The Future of Rooftop Gardens
on the University Of Waterloo Campus

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Table of Contents

1.0 Introduction .......................................................... 3
2.0 Systems Analysis .................................................... 4
  2.1 Actors ................................................................. 5
3.0 Background Information ............................................. 9
4.0 Case Study (MEC) .................................................. 10
5.0 Construction Info .................................................... 11
  5.1 Soil ................................................................. 12
  5.2 Plants ............................................................... 13
  5.3 Design Structure .................................................. 13
6.0 The Environmental Studies I Building ...................... 15
7.0 Benefits ............................................................... 17
  7.1 Air Quality ......................................................... 17
  7.2 Urban Heat Island Effect ....................................... 17
  7.3 Storm Water Mitigation ........................................ 18
  7.4 Cost Benefit ...................................................... 19
  7.5 Habitat and Biodiversity ......................................... 20
  7.6 Aesthetics and Health ........................................... 21
8.0 Limitations ............................................................ 21
9.0 Methodologies ........................................................ 21
  9.1 Justification ....................................................... 22
  9.2 Triangulation Method ............................................ 22
10.0 Cost Analysis .......................................................... 26
11.0 Recommendations .................................................. 28
12.0 Conclusion ........................................................... 28
Bibliography ................................................................. 30
Appendix A: Indigenous Plants ................................. 32
Appendix B: Group Work Breakdown ...................... 33

Figures and Graphs

Figure 1. Rooftop Garden Systems Analysis:
  Building with Roof Top ........................................ 7
Figure 2. Roof Top Garden Systems Analysis:
  Building without garden ...................................... 8
Figure 3. Mountain Equipment Co-op,
  Toronto, Ontario ................................................... 10
Figure 4. Typical Extensive Rooftop Garden Layers ............ 14
Figure 5. Average Annual Temperature .......................... 15
Figure 6. Average Annual Precipitation ........................ 16
Introduction

The Regional Municipality of Waterloo suffers from extremely poor air quality. This problem stems from a variety of sources, including carbon emissions, ground-level ozone and the Urban Heat Island Effect. As a large academic institution, the University of Waterloo has many buildings and paved areas which contribute to these problems. The rooftop area on campus constitutes about 10 acres of barren space. In order to counteract the effects of these buildings, we propose using the roofs to increase green space on campus, by installing rooftop gardens. **Rooftop gardens on the University of Waterloo (UW) campus are feasible and beneficial to the community.**

An extensive rooftop garden system is characterised by its "low weight, low capital cost and minimal maintenance" (Peck and Callaghan, 1999). The garden that is proposed for the Environmental Studies 1 (ES1) would be constructed using a diversity of indigenous, low-lying plants. Environmental Studies 1 is an ideal building for the first rooftop garden on campus because it represents efforts towards a more sustainable relationship with the natural world, similar to the mandate of the Environment and Resource Studies Department based in ES1. Due to the congruent ideals, it is more likely that faculty and students will volunteer in the maintenance of a rooftop garden system.

Air quality impacts are mitigated by a plant’s ability to reduce airborne toxicants, like nitrous oxide and volatile organic compounds (VOC), and to reduce airborne particulate matter (Peck and Callaghan, 1999). Beyond air quality improvements, rooftop gardens benefit our societies economic, education environmental, and social sector.

Rooftop gardens have been implemented throughout Europe especially in Germany and are finding acceptance in North America, including Canada. Increase in popularity of rooftop gardens are becoming visible in Canadian cities as seen with the rooftop meadow on the Mountain Equipment Co-op building and other Toronto buildings. Rooftop garden systems are growing in popularity due to improved aesthetics, air quality, energy efficiency and a variety of other
benefits resulting from the enhanced green spaces. Therefore, we hypothesise that UW and surrounding areas will benefit from installing rooftop gardens.

2.0 Systems Analysis:

All buildings have both ecological and human systems and a variety of associated inputs; a building with a rooftop garden will have more positive connections with the environment and people than one without. Figures one and two compare the systems of a building with a rooftop garden with those of a typical building on the UW campus. The illustrations show the systems involved in the building’s maintenance and its interactions with the community and environment.

The building with a rooftop garden (figure 1) interacts more sustainably with the natural world; plants, through photosynthesis, use the solar energy and entropy is increased (energy is readily available). Runoff from precipitation is minimised on buildings with gardens. Precipitation falls and is absorbed into the soil and is subsequently used by the plants to grow and is transpired back into the environment. Carbon dioxide from emissions can be absorbed by the vegetation and is converted into oxygen and by-products, continuing the carbon cycle.

The campus and community systems contributing to the garden are the plant operations and faculty, staff and students. All of these bodies will be involved in the planning and implementation of rooftop garden as well as the subsequent maintenance and use. By involving the students, faculty, and staff in the creation and maintenance of the rooftop garden, the increased labour, in theory, would provide the people on campus with an environment that fosters a greater sense of community.

The building without the rooftop garden (figure 2) has many of the same inputs but a greater number of negative outputs. Sunlight is absorbed by the roof and subsequently radiated as heat, contributing to the urban heat island effect. Volatile organic compounds are released from roofing materials, contributing to poor local air quality. The flat roof of the building make it difficult for all the water
to drain off, potentially causing damage to the structure of the roof. The water runs off into local creeks through storm sewers.

