatica) tree, which was probably bought by Mr. Higgins back when he lived in the estate. This tree measures thirty-eight inches in diameter (DBH), and is a very rare and expensive tree. The tree was estimated to be worth approximately $15,000 by

[36] Smiley Ph.D., E. Thomas, and Bruce R. Fraedrich, Ph.D. Tree Inventory and Management Plan for Higgins Estate. The F.A. Bartlett Tree Experts Co. Charlotte, NC. August, 1993.

one of the Bartlett Tree Experts that helped with this project. There were also many others species that only appeared once in the area, however there are too many to list. The distribution of trees around the Higgins House can be seen below in Figure 4.4.

Figure 4.4: Bartlett Tree Survey Distribution



The diameter breast heights (DBH) were also taken by the Bartlett Tree Experts. The majority of the DBH's ranged from thirteen to eighteen inches in diameter. However there were many that were less than six inches and a few that were even greater than forty inches in diameter. The largest tree in this area was the White Oak (Quercus alba) measuring a whopping sixty-one inches. The next largest trees were also White Oak's measuring forty-six and forty-eight inches in diameter. Being so large, and most likely so old, the tremendous amount of weight that each branch begins to hold after time becomes immense. The tree experts use cables to support these massive branches, therefore preventing breakage and further damage to the tree.

As indicated previously, the Bartlett Tree Experts Co. plays a crucial role in the upkeep of the trees at WPI. For pruning and trimming purposes, WPI outsources almost all of its work

to the Bartlett Tree Experts Co. Since the WPI staff is so small, normal everyday maintenance activities take up too much time during the day to be able to take time to prune the trees on a monthly or yearly cycle. Therefore Bartlett walks around with WPI grounds crew members and indicates whether trees need to be supported with cables and/or pruned. For the most part, Bartlett takes care of most of the maintenance tasks performed on the trees.

4.4 Flowerbeds

The next aspect covered by the group was the flowerbeds around the campus, which indeed give the campus its true beauty. This area was very difficult to map out all of the aspects of each flowerbed, which include flowers, shrubs, bushes, small trees, etc. To map out each individual plant in each flowerbed was just too difficult to accomplish in the allotted time. The group did manage to map out most of the flowerbeds along the campus tour and within the buffer zones.

For the mapped out flowerbeds, one hundred and seventy-five in total, the total surface area encompasses 79,342 square feet. The largest flowerbed is located on the side of the hill next to the entrance to WPI, situated in the Stratton Hall zone. This flowerbed (SH-FB-1) was measured at 2,980 square feet. The next biggest flowerbed is located in front of Atwater Kent; the bed (AK-FB-3) measures 2,341 square feet. The third largest bed (CC-FB-2) is located on the back side of Olin Hall in between it and the Campus Center, measuring 1,937 square feet. The flowerbeds on campus vary in size all the way down to twenty-three square feet, which is a flowerbed (MH-FB-7) in the entrance to Morgan residence hall.

As explained previously, there are a tremendous amount of flowerbeds located on the WPI campus. To map out each one with all of its aspects was not manageable, therefore the group mapped as much as was possible in the prearranged time, concentrating mainly on the

campus tour areas and the areas within the buffer zones. Many flowerbeds only consist of one to two plants and/or trees, covered with mulch. The larger flowerbeds consisted of multiple plants and flowers all covered in mulch. Figure 4.5 below shows the mapped out flowerbeds in GIS.

Figure 4.5: Map of Flowerbeds

4.5 Hard Surfaces

The final aspect of grounds maintenance that the WPI grounds crew must maintain is the hard surfaces such as walkways, sidewalks, private driveways, stairs, and anything else that does not get plowed by a truck during snowstorms. The total area in grey mapped out by the group is 217,978 square feet or approximately five acres. The upkeep of the walkways and other hard surfaces at WPI mostly only require snow removal, and maybe a seasonal sweeping of the sand that has accumulated over the winter from sanding and salting the walkways. The hard surfaces on the campus, are second in maintenance size smaller only to the lawn areas. However, as abovementioned the hard surfaces do not require much maintenance.

In Figure 4.6 below, the hard surfaces maintained by the WPI grounds crew are seen in grey. There are more hard surfaces, such as the parking lots, main driveways to campus, and the streets surrounding the campus, nevertheless they are not maintained by the grounds crew.

Figure 4.6: Map of Hard Surfaces

5. ANALYSIS

The main goal for this project was to map out all the entities of the WPI campus grounds. While doing so, the question in mind was how to continue to beautify the campus in an easier yet more productive fashion. The group took the current eight zones and broke them down into twenty-seven different areas. Creating these areas allows Plant Services to analyze and create new zones which could be more affective based upon the different components within each area which the group then calculated into labor hours for the campus tour buffer zones. The group proposed 27 new areas to maxims man power efficiency compared to the original 8 zones (Figure 5.1) which were currently being used. This same analysis was then applied to the rest of the campus areas created. The team looked at various parts of the campus to examine and decided upon the campus tour as our focal point.

Figure 5.1: Map of Original Campus Zones

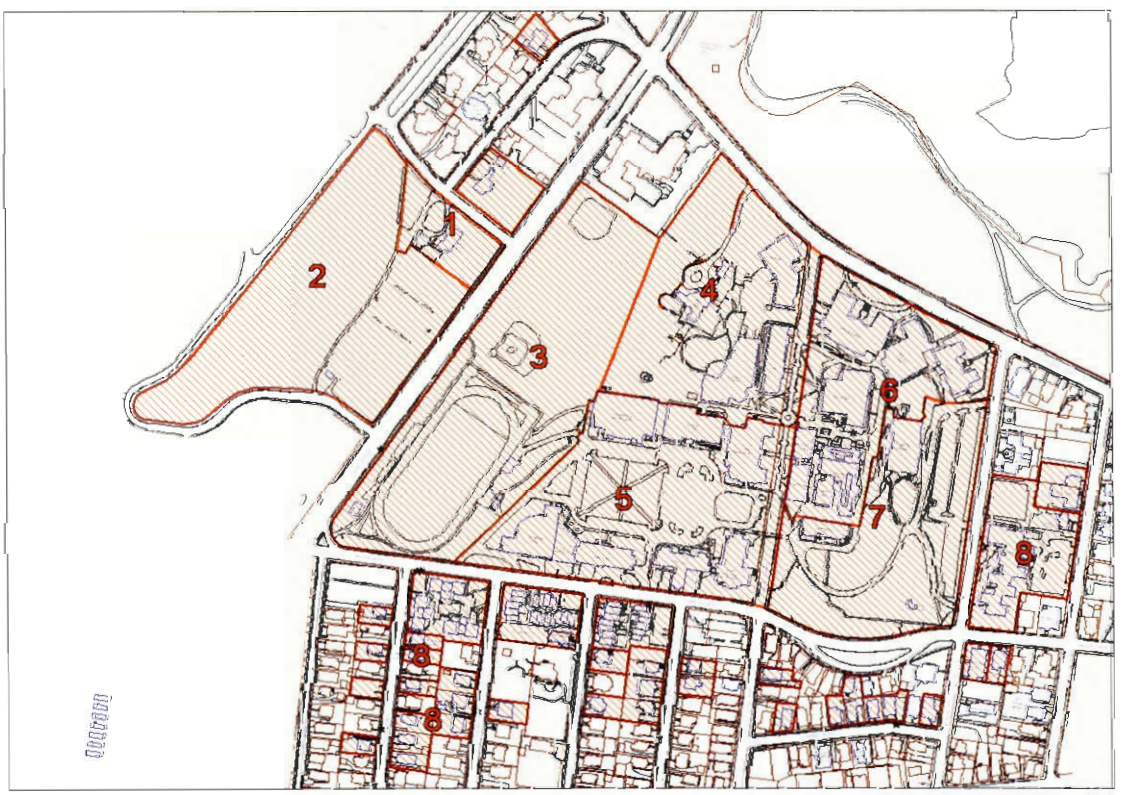
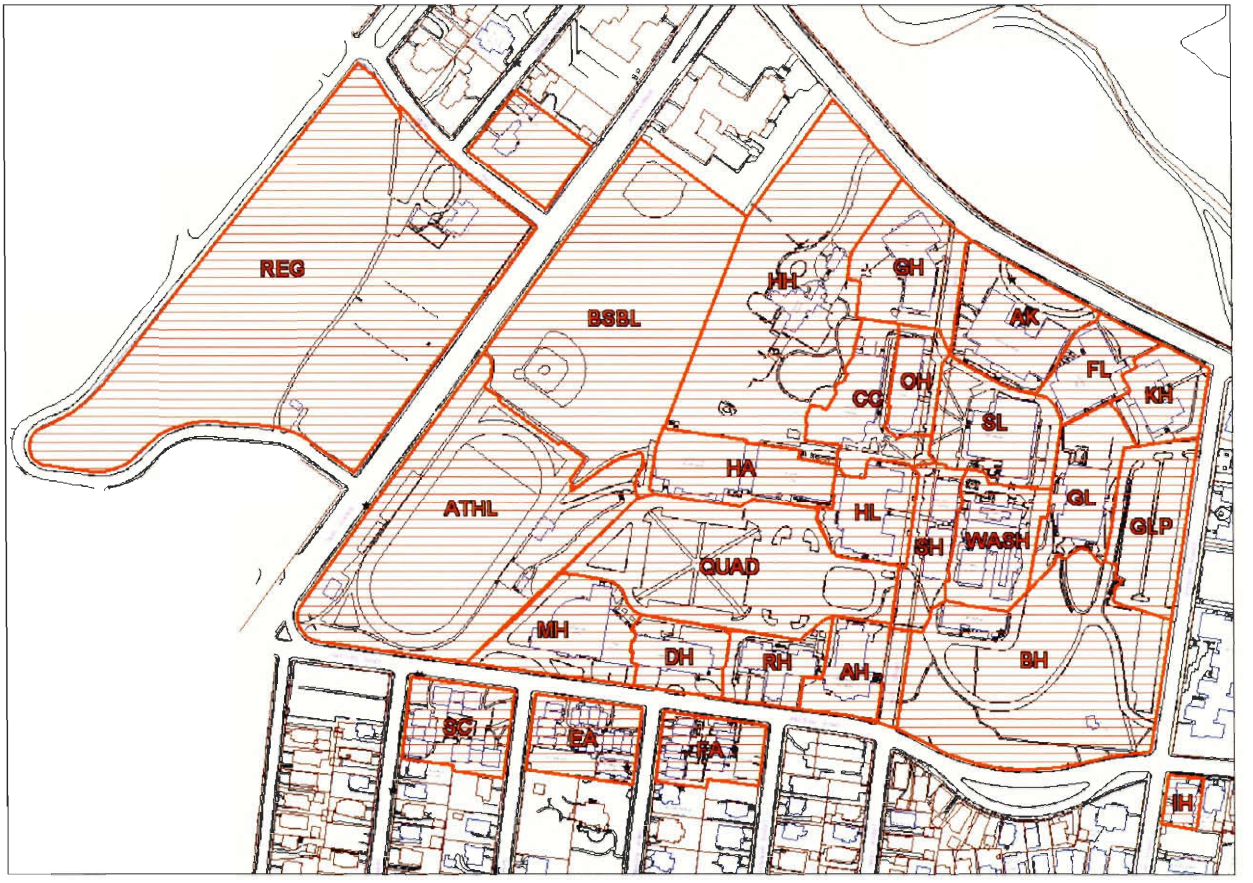