2.1 Actors

Many people are involved in the implementation of the rooftop garden systems. Feasibility research on the system being designed for installation on the ES 1 building, is performed by the student investigators. Supporting actors of the rooftop garden implementation include University of Waterloo staff, Patti Cook of Waste Management and David Churchill of Plant Operations. Cook and Churchill are integral actors in that they have the historical and structural information needed for implementation. Dean of Environmental Studies, Professor Geoff Boyle is an essential actor, as he will maintain the mandate of the faculty and the building. Knowledge of indigenous plants and garden structure will be gathered from Larry Lamb of the Ecology Laboratories.

Should-be actors are multiple in nature. Environmental Studies Society will provide the bulk of volunteers for installation and will benefit the most from the garden. Increased green space for the students of all departments, architecture, geography, urban planning and environment and resource studies will be beneficial to building and strengthening inter-departmental community. Projects may stem from the garden in that many unknown effects of rooftop gardens exist. UW Administration would be able to receive national and continental recognition as a progressive University attracting new students and attention. Soprema® owns the rights to the Sopranature system of Rooftop Gardens. Upon approval of the project by the University of Waterloo, a partnership may be formed. Students can perform qualitative research on the unknown effects of the garden benefiting the environment and Soprema®. Canada Mortgage and Housing (CMHC) are interested in the promotion of rooftop gardens and the implementation of such a garden at the University of Waterloo will increase and promote the popularity of the garden. Environment Canada, Air & Waste Management Association, Rooftop Gardens Resource Group and Toronto Food Policy Council have been actively involved in previous
workshops and in financing research for gardens. These active groups would be interested in the participation of UW and the popularity it will create.
Figure 1: Rooftop Garden Systems Analysis

Building with Roof Top

- **SUN**
- **Nutrient cycle**
- **Plant Operations (i.e. maintenance)**
- **Architecture**
- **Energy Grid**
- **Heat Loss**
- **Radiated Heat**
- **Transpiration**
- **Hydrological Cycle**
- **Precipitation**
- **Carbon Dioxide**
- **Oxygen**
- **Students, Faculty and Staff**
- **Energy Grid**
- **Heat Loss**

- **Radiated Heat**
- **Transpiration**
- **Hydrological Cycle**
- **Precipitation**
- **SUN**
- **Plant Operations (i.e. maintenance)**
- **Architecture**
- **Energy Grid**
- **Heat Loss**
- **Students, Faculty and Staff**
- **Energy Grid**
- **Heat Loss**
- **Students, Faculty and Staff**
Figure 2 -- Roof Top Garden Systems Analysis

Building without garden
3.0 Background Information

Rooftop garden systems have been in existence for centuries. Early Roman civilisations gave great value to gardens and greenery. This value increased as the urban population increased. Archaeologically, it is difficult to prove the existence of rooftop gardens in ancient times, but there are literary references to them. *Scriptores Historiae Augustae* by Seneca describes rooftop gardens on ancient roman buildings (Farrar, 1996). While, Jashemski (1993) reports finding houses in the southwestern and western part of Pompeii with impressive terrace and roof gardens for social status and insulation advantages. Vikings used turf on the walls and roofs of their homes to protect against wind and rain (Donnelly, 1992).

Contemporary architecture has incorporated green rooftop and vertical garden designs such as the Midway Gardens in Chicago, Mountain Equipment Co-op in Toronto, and the Boyne River Ecology Centre in Shelbourne, Ontario. (Hoffman, 1995; Peck and Callaghan, 1999)

Recently, countries of Northern Europe, especially Germany, Switzerland, Austria, and Scandinavia, have adopted the concepts of rooftop garden systems. This renewed interest has been attributed to “rising concerns regarding the degraded quality of the urban environment and the rapid decline of green space in intensely developed areas” (Peck and Callaghan, 1999).

State legislation and municipal government grants in Germany catapulted the rooftop garden markets since the 1980s to produce ten million square metres of ‘greened’ roofs by 1996 (Boivin, 1992). For many European municipal governments, a key motivator in green roof initiatives has been the improved storm water quality and quantity management. A municipal by-law was passed in Stuttgart, Germany, requiring that all flat-roofed industrial buildings have a grass roof (Johnston and Newton, 1996, p.48). Peck and Callaghan (1999) believe a new industry has been created for plants and material suppliers, roofing
professional, etc. as a direct result of government policy and programs in Europe. New interests are developing in North America from commercial industries like Mountain Equipment Co-op, Non-Governmental Organisations (NGO) to the Good Food Box. Chicago’s 12-storey city hall building will have a 21 000 square foot garden by the fall. The topographical features of the roof are being incorporated into the garden with more than 20 000 herbaceous plants, vines, green grass and a crab apple and hawthorn tree. (Huang, 2000)

4.0 Case Study – Mountain Equipment Co-op, Toronto, Ontario

Mountain Equipment Co-op (MEC) of Toronto, Ontario built an extensive, inaccessible meadow on the rooftop of their downtown store. The initial incentives for the installation of the garden were improved insulation and to stop runoff from the building’s rooftop. Specific plants were chosen for the garden
due to their ability to withstand the intense temperature ranges encountered by rooftop gardens in Toronto. Wind or birds transported many of the plants that are growing today on MEC’s rooftop. In forethought, MEC has installed an irrigation system to encourage and aid the plants’ growth. Peter Carr-Locke (2000), the Member Services Team Leader believes that enhancing the environmental benefits of a rooftop garden are the aesthetic qualities and mental refreshments the garden offers. For the latter reasons, in retrospect he would have made the garden accessible with more access points.

The garden has acted as a nesting area for a family of ducks. In the spring, a mother duck made her nest in the grassy parts of the roof, giving birth to 9 ducklings. It is the hopes of MEC that they will be a role model for other corporations and soon Toronto will be covered in green roofs.

5.0 Construction Information

Rooftop gardens fall under either two categories, intensive or extensive. Intensive rooftop garden systems are able to handle greater amount of weight and allow deeper and heavier soil, providing conditions for a greater variety of plants. The soil depth of an intensive garden is about 152 mm and is composed of a higher organic content than mineral. The plants used, such as grasses, perennials and annuals flowers, shrubs, and small trees, generally require regular maintenance. Regular irrigation, fertilisation, mowing, and pruning will be required for this type of garden. Intensive gardens tend to be expensive as a result of the specialised plants, the soil depth, and the regular maintenance it requires.

Extensive rooftop gardens are lower in capital cost because of less weight requirements placed on the roofs and the minimal to no maintenance that it requires. As a result, plants are restricted to the garden are resistant to frost, wind, droughts, and sudden flooding. To conform to weight restrictions and prevent construction to improve the roofs total load capacity the soil layer has to be very shallow. Composed of mainly mineral material mixed with some organic medium (American Hydrotech, Inc.).
Extensive and intensive rooftop garden systems can be designed to be accessible or inaccessible for use by the private owner or the general public.

Accessible rooftop gardens are built on flat open spaces and are intended for use by people as gardens and terraces. Before implementing an accessible rooftop garden the structural integrity of the roof has to be ensured so that the load of the garden (soil, plants, added structures) and its occupants. The garden would be designed to include features such as pathways, seating, water features, play areas, shade structures, planter boxes, and surface planting. The Ontario Building Code requires an accessible rooftop garden to have a 3.5-foot high continuous guardrail on the perimeter of the building, adequate access and exits and safety measures.

An inaccessible garden is only accessible to people for the purpose of periodic maintenance. This prevents the designers and the builders from having to comply to safety requirements under the Ontario Building Code because its purpose is to viewed and not used. Inaccessible gardens can be implemented on roofs that are curved and sloped (Peck and Callaghan, 1999).

The ideal garden roofs for use on the buildings on the University of Waterloo, specifically Environmental Studies 1, would be extensive and inaccessible. Extensive inaccessible rooftop gardens are 50 to 80% cheaper then an intensive accessible garden. This is because less money would have to be spent on improving the structural integrity of the roof to withstand the extra load and exotic plant species, which require more maintenance than hardier indigenous species. An inaccessible garden will prevent the university from spending extra money on complying with the Ontario Building Code regulation placed upon accessible gardens.

5.1 Soil

The soil on a rooftop garden has no direct link with the natural ground. The soil has to be lightweight to conform to the limited load capacity of the roof. A firm anchorage of the plant’s roots should be provided by the soil to ensure proper growth and uptake essential nutrients and avoid soil loss from erosion.
Pathways should be added to the design of the garden to prevent the soil from being trampled and compacted. Acidification of the soil can increase when it has been compacted resulting in the degeneration of the garden. It is important that the soil has good drainage to ensure proper balance of water in the soil for the plants and avoid excess build up.

The ideal soil for extensive Rooftop garden systems is composed of 75% mineral and 25% organic soil. Mineral soil is composed of crushed clay and pumice lava giving it a high porosity that allows water retention, drainage, and aeration. Well-rotted humus and mature compost containing a high organic fibrous material content is the composition of organic soil. The average depth of the garden soil is very shallow, 5 to 15 cm, with a weight of 72.6 – 169.4 kg/m² (Peck and Callaghan, 1999). The mineral-organic soil should be premixed before it is installed to allow for easier application (American Hydrotech, Inc.).

5.2 Plants

Plants used in extensive rooftop garden systems have to contend to extreme conditions that occur on rooftops and having to contend with minimal soil availability. Plants chosen for the garden need to be able to successfully withstand exposure to direct sunlight and radiated heat off of building surfaces, forcible winds, frost and freezing conditions, along with long dry spells and sudden flooding. Plants most suited for extensive gardens are low and hardy, regenerative, indigenous plants. These plants have special defence mechanisms and shallow root systems that can cope with shallow soil and extreme environmental conditions.

5.3 Design Structure

There are many factors to consider when designing an extensive rooftop garden besides soil and plant type. Considerations include the existing structural capacity of the roof, any new construction or rehabilitation that is required, maintenance and accessibility and aspects of wind loading and fire protection (American Hydrotech, Inc.).
The design and instillation of a green roof is limited by the roof’s carrying capacity and the owner’s preparedness to upgrade the building’s structure. The typical loading capacity of a residential roof in Ontario is 146 -195 kg/m² (not including snow load). Wet soil generally weighs about 1597 kg for each metre cubed. The strain of extensive rooftop garden soil is 55 kg/m² for a layer of substrate 6cm deep. Therefore, little load capacity upgrade would be required on most roofs’ (Peck and Callaghan, 1999).