Figure 5.2: Map of Coded Zones



5.1 Level of Service

Offsetting the campus tour, the group created fifty, one-hundred, and one-hundred and fifty foot buffer zones. Within each zone we looked at two aspects of the campus grounds: lawn and flowerbeds. The fifty foot buffer contains 103,000 square feet and 32,150 square feet of lawn and flowerbed areas respectively. The one-hundred foot buffer overlaps 114,430 square feet of lawn surface and 18,350 square feet of flowerbed surface. Lastly, 67,000 square feet of lawn and 14,300 square feet of flowerbed lie in the one-hundred and fifty foot buffer. For analytical purposes, the group decided upon a level of service 1 for the fifty foot buffer, level of service 2 for the one-hundred foot buffer, and a level of service 3 for the one-hundred and fifty

foot buffer. The APPA booklet's matrices contain the Maintenance Tasks which is a series of tasks done within a flowerbed or lawn with time adjustment factors.

5.2 Lawns

The aforementioned lawn staffing matrix was completed on a Microsoft Excel spreadsheet and calculated for levels of service 1, 2, and 3.

Table 5.1: Level of Service for Lawns

	Level of Service (Attention) Hours per Week		
Maintenance Task	**1 (50 FT.)**	**2 (100 FT.)**	**3 (150 FT.)**
Mow - 21" Power/Self	15.45	11.44	6.70
Fertilize	0.67	0.40	0.23
Crabgrass Control	1.80	0.86	0.50
Weed Control	0.22	1.07	0.63
Sweep - 30" Power Rake	0.69	0.38	0.16
Edge, Trim and Clean Walks - Gas-Powered			
Edger	12.88	9.54	2.79
Shrubs	8.58	6.29	1.90
Trim around Raised Objects - String Edger	2.58	1.91	0.56
Overseed	3.61	1.72	1.01
Aerate	10.30	5.72	2.35
Total Hours/Week	56.77	39.33	16.82
6 Hours/Day	9.46	6.55	2.80
5 Days/Week (staff number)	1.89	1.31	0.56
Square Feet/Person	54,430	87,294	119,522
Lawn Area (sq. ft.)	103,000	114,430	67,000
Buffer Zones for Campus Tour (ft.)	50	100	150

The most time consuming task for lawns would be mowing and edging/trimming for any level of service. For analysis purposes, the group will concentrate on a level of service 2. The combined time for mowing and edging/trimming is about twenty-one hours per week. The total hours per week to complete all the maintenance tasks is approximately forty hours per week which results in 1.31 staff members working a six hour day, five times a week. Each member

would be responsible for 87,292 square feet of grass. Yet, only certain tasks would be performed. For example, one could mow, trim, and weed control summing to about twenty-two hours per week. The graph, total hours/week for level of service, depicts the total hours per week needed to complete all maintenance tasks for each level of service for each area zone.

Figure 5.3: Mainteance Tasks For Lawns

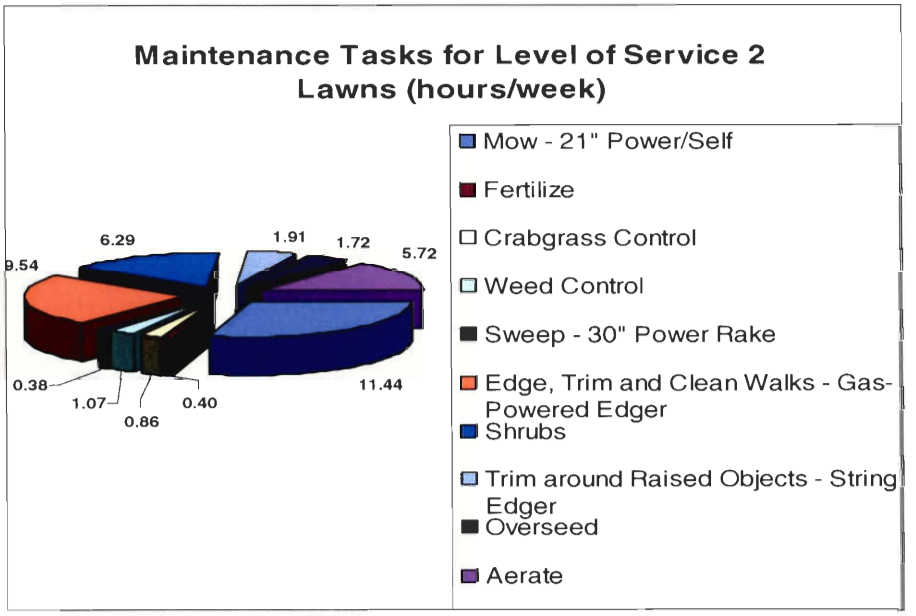
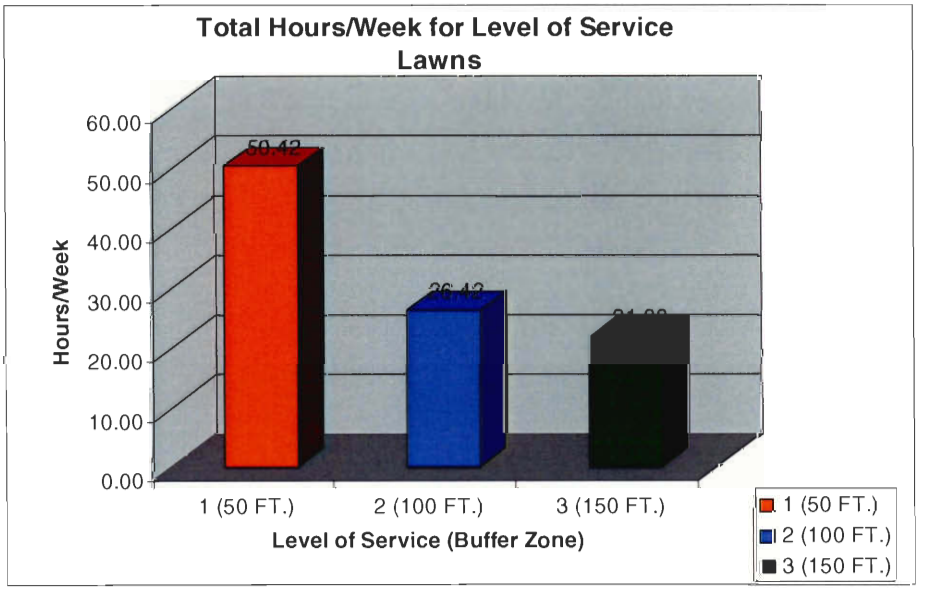


Figure 5.4: Total Man Hours for Lawns



With the lawn areas to be calculated for each ground area, the staffing could be complete and optimized.