Typically a rooftop garden is composed of various layers in order to ensure proper maintenance and care of the roof and the garden. The bottom layer is the original roof structure consisting of some insulation. Above this layer needs to be a waterproof membrane to prevent leakage. A drainage layer with a built in water reservoir needs to be placed on top of the waterproof membrane. Filter cloth is then placed on top of the reservoir to contain the roots and the soil, preventing clogging of the drainage system with sedimentation or destruction of the roof by the roots. The soil would then be layered on top of the filter cloth followed by the layer of vegetation (Figure 4) (Peck and Callaghan, 1999).

*Figure 4. Typical Extensive Rooftop Garden Layers (Velazquez, 2000)*
Simple plant community; Height 2-3 inches

(Rest of the content continues from the previous page)
up of vegetation, and help improve the wind stability of the roof (American Hydrotech, Inc.).

In general, an extensive rooftop garden should require a minimal amount of technical and practical experience to install and require little maintenance. Maintenance of the garden should consist of watering and fertilisation for a year until it has been established. Afterwards the garden should only require 2 to 3 visits every year to weed invasive plant species and for safety and membrane inspections.

6.0 The Environmental Studies Rooftop Garden

The proposed rooftop garden on the Environmental Studies 1 building is a typical extensive, inaccessible garden. Indigenous and native plants will be used to replicate local areas to act as stepping-stone habitats. Rooftops are exposed to direct sunlight and severe environmental changes. The Waterloo-Wellington area receives a range of 72.6 to 93.3 mm of precipitate within 10 to 12 days each month during the growing season (Graph 1). While experiencing a daily mean temperature between 5.8 to 19.9°C with a daily maximum temperature between 11.2 to 26.1°C (Graph 2) (Environment Canada, 1998). The plants chosen for the garden would also have to be able to survive these conditions and live in shallow mineral-high soil.
An ideal garden would try to mimic an old-field, meadow, or prairie habitat while incorporating plants that will attract butterflies (Appendix A), promoting and enhancing the campus biodiversity. Butterflies require sunny, sheltered open areas with lots of plants that provide nectar and foliage (Lamb, 1996). Larry Lamb (2000), an ecology instructor at the University of Waterloo, recommended the garden should be kept simple, planting in large simplistic patches. Symmetry should be avoided, but balance should be maintained when replicating the natural disorder of an ecosystem. The native plants required for the garden can be purchased from nurseries or started from seed and seed cuttings (Lamb, 1996).
7.0 Benefits of Rooftop Garden Systems

The University community and the Region of Waterloo benefit from rooftop garden systems on campus in five ways. Rooftop garden systems improve air quality, decrease the urban heat island effect and improve storm water mitigation with beneficial building maintenance costs and aesthetics.

7.1 Air Quality

As air moves across a garden air borne particles and gaseous pollutants are filtered out of the air by the plants. Plants are natural filters of toxins, they are able to trap particles on their leaves, branches, and stem surfaces until it rains and they are washed into the soil. For every one meter square of grass roof, about 0.2 kg of air borne particles can be removed from the air every year (Velazquez, 2000). Nitrous oxides and volatile organic air pollutants that can be absorbed by the foliage are either sequestered in the leaves or used by the plant for photosynthesis (energy production). Rooftop garden systems can also improve the air quality of the surrounding environment by improving building insulation therefore decreasing the thermal air movement around the building. Improved air quality conditions will be beneficial to the people on campus whom suffer from asthma and other breathing ailments which can be enhanced by summer smog and other types of air pollution (Peck and Callaghan, 1999).

7.2 Urban Heat Island Effect

Urban heat island effect describes the temperature difference between high-density urban area and its surrounding countryside. Urban areas consist of large expanses of tightly sealed impervious reflective surfaces that absorb solar radiation and radiate heat to other hard surfaces. “Asphalt in parking lost and on rooftops, in particular, soak up everything (UV radiation) and radiates it as thermal infrared radiation. The heat is released after sunset and forms a dome of higher temperatures over the cities,” (Velazquez, 2000). Trapped urban heat increases temperature levels by differences of approximately 8°C compared to its surrounding area. Increasing temperatures result in an increase of air pollution levels and improve chances of rainfall and severe thunderstorms. The heated air
can also stir up dust and air borne particles, decreasing air quality. These results are due to instability in the atmosphere by increased temperatures.

The temperature of an average roof can range between -20° to 80°C over a single day. A garden on the roof decreases the range in temperature to 10°-30°C (Peck and Callaghan, 1999). The canopy of biomass incurs a cooling effect when precipitation is absorbed by the plants and then released through transpiration (Velazquez, 2000). Vegetation can decrease the urban heat island effect by absorbing solar radiation. Two percent of the energy absorbed by a plant is used in photosynthesis, while 48% is stored in the plants water system, 30% is transformed into heat, and the remaining 20% is reflected back into the air. Rooftop garden systems can regulate the extreme changes in temperature, which occur on a roof by absorbing energy during warm summer days, decreasing the temperature and regulating humidity. While at night and during the winter the gardens release the stored energy and heat from the plants regulating urban temperature and decreasing the urban heat island effect (Peck and Callaghan, 1999).