5.3 Flowerbeds

The following chart represents the flowerbed staffing matrix, similar to the lawn staffing matrix with different maintenance tasks. With all the same characteristics and trends as the lawn staffing matrix, the flowerbed matrix for a level of service 2 requires 0.88 gardeners to complete approximately twenty-seven hours of work in six hour working day, five times a week. The gardener would be responsible for about 21,000 square feet of flowerbed area. The most time consuming maintenance task for levels of service 1 and 2 would be police by hand.

Figure 5.5: Maintenance Tasks for Flowerbeds

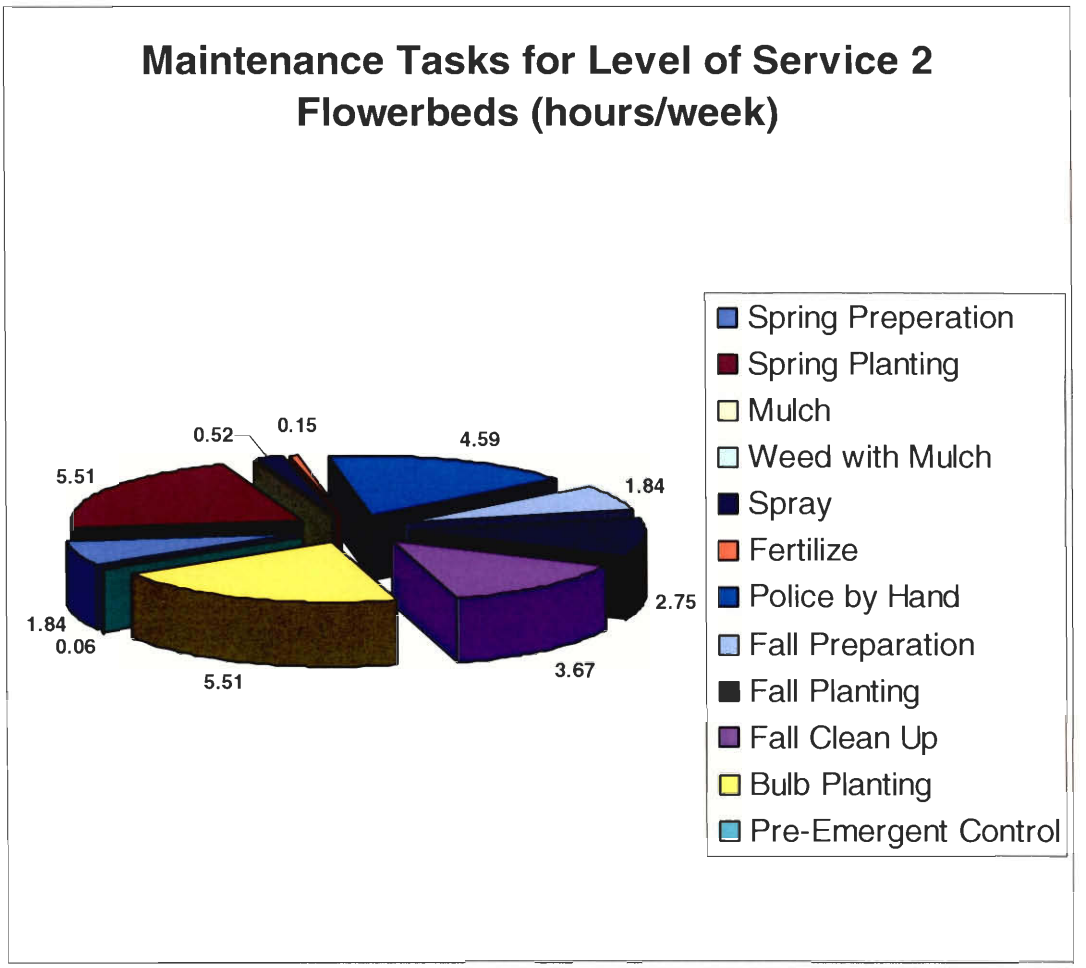


Table 5.2: Level of Service

	Level of Service (Attention) Hours per Week		
Maintenance Tasks	**1 (50 FT.)**	**2 (100 FT.)**	**3 (150 FT.)**
Spring Preperation	3.22	1.84	1.44
Spring Planting	9.65	5.51	4.31
Mulch			0.22
Weed with Mulch			4.78
Spray	0.91	0.52	0.24
Fertilize	0.38	0.15	0.10
Police by Hand	12.06	4.59	
Fall Preparation	3.22	1.84	1.44
Fall Planting	4.82	2.75	2.15
Fall Clean Up	6.43	3.67	2.87
Bulb Planting	9.65	5.51	4.31
Pre-Emergent Control	0.11	0.06	0.05
Total Hours/Week	50.42	26.42	21.88
6 Hours/Day	8.40	4.40	3.65
5 Days/Week (Staff Number)	1.68	0.88	0.73
Square Feet/Person	19,129	20,833	19,672
Flowerbed Area (sq. ft.)	32,150	18,350	14,350
Buffer Zones for Campus Tour (ft.)	50	100	150

Spring and bulb planting, relevant in all three levels of service, take the most time to complete. The square foot per person seems pretty consistent throughout only because the flowerbed areas differ with each buffer zone. If the figures were the same, the same trend would occur as in the lawn matrix with increasing square foot per person and decrease hours per week for each level of service.

Figure 5.6: Total Hours for Flowerbeds

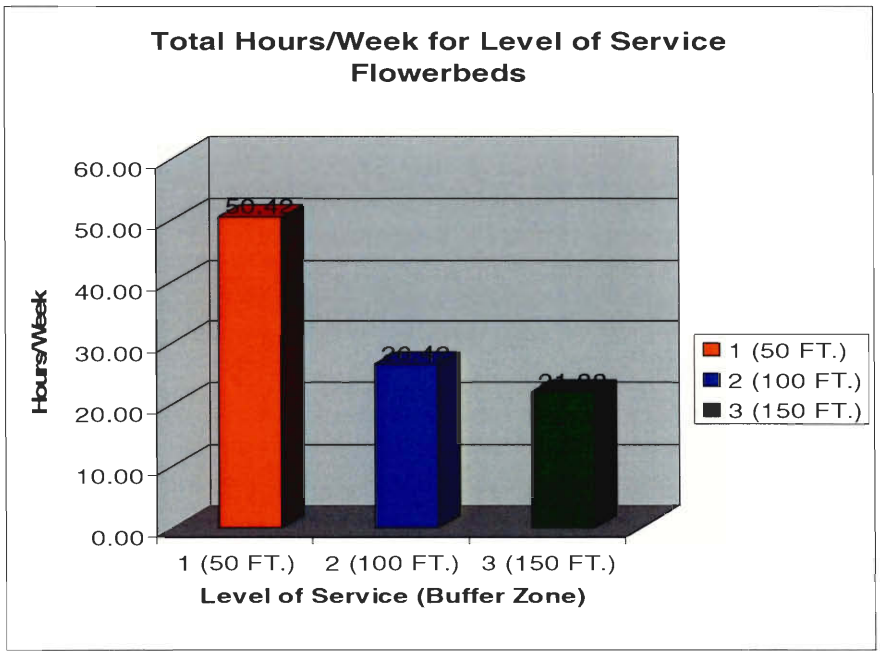
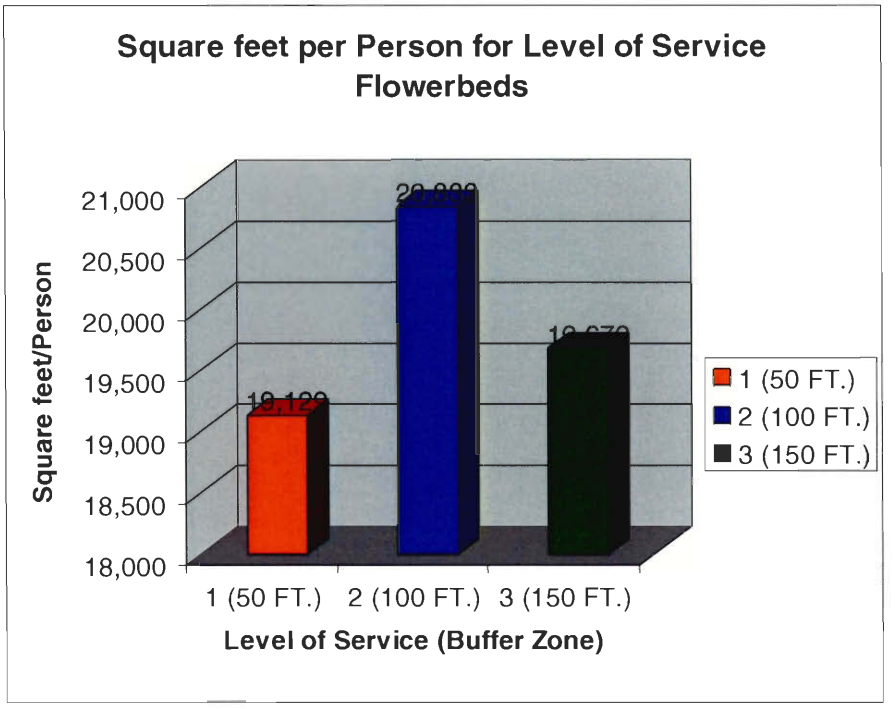


Figure 5.7: Square Footage Per Person



All of the flowerbed areas could result in multiple matrices such as scheduling, budget, ect. The staffing matrix for flowerbeds and lawns allows one to calculate the number of staff members needed for a specific job.

5.4 Hard Surfaces

Since the APPA booklet does not have an adjustment factor, the group came up with their own factor of 15. By taking the overtime hours and dividing it by the snowfall in inches, the team calculated an average of 15 hours per inch. Therefore, if the expected snowfall of 2004-2005 can be determined in advance, 15*x = the amount of overtime hours y to prepare the budget.

Year	Snowfall (in.)	Overtime (hrs.)	Area (sq. ft.)
2001-2002	36.1	658.5	217,978
2002-2003	87.3	1353	217,978
2003-2004	46.6	674	217,978
2004-2005	x	y	217,978

For example, if the predicted snowfall in 2004-2005 is an average of 50 inches, then the overtime hours would be approximately 750 hours. This could better help prepare the budget for cases of snowstorms, and use the money of little snowfall for other projects.

5.5 Scenario 1

WPI is about to hold their annual commencement event. Increase in preparation for flowerbeds is necessary to accommodate this special event. By figuring out the areas to be planted, one can calculate the staff number needed to accomplish this task. For example, let's say they have a total of 35,000 square feet of flowerbeds to be maintained. Since commencement is a special event and important to the WPI community, at least a level of service 2 is requested by Mr. John Miller. Therefore, 35,000/10,000 = staffing at 3.5. The 10,000 is the square foot per person per 1,000 square feet. A level of service 1 would require 35,000/7,692 = staffing at 4.5. Mr. Ron Klocek can now decide if he can afford a level of service 1 for the

special event. This is just one of the many computations the matrices can perform and optimize WPI's Plants Services.

6. RECOMMENDATIONS

This IQP has laid a solid foundation for future IQP projects by establishing GIS maps of the entire campus and related Access databases which can be expanded. The expansion of the database system is dependent on what Plant Services will use it for. As of right now, a solid structure is included in all of the databases, however some information was not recorded due to time constraints and seasonal factors. If the IQP were to be continued by another group, we would recommend the project be conducted in the fall when data collection outside is still possible. For the most part our IQP took place during the winter months, therefore limiting the data collection process to happen during D-term.

After completing this project in its entirety, the team has realized that this IQP could be extended into another IQP where various analyses could be performed. For example, a disease tracking system where diseases through the trees amongst campus could be tracked by researching the trees in each region. In addition to tracking diseases, the canopy radii for each tree can be measured and compiled in the created Access databases. With the canopy, information students can analyze the energy consumption through formulas and experiments. The methods currently in place could use some analysis of the specific process and schedule.

A future extension to the tree database can greatly be influenced by the current Access databases containing information on the Higgins House area. By expanding upon this model, WPI's Plant Services division will have up-to-date, modern technology, and will have the edge in their grounds maintenance processes. In addition to receiving all of the canopies, the diameter breast heights from each tree could also be recorded through further field analysis and data collection.

One of the major resources on campus is the abundance of trees. Trees like the white hemlock are found in very few locations around the world. This is why it is important for us as engineers to protect them and Mother Nature in order to preserve the beauty of the campus. Trees are treated with oils to prevent the spread of disease monthly during the spring and summer. Although it is currently recorded when a tree is treated with oil to prevent disease, it is never recorded as what trees have certain types of disease, where they are located, and the progress of recovery. All of this information can be easily stored in Access databases.

One of the areas, which the project did not focus on, was leaf collection. One of Plant Services major jobs throughout the fall season is leaf collection. By mapping out the specific areas of leaf collection and plotting them on GIS layers, WPI Plant Services would be able to track collection times, calculate man-hours, and distribute workloads better. This is also the case with dealing with trash collection. Though collecting trash is a daily process, recording the amount of collected garbage in areas around campus would help determine where staff should concentrate their focus each day, better distribute workloads, and utilize staff more effectively. Mapping these collection processes requires a lot of data collection, and fieldwork.

Adding to the databases, specific information on each flowerbed, as far as exactly what plants, flowers, shrubs, and trees are located in each bed. The databases were set up to record this type of information, but as explained previously, time constraints and the massive amount of elements to map, limited the team to only certain aspects of the grounds. The flowerbeds of campus are an interregnal part of the WPI beauty on campus.

Priority levels were established based on the campus tour given by the Admissions Department. The tour was mapped and the three buffer zones were mapped around the tour, setting up priority levels or levels of service. Each buffer zone had a separate level of service,

starting with the highest priority going to a middle-range priority level. However as you can see in Chapter 4 in Figure 4.1, there are small gaps in the middle of the campus where there is no buffer zone, therefore would demand no attention from Plant Services. This obviously could not happen in the real situation, since all of the campus deserves at least some attention. We suggest that the buffer zones be looked at more closely and some solution be developed to account for every part of the campus.

In addition to the established buffer zones, zones should be set up in the four corners of the campus where the main entrances are. These areas are heavily traveled by visitors and motorists daily, therefore a high priority level must be established in these areas. The buffer zone would have to include some sort of concentric rings in which the areas would receive attention based on their visibility from the road.

With the information about the surface areas, the group concluded the man-hours it would take to perform certain tasks. Figures on the budget concluded that WPI has close to $750,000 to spend each year on campus grounds maintenance. With further analysis and figures that were unobtainable for this project, a group could do an extensive budget analysis, concluding what was spent, where it was spent and where it needs to be spent.

7. SUMMARY

In the literature review we researched and analyzed grounds maintenance in general and the process that WPI Plant Services achieve. The methodology then described the steps taken to complete this project in a methodical fashion. After describing the process it would take to accomplish such goals, results were shown with screen images from the GIS layers. The analysis concluded with levels of service attainable using the various resources available. The WPI Plant Services can greatly benefit from this project and further projects expanding on our results and analysis.

APPENDIX A: ANNOTATED BIBLIOGRAPHY

Alford's Ground Maintenance. <http://www.alfordsgrounds.com/> 1999.

This website does not have much information, but it does have useful gardening tips that are useful to our project. For example it has information on bulb planting and information on planting trees that will be useful in the proposal to Plant Services.

Bartlett Tree Company. <http://www.bartlett.com/au400.cfm> 2003

This website is the current website for Bartlett Tree Company, the current tree care company that WPI out sources its pruning and tree care to.

Cridland, Robert B. Practical Landscape Gardening. New York: A.T. De La Mare Company, Inc. 1927.

This book deals mostly with houses and the processes before the actual layout. It deals a little with the up keeping, but the information is too out of date for our project.

Crockett, James Underwood. Flowering Shrubs. New York: Time Life Books, 1972.

This book provides an illustrated encyclopedia of flowering shrubs. It shows different ways to care for each type of shrub. This book will be very helpful in determining each type of plant that is on the WPI campus.

Crockett, James Underwood. Lawns and Grounds Covers. Morristown, NJ: Time Life Books, 1971.

This book provides an illustrated encyclopedia of lawns and grounds covers. It provides a detailed description of fertilizers, soil types, weeds, diseases, and how to handle pest control. This book will be very helpful in determining the long-term care of each aspect of the grounds and how to solve fertilization/concentration problems.