7.3 Storm Water Mitigation

Urban areas have very little space in which water can penetrate the landscape, placing stress on the sewer system and causing storm water management problems. Storm water is normally contaminated with pollutants accumulated before reaching the storm drain. This polluted storm water flows into the locals rivers unfiltered. A large influx of storm water has commonly resulted in sewer overflow causing dangerous levels of pollutants to enter the natural systems (Peck and Callaghan, 1999). As more precipitation runoff is diverted to the sewer system, the local water tables gradually decline from lack of replenishment of water that has filtered through the soil. Availability of permeable land on the University of Waterloo campus is declining as green space is being lost to new buildings such as the Mackenzie King Village, the Co-operative Education building, and the Centre for Environmental and Information Technologies. The introduction of new buildings without a rooftop garden will result in added stress to the campuses storm management system.
Rooftop garden systems will mitigate storm water runoff. Water retention rate of rooftop gardens are dependent on substrate and vegetation depth, temperature, solar radiation, and wind speed, resulting on average of 70 to 100% retention in the summer and 40 to 50% in the winter (Peck and Callaghan, 1999). Water uptake is directly proportional to the diversity of grasses and plants, decreasing erosion and increasing the water retained on the green roof surface (Velazquez, 2000). The garden interrupts rainfall and delays runoff by several hours, thereby decreasing the potential for flash floods and the frequency of sewage outflow. In Berlin, Germany, Rooftop garden systems are able to absorb 75% of the precipitation that falls on them, allowing less than 25% of the water into the sewer system (Peck and Callaghan, 1999). Besides decreasing the quantity of water that reaches the sewer system, rooftop garden systems are able to improve the quality of water by absorbing its pollutants. Heavy metals and nutrients are bound in the soil instead of being discharged into the ground water, sewers, or rivers. Nitrogen levels are decreased and 95% of cadmium, lead, and copper along with 16% of the zinc is removed from the rainwater.

7.4 Cost Benefit

Buildings with rooftop garden systems can benefit from cost savings, by improving the buildings’ insulation and extending the life of its infrastructure. The extra layer of soil and vegetation added to the roof improves the building’s insulation by decreasing the heat transfer from internal to external. Air traps prevent summer heat from reaching the building’s skin, decreasing the rate of heat transfer from the outside. The indoor temperature of a building with a green roof is usually 3 to 4°C lower than an outdoor summer temperature between 25 - 30°C. During the winter the extra biomass layer prevents internal heat from escaping. Improved insulation of a green roof building results in energy cost savings by decreasing the need for space heating and cooling.

The added layer of a rooftop garden protects the roofing membrane from wear and tare, increasing the materials life span. Extreme temperature fluctuations experienced by a roof everyday, causes cracking and ageing. After 5 years of rainwater pooling on a flat roof, 50% of the roof is susceptible to
damage. Gardens protect roofs from the influence of ultra violet (UV) radiation, fluctuating temperatures, water damage, and physical damage resulting from maintenance and recreation. In 1988, the German government indicated in the “Building Failure / Damage Report”, that rooftop gardens were the solution to flat roof membrane failure. Rooftop gardens increase the life span of roofing material and save the owner money in replacement and maintenance (Peck and Callaghan, 1999).

7.5 Increasing Habitat and Biodiversity

As green spaces decline on campus due to the construction of new buildings, it is important to reclaim this green space with rooftop gardens that will promote biodiversity. Rooftop gardens can not replace natural habitat, but they can be designed to be acceptable and extremely protected alternatives. In Europe, there are two types of rooftop gardens that are used as wildlife corridors in urban areas, stepping-stone and island habitats. Stepping-stone habitats connect isolated habitat pockets with each other, allowing air borne organisms like nesting and migrating birds, insects, and seeds to use it. Island habitats are isolated from other habitats. The gardens are home to a variety of plant species whose seeds are not able to spread by air or over short distances.

Using native and indigenous plants improves the efficiency of rooftop garden systems by providing better food, shelter, and cover for the local animals. Plants are able to survive better when they can evolve with the animals that depend in them for their basic needs (Velazquez, 2000). Extensive rooftop garden systems are more protected garden habitats than intensive because of the limited access. Inaccessible gardens are ideal habitat for sensitive plants, insects and ground-nesting birds. The deeper the garden soil, the greater diversity of insects the roof can support. Animals and invertebrates that can utilise rooftop gardens have to be highly mobile to access it. Butterflies can visit a garden 20 story’s high, while bees and birds can reach rooftop garden systems that are 23 and 19 floors high, respectively (Peck and Callaghan, 1999).
7.6 Aesthetics and Health

Green gardens contribute to improved visual appearance of the campus as well as the health of University of Waterloo faculty, staff and students. Plants can enhance the design of a building and allows them to blend in better with their surrounding area. A variety of health benefits can be attributed to rooftop garden systems and gardens. They improve a person’s psychological wellbeing and reduce stress. Visual contact with vegetation holds the viewers’ attention, diverting it away from themselves and their worries, putting them in a meditative state. Natural settings can relax an individual by decreasing ones heart rate, providing recovery from stress. Increased green spaces from rooftop gardens decrease the populace’s susceptibility to illness by increasing the oxygen content of the air, filtering out air borne particles and controlling humidity (Peck and Callaghan, 1999).