Clyde Snobelen Landscaping Ltd. <http://www.vvv.com/~csl/> 2001.

This Landscaping company is located in British Columbia. The website contains very useful information on how to care for different types of plants. This site will be useful for the background information and tips for good grounds maintenance. This company is one of the leading landscapes companies in British Columbia and has many useful topics discussed in detail on the website.

Del-Jen, Inc. <http://www.del-jen.com/services/grounds.htm> 2003.

This website provides all information regarding the company (Del-Jen, Inc.). We looked into contacting the company, however it was very difficult since the company was so large. This company focuses on more than just grounds maintenance, therefore we regarded this information not useful to our project.

Eckbo, Garrett. Urban Landscape Design. New York: McGraw-Hill Book Company, 1964.

This book shows various designs done on other campuses around the country. This book will not be useful for our project since the design of the campus is not a focus for our project. This information was regarded as irrelevant and out of scope.

Eckbo, Garrett. The Landscape We See. New York: McGraw-Hill Book Company, 1969.

Similar to the other book by Eckbo, the book deals mainly with the landscaping design, which we are regarding as out of scope for our project.

Fickes, Michael. "Six Steps to Grounds Maintenance Master Planning." Peter Li Education Group. <http://www.peterli.com/archive/cpm/49.shtm> 2003.

This site discusses, in general terms, what common mistakes campuses make around the nation in terms of grounds maintenance. Also, it gives some good ideas to lower maintenance costs and create a campus of enduring beauty.

Ginsburg, Janet. The City of Chicago Guide to Urban Tree Care. Chicago, IL: City of Chicago Department of Environment, 1994.

This book is very useful in determining the proper care of trees. The book informs of certain things to look for when planting trees and/or caring for them. It provides information with respect to tree care on parking lots, sidewalk pits, above-ground containers, power lines, mulching, and pruning. It also gives types of trees that should be planted in each situation.

Grounds Maintenance Magazine. <http://grounds-mag.com/> 2003.

This website will be very helpful for seeing up to date issues regarding grounds maintenance issues. This website contains many articles and issues that will be very useful in our project. We may also be able to find various links to other advertised grounds maintenance websites.

Klocek, Ronald. "Bed Maintenance (Spring, Summer, Fall)" 2000.

These three documents describe the exact tasks required for each season's flowerbed maintenance. It will be helpful in determining the exact jobs performed by the WPI crews.

Klocek, Ronald. "Fertilization Program." 2000.

This document describes the fertilization program that is implemented at WPI. It breaks down the fertilization into two classifications: one for high maintenance and one for low maintenance. It also includes a chart of the areas of the campus and what classification each area is. It will be helpful in determining the current fertilization program.

Klocek, Ronald. "Gardener I Job Description." 2000.

This document describes the exact description of the Gardener I functions, principal duties, responsibilities, and qualifications. It will be helpful in determining the exact description of what is expected of Gardener I.

Klocek, Ronald. "Gardener II Job Description." 2000.

This document describes the exact description of the Gardener II functions, principal duties, responsibilities, and qualifications. It will be helpful in determining the exact description of what is expected of Gardener II.

Klocek, Ronald. "Groundskeeper Job Description." 2000.

This document describes the exact description of the Groundskeeper functions, principal duties, responsibilities, and qualifications. It will be helpful in determining the exact description of what is expected of the Groundskeeper at WPI

Klocek, Ronald. "Interview with Ronald Klocek." Recorded by T.J. McLaughlin. December 11, 2003.

During this interview various documents were received from Klocek. Also questions were asked about the current budget, fertilization programs, irrigation systems, job descriptions, and future plans.

Klocek, Ronald. "Lawn Maintenance (Spring, Summer, Fall)" 2000.

These three documents describe the exact tasks required for each season's lawn maintenance. It will be helpful in determining the exact jobs performed by the WPI crews.

Klocek, Ronald. "Maintenance Mechanic (Grounds) Job Description." 2000.

This document describes the exact description of the Maintenance Mechanic functions, principal duties, responsibilities, and qualifications. It will be helpful in determining the exact description of what is expected of the Maintenance Mechanic of the Grounds at WPI.

Klocek, Ronald. "Manager of Grounds and Properties Position Description." 2000.

This document describes the exact description of the Manager of Grounds and Properties functions, principal duties, responsibilities, and qualifications. It will be helpful in determining the exact description of what is expected of Ronald Klocek, Manager of Grounds and Properties at WPI.

Klocek, Ronald. "Mulching Plan" 2000.

This chart was a list of all the area that are going to be mulched. It describes each area and for what year the scheduled mulching is planned.

Klocek, Ronald. "Soil PH Levels." 2000.

This document is a chart of the current pH levels in all zones of the campus. It will be extremely helpful in the data collection portion of the project, since the previous pH levels will be needed.

Klocek, Ronald. "Plant Services Vehicles Data" 2000.

This document is a chart of all of the vehicles that WPI Plant Services owns. It states the year and model of the vehicle, along with the Vin number, license number, current use, mileage, condition and any comments noted.

Miller, John. "WPI Alumni: The Bridge" <http://www.wpi.edu/Admin/Alumni/Bridge/0703.html> July 2003.

This website describes a few quick facts about WPI Grounds keeping. It will be helpful during the background section information. It will give us various facts about certain aspects of the campus.

Miller, Robert W. Urban Forestry. Upper Saddle River, NJ: Prentice-Hall, Inc., 1997.

This book will help us plan and manage the grounds in order to enhance the quality of life at WPI. We will further understand the social needs and values that trees and plants bring to the community of WPI.

Phillips, Leonard E. Urban Trees. New York: McGraw-Hill Inc., 1983.

This book mainly provides information on trees and their uses. For the most part we are going to use this book for information on keeping a tree inventory. It will be extremely helpful, since the goal of this project is to map each tree onto GIS. We will utilize this book by knowing what information we need while gathering inventorial data.

Rice University. <http://www.owlnet.rice.edu/~bake302/compost/page1.html> 1998.

This website gives a good outline on how to recycle waste in an attempt to save money. Perhaps this process could be implemented at WPI if not already in use.

Roth, L.O., F.R. Crow, and G.W.A. Mahoney. An Introduction to Agricultural Engineering. Westport, CT: AVI Publishing Company, Inc., 1982.

This book provides a lot of information on farming and how to keep up an agricultural area. However we will use the book to determine irrigation methods and the proper way to water plants, i.e. how much water to apply and when to apply it.

Stanford University Grounds Services. <http://grounds.stanford.edu/index/html> 2001.

This website has a lot of information on how Stanford University maintains its grounds and the processes that they use to keep it up. It will be helpful in our project by showing us what successful grounds maintenance on a campus does to maintain their grounds. This site also contains many horticultural topics that include problems that you may encounter when keeping up the grounds in each season.

University of North Dakota Grounds Maintenance. <http://www.safety.und.edu/manual/grounds/grounds.html#anchor57101> 2003.

This site provides safety tips when working on grounds maintenance issues. This site will be useful if we decide to get into safety issues. It also has useful information regarding environmental issues, which will be helpful when writing about the Environmental Issues.

Weddle, A.E. Landscape Techniques. New York, NY: William Heinemann, 1979.

This book gives a detailed description of enclosure plants versus cosmetic plants. We will use this book to determine the care of each type of plant.

Worcester Polytechnic Institute. "IQP Project – Re-greening Worcester" <http://www.wpi.edu/News/Releases/20001/regreen.html> 2000.

This website has information on the IQP done in Worcester on re-greening the trees of Worcester. The specific IQP document at the library will be useful to see their resources and what they did in their project and what can be useful in our project.