8.0 Limitations

The lack of knowledge and awareness of Rooftop garden systems places barriers and can act as a disadvantage to implementation. The government of Canada provides no incentives to support this technology, often-preventing private homeowners and corporations from implementing Rooftop garden systems. Further information is required on the cost of building and retrofitting rooftops for the variety of garden options available. A key disadvantage to implementing rooftop gardens is the lack of information on technical issues and the risks associated with rooftop gardens. A green roof market has not been established in Canada, from which specialised products and services can be obtained (Peck and Callaghan, 1999).

9.0 Methodology:

Roof top gardens on the University of Waterloo Campus are both beneficial and feasible. The meaning of beneficial is improvements in quality of life, efficiency and sustainability. These are accomplished through changes in the aesthetic, biophysical and financial environments of the campus.
The feasibility of this statement focuses upon the structural limitations of the buildings involved, environmental limitations of climate, the types of species used in the garden and the administrative will to implement this type of project. Cost is a criteria in the feasibility of the system’s implementation but was not a determining factor.

9.1 Justification

Air quality in the Kitchener Waterloo area is some of the worst in Canada. Conventional roofs contribute to this problem. Alternatively, roof top gardens improve air quality, decrease the urban heat island effect, improved storm water mitigation with beneficial building maintenance costs and aesthetics. Consequently, putting a rooftop garden on a University of Waterloo building would be beneficial for the Region as well as the university community, having various academic, public relations and environmental derivatives.

9.2 Triangulation Methods

Our research team used a qualitative approach using three different non-probabilistic sampling techniques. These included purposive informant interviews, a background literature review and a case comparison. The results of these three techniques were triangulated towards formulating our conclusion which is as Palys (1997) noted as typical, an attempt at generating a universal result. We felt a qualitative approach would best fit our project considering the difficulty of experimenting to determine whether or not rooftop gardens are beneficial.

Informant Interviews

The rational for choosing to do informant interviews lies in the fact that we believed the people named below, would be better able to answer and comment constructively on our questions and project direction than we would have been able to derive from other people or media. We believed this because each of the interviewees held a position requiring significant knowledge in the line of questioning that we intended to pose. We were correct in our assumptions as each person interviewed not only answered our questions satisfactorily, but they also went out of their way to draw upon personal contacts and background
knowledge, as per a minor snowball effect (Palys, 1997), to help us with this project. We had very good response rate with three of the three interviewees consenting to be interviewed.

This technique worked very well for us. We were directed to solve several questions that were previously unconsidered by our group as well as pointing us in new directions for information. Thus the open-endedness of the face to face interview worked considerably in our favour (Palys, 1997).

**Key Informants:**

There were four areas of knowledge that questions were formulated around; structural specifications of the UW buildings selected, ecological limitations of a rooftop garden at the University of Waterloo, experiential knowledge from a previously constructed garden project and the administrative hurdles necessary to overcome.

The inquiries made of David Churchill at plant operations on the UW campus concerning the structural specification of each of the three buildings are as follows:

- What are the roof areas of Environmental Studies 1, Minota Hagey graduate student residence and Village 1 residence?
- What building regulations were each of the buildings built under?
- Do they comply with current standards?
- What is the weight allowance of each roof?
- Is there access to water and appropriate drainage?
- What kind of wear and tear do these buildings encounter over the long term and short term?
- What are the costs involved in these repairs?
- What are the heating and air conditioning costs?
- What do you think about the garden initiative?
- Providing the implementation of this kind of a garden is structurally feasible, will there be any funds from the plant operations to pursue it?
- Is there anything else you would like to contribute?
David Churchill was very generous with his time and answered each question via email. He also made some inquiries of elaboration to some of his colleagues both on campus and at other campuses in the province. His response posed several good questions that the research team had not considered at great length, as well as some disconfirming answers.

Larry Lamb, who is an instructor in the environmental studies faculty, was interviewed in person by one of the researchers. His wealth of indigenous biological knowledge was invaluable in determining which species would best fare in a rooftop environment. The only difficulty experienced was that of timing, since he was going on vacation soon after we decided to interview him. The questions posed to him are as follows:

- What has been the average annual precipitation over the past 10-15 years?
- What low-lying plant species indigenous to the KW region would you recommend for our rooftop garden? This list of plants should have minimal maintenance needs, maximise the potential biodiversity and suit the conditions of the roof with respect to moisture and sunlight.
- What soil quality is required to maintain the plants recommended?
- What is the availability and cost of these plants?
- Would they have to be purchased, or could they be seeded and grown on campus?
- Which native species would provide the best habitat for animals able to access the rooftop garden? What would those animals be?
- Do you have any comments about what we should think about when addressing issues of the feasibility of this project?
- Is there anything else you would like to contribute?

For Peter Carr-Locke, the membership services manager at the Mountain Equipment Co-op store in Toronto we had the following questions:

- Which species did you use for your rooftop garden?
- Why did you use those species?
• How has it benefited your employees, members, etc?
• Has it saved you money on heating and cooling?
• Do your employees use the garden?
• Knowing what you know now that the garden is completed, would you do anything differently if you had it to do again?
• Are there special considerations we should be aware of?
• Is there anything else you would like to contribute?

This interview is tied closely with the case comparison because the MEC building in Toronto is the building most closely examined and compared to the buildings on campus. Since the MEC building was not originally designed to have a rooftop garden there are some close similarities to an endeavour on the UW campus.

Limitations:

The limitations of this technique include possible gender bias in the face to face interviews. Female researchers performed the two face to face interviewer and although there is no way of knowing, this may have affected the interviewee’s responses. Similar problems could potentially exist in the form of an age bias, though this too would be difficult to determine. In fact, these potential biases are unlikely to have affected the results in any meaningful way within the context of this project. The benefits, obviously far outweigh the limitations of this technique

Literature Review

There is already a wealth of information available on the topic of rooftop gardens and meadows in print form. Written material is usually the result of someone else’s research or experience and will have a relevant bibliography that can quickly increase the potential understanding of the reader. In the media of print, salient information can be acquired very efficiently and gaps in the researchers understanding can be more quickly ascertained and remedied.

Limitations:
Printed material is one-sided flow of information. There is no capacity for query or further elaboration within any reasonable time frame save an extensive bibliography.

Opposingly, web based resources have an venue for interaction. Newsgroups and email allow for further lines of query but they are not guaranteed to divulge valid and reliable information.

**Case Comparison**

The most accessible rooftop garden project the group knew about was the rooftop meadow on the Mountain Equipment Co-op building in Toronto. The MEC building rooftop was comparable to the roofs we were interested in retrofitting on campus both in height, area and climate, the MEC meadow was thus deemed appropriate for our comparison. This method does not stand by itself, however, since most of the information accumulated about the MEC meadow was derived from the interview with Peter, the MEC membership service manager.

**Limitations:**

It is difficult to compare a physically existing structure with one that has not even been planned.

**10.0 Financial Requirements:**

In consultation with the Canadian Mortgage and Housing Corporation handbook, an approximate figure for the costs of building a rooftop garden on the University of Waterloo campus was developed. The detailed cost figures of MEC building in Toronto and Vancouver Public Library (VPL), both extensive rooftop gardens, were used with extrapolation techniques to determine an estimation for the construction of UW’s rooftop garden. The nominal figure of $150,000.00 for the construction of a rooftop garden is the estimated cost for ES1.
<table>
<thead>
<tr>
<th></th>
<th>Net Area</th>
<th>Cost in $</th>
<th>Cost per square foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEC Toronto</td>
<td>903 m²</td>
<td>169,998.78</td>
<td>$188.26/m²</td>
</tr>
<tr>
<td>Vancouver Public Library</td>
<td>2400 m²</td>
<td>250,008.00</td>
<td>$104.17/m²</td>
</tr>
<tr>
<td>ES1</td>
<td>1090.8 m²</td>
<td>158,166.00</td>
<td>$145/m²</td>
</tr>
</tbody>
</table>

Per unit cost analysis resulted in $145/m² for the ES1 building. This figure is an illustration of the level of magnitude for cost intended to give a very rough idea of the costs that might be incurred. It was generated as a ‘middle of the road’ cost using the MEC cost per square metre as the high end cost and the VPL as the low end. VPL had their garden built into the plans from the beginning and so had no extra costs for redoing any architectural plans or retrofitting a pre-existing structure. The plans for the MEC building did not originally contain a garden but one was added to the plans at an additional cost.

Financial measurement represents the cost of materials and labour, but does not account for the environmental and social benefits. The theory of Green Economics examined by Michael Jacob (1991) approaches economics from a more holistic perspective. It is inclusive of all inputs and outputs of systems. Problems stemming from ‘externalities’ like VOC emissions from heated asphalt are included in the cost accounting of the green economic measure. An orthodox economic perspective does not internalise problems occurring in public resources. For example, problems such as Volatile Organic Compound release is not included in cost since they are difficult to trace and air, leading to the tragedy of the commons. Therefore the sociological and ecological problems that stem from damage to the air will not be included as costs. Only the cost of the material, production of the good and the labour and resources involved in the construction and maintenance can be considered in financial terms. An alternative consideration of costs is required given the environmental problems attributed to conventional roofs and problems that affect air quality, a public resource.

Good air quality, moderated air temperatures, the systemic benefits of improved energy efficiency through insulation as well as the biological value of
the presence of a roof top garden go far beyond the financial costs of implementation, albeit they cannot be measured by conventional dollar figures (Jacobs, 1991).

11.0 Recommendations

Rooftop garden professionals should be consulted about insulation and pest management in order to alleviate concerns about potential problems that might occur. Estimates should be requested for the ES1 building and potential pitfalls in the implementation of this garden should be determined.

A structural analysis of the Environmental Studies 1 building should be performed to determine the present weight allowance. This would reveal how much the existing roof structure would have to be altered to make the structure viable for a rooftop garden.

Examine potential opportunities for integrating rooftop gardens into new or proposed buildings on campus. The new Centre for Environmental and Information Technologies building would benefit especially from an addition such as a rooftop garden.

Permission and support from the administration is required to build a rooftop garden. Consequently the Dean of Environmental Studies should be informed of the benefits of this type of project to aid in the approval process.

Proposals for funding should be submitted to WESEF and other bodies with environmental mandates. The government should be lobbied for support through funding, grants or legislation as in Germany and Switzerland (Boivin, 1992).

The garden should be built.