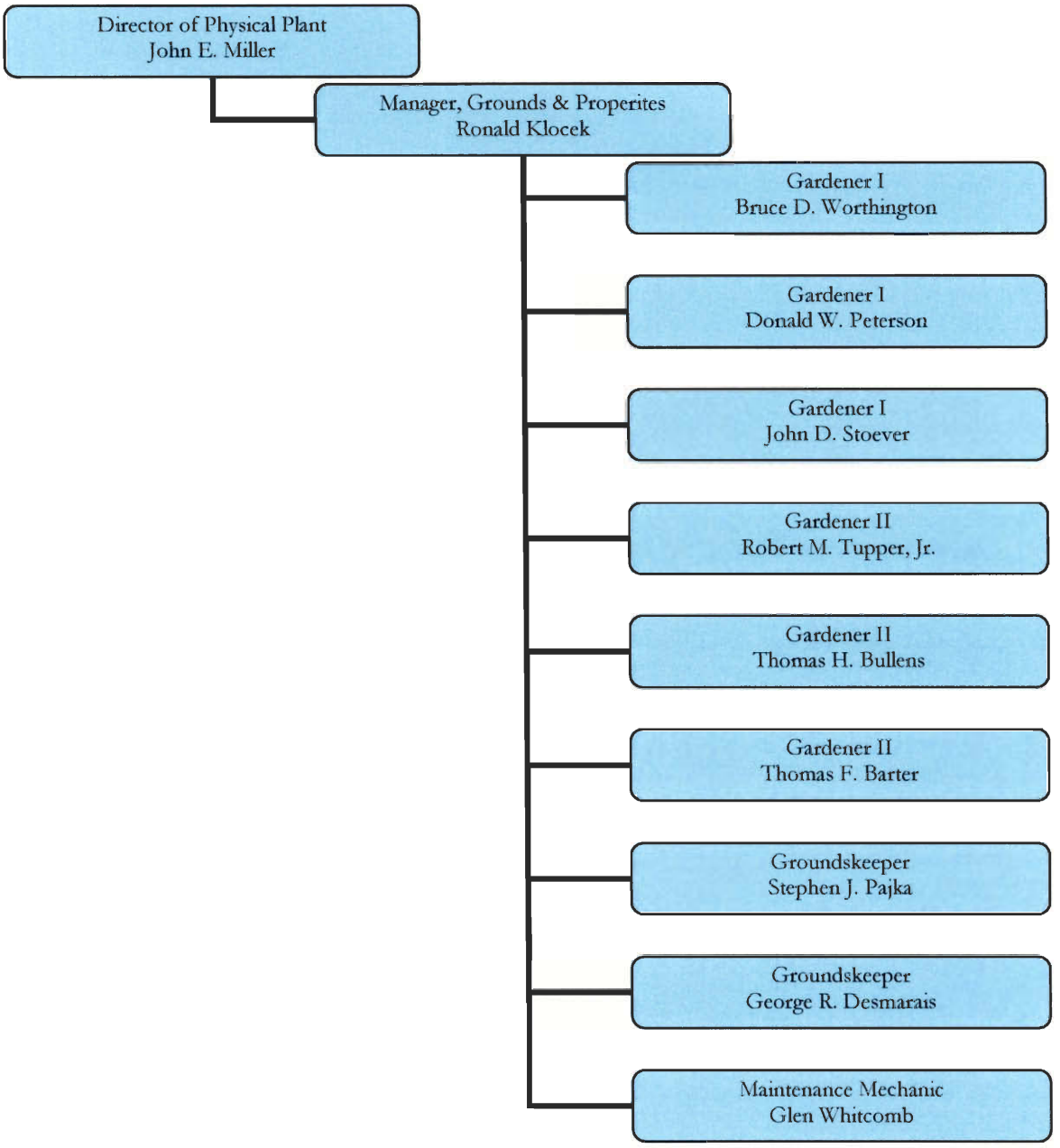
WPI Grounds Services. "Mission Statement for WPI Plant Services" <http://www.wpi.edu/Admin/Plant/Grounds/> 2003.

This website describes the WPI Plant Services Mission Statement and their contact information. It will be useful in our introduction.

WPI Plant Services. "Ronald Klocek" <http://www.wpi.edu/Admin/Plant/People/rkolcek.html> 2003.

This website tells us Ronald Klocek's information: his job description and his contact information.

APPENDIX B: ORGANIZATIONAL CHART



APPENDIX C: FERTILIZATION PROGRAM

Fertilization Program

Zone	Location	Classification	Sq. Ft.	Cost
1	Stoddard Inner	2	7,000	$21.49
2	Stoddard Outer	2	7,000	$21.49
3	Morgan South	1	6,000	$59.34
4	Morgan West	1	20,000	$197.80
5	Alumni East	2	30,000	$282.75
6	Baseball Field	2	114,000	$349.98
7	Softball Field	2	63,000	$193.41
8	Quad	1	40,000	$395.60
9	Beech Tree	1	8,000	$79.12
10	A.J. Knight East	2	16,000	$49.12
11	Mass. Ave.	2	20,000	$61.40
12	1 Drury Park Area	2	38,000	$116.66
13	1 Drury Circle	2	8,000	$24.56
14	15 Regent St.	2	25,000	$76.75
15	Higgin's House Lower	2	130,000	$399.10
16	Higgin's House East	2	5,000	$15.35
17	Higgin's House Southwest	1	4,000	$39.56
18	Atwater Kent North	1	25,000	$247.25
19	Kaven Hall North	1	25,000	$247.25
20	Boynton Hill	2	40,000	$122.80
21	Boynton Institute West	2	35,000	$107.45
22	Skull Tomb	2	50,000	$153.50
23	Founder's Hall	1	8,000	$79.12
24	Ellsworth Apartments	1	10,000	$98.90
25	Fuller Apartments	1	2,000	$19.78
26	West St. Parking Lot	1	5,000	$49.45
27	Institute Hall	1	5,000	$49.45
28	Daniel's North	1	15,000	$148.35
29	Alden-Riley Hall South	1	20,000	$197.80
30	Alden Hall East	1	5,000	$49.45
31	Gordon Library South	2	10,000	$30.70
32	West St. East	1	15,000	$148.35
33	West St. West	1	15,000	$148.35
34	Higgin' House Upper	2	4,000	$12.28
35	Gordon Library North	2	15,000	$46.05
36	Gordon Parking Lot West	2	5,000	$15.35
37	1 Drury Lane East	2	30,000	$92.10
38	A.J. Knight Field	2	36,000	$110.52
39	A.J. Knight Field West	2	12,000	$36.84
40	4 Regent St.	2	2,000	$6.14
Total			**930,000**	**$4,600.71**

APPENDIX D: MULCHING PLAN

Mulching Plan							
Area	**Year**						
	2003	2004	2005	2006	2007	2008	2009
Quard	X	X	X	X	X	X	X
West St.	X	X	X	X	X	X	X
Higgin's House	X	X	X	X	X	X	X
Freeman Plaza	X	X	X	X	X	X	X
Malone Mall	X	X	X	X	X	X	X
Service Drive	X	X	X	X	X	X	X
Boynton Hall	X	X	X	X	X	X	
Campus Center	X	X	X	X	X	X	
Dover St. Parking Lot	X		X		X		X
Stoddard Complex	X		X		X		X
Ellsworth Apartments		X		X		X	
Fuller Apartments		X		X		X	
West St. Parking Lot		X		X		X	
20 Trowbridge Rd.	X		X		X		X
157 West St.		X		X		X	
Institute Hall	X		X		X		X
Founders Hall	X		X		X		X
39 Dean St.	X		X		X		X
Skull Tomb			X		X		X
Gordon Parking Lot		X		X		X	
Kaven Hall		X		X		X	
Morgan Dining Hall		X		X		X	
Morgan Institute Rd.side		X		X		X	
Daniel's Hall Institute Rd side		X		X		X	
Fuller Labs		X		X		X	
Salisbury St.	X	X		X		X	
Alden S/E	X	X		X		X	
Gordon Library S/E	X	X		X		X	
ALL BEDS RAKED,EDGED AND FERTILIZED ANNUALLY							

APPENDIX E: SOIL PH LEVELS

Soil PH Levels

Zone	Location	Sq. Ft.	1997	1998	1999	2001
1	Stoddard Inner	7,000	5.7	5.7	6.5	6.4
2	Stoddard Outer	7,000		5.7	6	6.8
3	Morgan South	6,000	5.8	5.2	6.5	6
4	Morgan West	20,000	5.4	5	6	6.8
5	Alumni Field East	30,000	5.6	5.2	6.3	6.2
6	Baseball Field	114,000	6.7	5.9	6.1	6.2
7	Softball Field	63,000	6.3	6.8	6.4	7
8	Quad	40,000	5.5	5.5	6.3	6.8
9	Beech Tree	8,000	5.3	5.4	6.5	5.6
10	AJKnight East	16,000	5.2	4.8	5.8	5.5
11	Mass Ave.	20,000	5.6	4.4	6	5.5
12	1 Drury Park Area	38,000	5.7	5.8	6.3	5
13	1 Drury Circle	8,000	5.4	5.3	5.9	5.5
14	15 Regent St.	25,000	5.5	6.1	6.1	6.5
15	Higgin's House Lower	130,000	5.1	4.9	5.1	5.1
16	Higgin's House East	5,000	5.1	5.3	5.3	6
17	Higgin's House Southwest	4,000	5.8	5.5	6.5	6.4
18	Atwater Kent North	25,000	5.6	6.1	6.1	6.2
19	Kaven North	25,000	5.9	5.4	6	5.5
20	Boynton Hill	40,000	5.3	4.8	6.3	5.5
21	Boynton Institute West	35,000	6.2	4.6	5.5	5
22	Skull Tomb	50,000	6.6	6.4	6.5	5.2
23	Founder's Hall	8,000	5.9	5.4	6	6.5
24	Ellsworth Apartment's	10,000		6.1	6.5	6.9
25	Fuller Apartment's	2,000		5.5	6.9	6.9
26	West St. Parking Lot	5,000		5.4	6.6	6.8
27	Institute Hall	5,000		6	6.6	7.1
28	Daniel's North	15,000		6	6.1	6.4
29	Alden-Riley Hall's South	20,000		7.2	5.9	7.1
30	Alden Hall East	5,000		6.5	6.1	6.3
31	Gordon Library South	10,000		5.7	6.1	6.3
32	West St. East	15,000		5.3	6	6.4
33	West St. West	15,000		5.4	6.4	6.4
34	Higgin's House Upper	4,000		5.1	5.3	5.1
35	Gordon Library North	15,000		6.2	6	5.7
36	Gordon Parking Lot West	5,000		4.7	5.1	6.3
37	1 Drury Lane East	30,000		4.6	5.3	5.9
38	AJ Knight Field	36,000		6.4	5.8	
39	AJ Knight West	12,000		6.6	6	6.2
40	4 Regent St.	2,000		6.7	5.8	5.4
41	Alumni Field West	12,000		6.7	5.5	6.3
42	Olin Hall West	80,000		5.1	5.9	