12.0 Conclusion

Rooftop garden systems date back to the historical ages of Pompeii and the Vikings, being used to improve insulation and weather protection as well as enhancing the aesthetics of a community. Northern European countries encourage rooftop gardens through legislation and by-laws, as a means of
Reducing the stresses of an increasing urban population. North America is beginning to embrace the idea of gardens with pioneering efforts by environmentally minded independent bodies. The University of Waterloo can be a forerunner in forging a new industry in Canada with many benefits to the environment and social sectors. The financial cost of implementing a rooftop garden is far outweighed by the social and environmental benefits. The initial sum should not be a detriment because the benefits will be felt for years to come. Results were collected through key informant interviews, secondary research and case study. Rooftop garden systems are both beneficial and feasible on the University of Waterloo campus.
Works Cited


Lamb, Larry. 1996. Front and Backyard Naturalization Efforts.  Waterloo: Faculty of Environmental Studies, University of Waterloo.


Appendix A.

Potential Indigenous and Native Plants for the ES1 Rooftop Garden (McKenny et al., 1968)

<table>
<thead>
<tr>
<th>Name of Plant</th>
<th>Family</th>
<th>Height</th>
<th>Growing Season</th>
<th>General</th>
</tr>
</thead>
</table>
| Black-eyed Susan       | Composite  | 1-3 ft | June - October | • Yellow  
| **Rudbeckia hirta**    |            |        |                | • Dry fields, roadsides, waste land                                      |
| Hairy Mountain-Mints   | Labiatae   | 1-2.5 ft |                | • White flower  
| **Pycanthemum pilosum**|            |        |                | • Dry woods, thickets, fields, upland                                   |
| Whorled Milkweed       | Milkweed   | 1-2 ft | June – September| • White  
| **Asclepias verticillata** |            |        |                | • Dry slopes, open woods                                                |
| Butterfly-Weed         | Milkweed   | 1-2 ft | June – September| • Orange  
| **Asclepias tuberosa** |            |        |                | • Fields, dry soil                                                      |
| Moss Phlox             | Phlox      | 2-6 in | April – May    | • Pink, violet, white  
| **Phlox subulata**     |            |        |                | • Rocky slopes, sandy soil                                              |
| Field Pussytoes        | Composite  | 4-12 in | April – May    | • White  
| **Antennaria neglecta**|            |        |                | • Form dense mats  
|                        |            |        |                | • Dry fields, open slopes                                               |
| Bearberry              | Heath      | May – July |                | • White / pink  
| **Arctostaphylos uva-ursi** |      |        |                | • Trailing shrub with papery reddish bark & small evergreen leaves   |
|                        |            |        |                | • Red berry  
|                        |            |        |                | • Sand & rock                                                           |
| Azure Aster            | Composite  | 1-4 ft | August – October| • Blue / violet  
| **Aster azureus**      |            |        |                | • Wood edges, fields, prairies                                           |
| Heath Aster            | Composite  | 1-3 ft | July – October | • Tiny white blossoms  
| **Aster ericoides**    |            |        |                | • Dry open places                                                       |
| Downy Wood-Mint        | Mint       | 1-3 ft | June – August | • Blue-purple  
| **Blephilia Ciliata**  |            |        |                | • Dry woods, thickets                                                   |
| Alumroot               | Saxifrage  | 2-3 ft | April – June   | • Green  
| **Heuchera americana** |            |        |                | • Dry woods, shady rocks                                                 |
| Woolly Blue Violet     | Violets    | Low plants | March – June | • Woods, meadows                                                       
| **Viola sororia**      |            |        |                |                                                                 |

<table>
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<tr>
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<th>Height</th>
<th>Growing Season</th>
<th>General</th>
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</table>
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| **Arctostaphylos uva-ursi** |      |        |                | • Trailing shrub with papery reddish bark & small evergreen leaves   |
|                        |            |        |                | • Red berry  
|                        |            |        |                | • Sand & rock                                                           |
| Azure Aster            | Composite  | 1-4 ft | August – October| • Blue / violet  
| **Aster azureus**      |            |        |                | • Wood edges, fields, prairies                                           |
| Heath Aster            | Composite  | 1-3 ft | July – October | • Tiny white blossoms  
| **Aster ericoides**    |            |        |                | • Dry open places                                                       |
| Downy Wood-Mint        | Mint       | 1-3 ft | June – August | • Blue-purple  
| **Blephilia Ciliata**  |            |        |                | • Dry woods, thickets                                                   |
| Alumroot               | Saxifrage  | 2-3 ft | April – June   | • Green  
| **Heuchera americana** |            |        |                | • Dry woods, shady rocks                                                 |
| Woolly Blue Violet     | Violets    | Low plants | March – June | • Woods, meadows                                                       
| **Viola sororia**      |            |        |                |                                                                 |
Appendix B

Group Work Breakdown

Meetings were held once a week, in addition to meetings with Anita every other week. Generally everyone attended meetings with Anita on a regular basis.

The proposal was divided equally between the three group members. Christy Wilson was responsible for Introduction, Systems Diagram, Background and Case Study. Amanda Dam completed sections pertaining to Construction Information, Benefits, Limitations and Description of ES1 garden. Colin Walke focussed on Methodology, Cost and Recommendations.

The Presentation was created together. Visuals: Colin created 3-D prop and Amanda drew the plans for the ES1 building.

Interviews were performed for individual sections in research projects. Christy Wilson interviewed and toured Mountain Equipment Co-op, Amanda Dam interviewed Larry Lamb and Colin Walke interviewed David Churchill.