APPENDIX F: LIST OF PDF DOCUMENTS

PLEASE NOTE: Documents Do Not State Actual Appendix Names, Actual Documentation is for the paper only. Also note that no page numbers are specified on Appendices G, H, I, J

Appendix G: Maintenance Schedules/Activities

Lawn Maintenance (Spring, Summer, Fall)

Bed Maintenance (Spring, Summer, Fall)

Appendix H: WPI Position Descriptions

Gardener Position Description

Gardener II Position Description

Groundskeeper

Maintenance Mechanic (Grounds)

Manager of Grounds & Properties

Appendix I: WPI Overtime Snow Removal Hours

For the Year of 2002

For the Year of 2003

For the Year of 2004

Appendix J: WPI Baseball Field Irrigation System Map

Lawn Maintenance (Spring)

1. Remove branches, twigs, papers, stones and any other debri from lawns.
2. Remove sand.
3. Repair ruts.
4. Remove thatch.
5. Spot seed and slice seed as needed.
6. Aeration
7. Seed.
8. Fertilize
9. Lime
10. Water (as needed)
11. Check mower for proper operation.
12. Cut lawns to a height of 2 ½'- 3".

Lawn Maintenance (Summer)

1. Remove branches, twigs, papers, stones and any other debri from lawns.
2. Check mower for proper operation.
3. Cut lawns to a height of 2 ½"- 3".
4. Water lawns as necessary. (1"of water per week)
5. Check lawns for insects.
6. Aerate lawns.
7. Fertilize.

Lawn Maintenance (Fall)

1. Remove branches, twigs, papers, stones and any other debri from lawns.
2. Remove leaves.
3. Check mower for proper operation.
4. Cut lawn to a height of 2 ½'– 3".
5. Aerate.
6. Fertilize.
7. Lime (As needed to reach proper P.H. level)

Bed Maintenance (Spring)

1. Rake out all debri.
2. Cut back all flowers.
3. Cut back all dead wood in shrubs.
4. Edge beds.
5. Fertilize beds.
6. Mulch beds.
7. Weed beds as necessary.
8. Water beds as necessary.
9. Dead head flowers.

Bed Maintenance (Summer)

1. Weed beds as necessary.
2. Water beds as necessary.
3. Dead head flowers.
4. Check plants for insect damage.
5. Replace any dead shrubs.
6. Fluff up mulch.
7. Cut back any dead wood in shrubs.
8. Add annuals and perennials to beds.

Bed Maintenance (Fall)

1. Weed beds as necessary.
2. Water beds as necessary.
3. Dead head flowers.
4. Cut back dead flowers.
5. Plant bulbs and perennials.
6. Cut back any dead wood in shrubs.

POSITION DESCRIPTION

TITLE: **Gardener**
GRADE:
STATUS: **Non-Exempt Staff**
REPORTS TO: **Director of Physical Plant Assoc. VP for Business Affairs**
DEPARTMENT: **Plant Services**

BASIC FUNCTION:
This is a skilled position, responsible for upkeep, maintenance and improvement of the campus exterior environment and landscape.

PRINCIPAL DUTIES AND RESPONSIBILITIES:
- Works independently or under supervision with oral or written instructions.
- Diagrams and plans to maintain the grounds consisting of lawns, trees, plantings, shrubbery, roads, lots, playing fields, etc.
- As the situation dictates, may be required to supervise and be responsible for student employees.
- Will be asked from time to time to consult or advise with other employees regarding selection and use of plants, shrubs and planting materials in general.
- Must be capable of making independent decisions with respect to plantings, pruning and similar related gardening activities.
- Will be responsible for determining, through calculation and measurement, the necessary applications of fertilizers, herbicides, lime and other related soil additives.
- During winter, participates in snow removal from walks, steps, hydrants, roads and lots. Also undertakes tasks such as salting and sanding, either by hand or mechanical means.
- Maintains athletics fields or facilities as assigned.
- Makes moves and relocation of equipment as assigned.
- Must be capable of operating all types of college owned motor vehicles, construction equipment, landscape equipment, power tools and related equipment, and must undertake regular and routine checks of equipment for the purpose of safety, equipment maintenance or function.
- Performs routine day-to-day maintenance of equipment used in the conduct of the job.
- Maintains records, inventories, etc., as is directed.
- Must be willing to undertake training and instruction related to the work assignment.
- Will be expected to prepare plans for future plantings, including selection and ordering of materials.

Title: Gardener II
Pay: As Established by Contract
Status: Union
Reports To: Manager of Grounds and Properties
Department: Plant Services

Basic Function:

This is a skilled position which is responsible for the maintenance and upkeep of campus and other college owned grounds, and general laboring tasks between buildings or between other specified locations.

Principal Duties and Responsibilities

Works under the direction of a supervisor with oral instructions, work orders, sketches or related plans to maintain lawns, trees, planting beds, shrubs, drains, roadways, lots and outdoor athletic facilities.

During winter, participates in snow removal from walks, steps, hydrants, roads and parking lots. In addition also undertakes such related tasks such as salting and sanding of the previously mentioned areas.

Operates various college owned motor vehicles, construction equipment, hand and power tools related to the job function, and all other equipment used to undertake the responsibilities of the job.

Loads, moves and unloads various material, furniture, and equipment as required, both in support of department operations or in coordination with other departments. From time to time, must be able to load, unload, or generally handle material such as salt and grounds additives that come in bags weighing 80 lbs.

Must be able to undertake computational tasks related to application of soil additives, mixing of weed control materials, pesticides, etc.

As the situation dictates, may be required to oversee activities of student employees.

Must be capable of making independent decisions with respect to planting, plant shrub and flower selection, mowing, pruning or similar gardener activities.

Performs mechanical maintenance on department equipment as may be required on a day to day basis.

Observes all safety requirements, maintains records and inventories as directed or required.

Qualifications:

High School or GED Diploma
Valid Commonwealth of Massachusetts Drivers License

Gardener Qualifications (continued)

Must have completed 3 years as a Groundskeeper at WPI
Completion of a minimum of 6 pre-approved credit hours of horticultural training
Valid Commonwealth of Massachusetts Pesticide Applicator License

REQUIREMENTS:

- High School or Vocational School degree preferred, but not required.
- Must demonstrate mathematical and verbal skills necessary to make sound judgments on chemical use.
- Class II operators license helpful but not required.
- Minimum of five years experience as a Groundskeeper at WPI or similar demonstrated and documented experience.

_____ _____

Employee Signature **Date**

_____ _____

Supervisor Signature **Date**

POSITION DESCRIPTION

TITLE: Groundskeeper
GRADE:
STATUS: Non-Exempt Staff
REPORTS TO: Manager of Maintenance Operations
DEPARTMENT: Plant Services

BASIC FUNCTION:

This is a skilled position, which is responsible for the maintenance and upkeep of campus and other college owned grounds, and general laboring tasks between buildings, or between other specified locations.

PRINCIPAL DUTIES AND RESPONSIBILITIES:

- Works under the direction of a supervisor or lead man primarily with oral instructions, workloads, sketches or related plans to maintain lawns, trees, planting beds, shrubs, drains, roads, lots, and outdoor athletic facilities.
- During the winter, participates in snow removal from walks, steps, hydrants, roads, and parking lots. In addition, also undertakes such related tasks as salting and sanding of the above mentioned areas.
- Operates various college owned motor vehicles, construction equipment, hand and power tools related to the job function, and all other equipment used to maintain the specified responsibilities.
- Loads, moves, and unloads various material, furniture and equipment as required, both in support of department operations or in coordination with other departments.
- Time to time, must be able to load, unload, or generally handle material such as salt and grounds additives that come in bags weighing 80 lbs.
- Must be able to undertake computational tasks related to application of soil additives, mixing of weed control materials, etc.
- AS the situation dictates, may be required to oversee activities of student employees.
- Must be capable of making independent decisions with respect to plantings, pruning, mowing or similar gardening activities.
- Performs mechanical maintenance on department equipment as may be required.
- Observes all safety requirements as directed.
- Maintains records, inventories, etc., as required.

REQUIREMENTS:

- High School, Vocational School, or GED preferred but not required.
- Valid Massachusetts Drivers' License required, Class II license desirable.
- Demonstrated equipment operation experience helpful.
- Minimum three years as Groundskeeper or related experience or training.

_____ _____

Employee Signature **Date**

_____ _____

Supervisor Signature **Date**

Title: Maintenance Mechanic (Grounds)
Pay: As Established by Contract
Status: Union
Reports To: Manager of Grounds and Properties
Department: Plant Services

Basic Function:

This is a skilled position involving the repair and maintenance of all Plant Services Department vehicles and Grounds Department equipment, including but not limited to; front end loader, trucks, vans, tractors, riding mowers, snow removal equipment, small engines, and other related tools and equipment. Incumbent shall be expected to perform grounds care and snow removal from time to time as required or directed by supervision.

Principal Duties and Responsibilities

Works under the direction of a supervisor with oral instructions, work orders, sketches, manuals or technical information to maintain vehicles, equipment, grounds, roadways, lots and outdoor athletic facilities.

During winter, participates in snow removal from walks, steps hydrants, roads and parking lots. In addition also undertakes such related tasks such as salting and sanding of previously mentioned areas.

Operates various college owned motor vehicles, construction equipment, hand and power tools related to job function, and all other equipment necessary to undertake the responsibilities of the job.

Loads, moves, and unloads various material, furniture, and equipment as required, both in support of department operations or in coordination with other departments. From time to time, must be able to load, unload or generally handle material such as salt and grounds additives that come in bags weighing 80 lbs.

Must be capable of making independent decisions with respect to planting, mowing, pruning or similar grounds care activities. Must be capable further of making independent decisions with respect to the application of various pesticides and herbicides.

Must be able to undertake computational tasks related to application of soil additives, mixing of weed control materials, mixing of pesticides, etc.

Must be capable of using equipment specifications, diagrams, shop manuals, and various electronic forms of information in the repair of vehicles and equipment.

As the situation dictates, may be required to oversee activities of student employees.

Works under the direction of a supervisor to coordinate and schedule routine and irregular maintenance of other Plant Services vehicles.

Performs minor welding on vehicles and equipment.

Maintenance Mechanic (Grounds) cont.

Maintains records for vehicles and equipment relative to maintenance and repair, purchases and maintains inventories of parts, lubricants and materials needed for repair.

Observes all safety requirements and maintains any related records or inventories as required or directed.

Qualifications:

High School, Vocational or GED Diploma
Valid Commonwealth of Massachusetts Drivers License
Minimum of 5 years documented vehicle maintenance experience
(The above may be waved with certification of skills recognized by Commonwealth)
Formal Horticultural training desirable but not required
Valid Commonwealth of Massachusetts Pesticide Applicator License

POSITION DESCRIPTION

TITLE: Manager of Grounds & Properties
GRADE: 830
STATUS: Exempt Staff
REPORTS TO: Associate Vice President for Business Affairs and Director of Physical Plant
DEPARTMENT: Plant Services

BASIC FUNCTION:

Manage the maintenance of all campus grounds and properties peripheral to the campus.

PRINCIPAL DUTIES AND RESPONSIBILITIES:

- Supervises the maintenance of all grounds, athletic fields, and site facilities both on the main campus and peripheral properties.
- Collaborates with others to hire, and train personnel within the assigned work group.
- As required, manages projects undertaken to modernize, upgrade or maintain existing campus grounds, peripheral properties, or other as assigned.
- Supervises the acquisition and maintenance of supplies and inventories required for all operations under the jurisdiction of the position.
- Conducts periodic inspection of facilities under his jurisdiction to establish needs for maintenance and repair.
- Supervises records and operations of Plant Services vehicles.
- Collaborates with others on the maintenance and operation of peripheral properties.
- Is responsible for all campus rigging and moving.
- Is directly responsible for budget expenditures in excess of $800,000.
- When required, act as primary negotiator in union contract discussions.
- Manages the activities of campus snow removal activities, and is on-call on a 24 hour basis for campus emergencies that may arise.
- Directs 9 semi-skilled non-exempt union employees and up to 10 student employees.

REQUIREMENTS:

- Associates Degree in horticulture or related field desirable.
- Six to ten years' experience in ground maintenance required, with a minimum of 3-5 years in a supervisory capacity.
- Licenses or certifications related to the position are desirable.

_____ _____

Employee Signature Date

_____ _____

Supervisor Signature Date

Snow Removal FY 2002

Date	Reason	Overtime Hours
December 9	Plowing	63
December 10	Salting	12
December 15	Salting	5
	Total	**80**
January 7	Plowing	35
January 8	Plowing	22
January 8	(Call In)	8
January 11	Salting	12
January 13	Plowing	51
January 13	Salting (Call back)	24
January 14	Salting	13
January 15	Salting	17.5
January 19	Plowing	31
January 20	Plowing	39
January 21	Salting	49
January 22	Salting	16
January 31	Salting	37
	Total	**352.5**
February 1	Salting	14
February 2	Salting	20

February 3	Salting		4
February 27	Salting		27
February 28	Salting		16
		Total	**81**
March 18	Salting		20
March 19	Salting		14
March 20	Plowing		63
March 21	Salting		46
		Total	**143**
		Year Total	**656.5**

Snow Removal FY 2003

Date	Reason	Hours
Nov. 17	Plowing and salting	43
Nov. 18	Salting	8
Nov. 25	Plowing	20
Nov. 25	Plowing	20
	Total	**91**
Dec. 3	Plowing	28
Dec. 5	Plowing	54
Dec. 6	Plowing	25
Dec. 11	Plowing	28
Dec. 12	Plowing	27
Dec. 12	Salting (Call In)	16
Dec. 13	Plowing	2
Dec. 17	Salting	17
Dec. 25	Plowing	54
Dec. 26	Plowing	63
Dec. 27	Lot Clearing	5
	Total	**319**
Jan. 3	Plowing	48
Jan. 4	Plowing	96.5
Jan. 5	Plowing	37
Jan. 6	Plowing	10
Jan.7	Salting	6

Jan. 9	Snow Removal	4
Jan. 10	Salting	18
Jan. 11	Lot Clearing	8
Jan. 12	Salting (Call In)	4
Jan. 13	Snow Removal	1
Jan. 14	Snow Removal	1
	Total	**233.5**

Feb. 1	Salting (Call In)	8
Feb. 2	Plowing	45
Feb. 3	Salting	10
Feb. 4	Salting (Call In)	17
Feb. 7	Plowing	50
Feb. 8	Plowing	22
Feb. 11	Plowing	29
Feb. 12	Plowing (Lots)	30
Feb. 13	Salting	2
Feb. 17	Plowing	95.5
Feb. 18	Plowing	89
Feb. 19	Plowing	44
Feb. 20	Plowing	4
Feb. 23	Salting (Call In)	15
	Total	**445.5**

March 2	Salting (Call In)		6
March 6	Plowing		44
March 7	Salting		16
March 13	Plowing		46
March 14	Salting		15
		Total	**127**

April 4	Salting		28
April 5	Salting		33
April 7	Plowing		18
April 8	Plowing		12
April 10	Salting		13
		Total	**101**
		Grand Total	**1320**

Snow Removal Fy 2004

Dec. 6	Plowing	42 DT
	Plowing	84
Dec 7	Plowing	57 DT
	Plowing	42
Dec. 8	Salting	15
Dec 15	Plowing	49
Dec. 16	Plowing & Salting	46
	Total	**335**
Jan. 13	Salting	12
Jan. 19	Salting	24
	Salting	8 (Call in)
Jan. 28	Plowing	74
Jan. 29	Plowing	20
	Total	**138**
Feb. 4	Salting	15
Feb. 6	Plowing	49
Feb. 8	Salting	20 (DT)
		4
Feb. 21	Salting	4 (Call in)
	Total	**92**
March 16	Plowing	55
March 17	Plowing	42
	Salting	12 (Call In)

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