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# THE GREENING OF STORMWATER MANAGEMENT

## MITIGATING THE RISKS OF STORMWATER ON STUDLEY CAMPUS THROUGH THE INSTALLATION OF GREEN ROOFS


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# 2 EXECUTIVE SUMMARY

Our project goal was to address the current issues with stormwater management on Studley Campus and apply a sustainable solution to mitigate the associated environmental damages. By reducing the amount of water on campus from reaching storm sewers, significant reductions can be made in urban road pollution being deposited into the harbour. We acknowledged that green roofing is an affordable and effective method for improving current stormwater management, and in helping promote Dalhousie's commitment towards a sustainable campus.

Dalhousie Master Plan allocated funds annually into sustainable development, specifying that all new developments on campus have green roofing (Dalhousie University, 2010). To complement this requirement, using geographic information systems (GIS) we defined the total viable surface area of buildings on the Studley Campus (250,000 $ft^2$) and estimated an installation cost of approximately $2-2.5 million to the University. Additionally, we examined the alternative benefits of green roofing on the Mona Campbell Building, Halifax Central Library and The Seaport Market. Our findings were applied to estimate effects similar installations would have on the Studley campus buildings.

Our recommendation for Dalhousie is to use this preliminary research to incorporate green roofing on all new buildings, as well as existing buildings with sufficient structural ability.

# 3 INTRODUCTION

## 3.1 Background Information

Globally, the world population is becoming increasingly urban; with cities constantly expanding in terms of space and density. This trend towards urbanization greatly decreases the amount of permeable surfaces, adversely effecting city infrastructure and the surrounding environment. When storm events occur, the water infiltration capability decreases as the surface runoff and the stress on existing stormwater infrastructure increases consequently making sewer flooding in urban areas more frequent (Berndtsson, 2010).

### 3.1.1 Stormwater Management as a Municipal Issue

Over time stormwater management has become an increasingly pressing issue within many municipalities as it creates a series of interconnected biophysical issues affecting both the natural and human environment. Halifax now spans a geographic area of 5,500 square kilometers and had a population of approximately 400,000 in 2011 (Statistics Canada, 2014). When Halifax was formed in 1996 through the amalgamation of four pre-existing municipalities, it resulted in the combination of various policies and procedures relating to stormwater management. In order to achieve consistency in its approach to stormwater management, Halifax partnered with Dillon Consulting and embarked on the development of the Stormwater Management Guidelines in 2006.

Halifax's current stormwater system includes a mix of Best Management Processes (BMP's) including: ditches and culverts, combined sewers, separate storm sewers, street curbs and gutters, and retention ponds and tanks (Sheppard, 2012). However, during heavy downpours, not all stormwater enters these systems; after encountering various surfaces including roofs, discharge pipes, parking lots, driveways, roadways, lawns, and ditches, much of this now contaminated stormwater goes directly into the nearby watercourses (Sheppard, 2012). This creates a series of biophysical issues in the area, affecting both the natural and human environment.

Since Dalhousie covers a significant portion of the Halifax peninsula, the University has the ability to drastically improve the stormwater management systems in place within the city.

### 3.1.2 Cost and Impacts of Stormwater

Mainly as a result of past land development practice and inadequate investment in infrastructure, there are numerous negative impacts that stormwater has on its receiving environment (Sheppard, 2012). Some of these impacts include: damages to water courses and receiving waters such as erosion and reduced water quality; flooding of properties resulting in costs to property owners and high insurance rates; sewage overflows from the inflow of stormwater and groundwater into the wastewater system; risks to public health through water contamination; and high operational and maintenance costs of stormwater management systems (Sheppard, 2012).

A common issue in stormwater management is the leakage of stormwater into the wastewater system. This is one of the most serious operational and compliance problems Halifax is currently facing relating to its wastewater system. A heavy storm event can increase the system flow up to 25 times causing sewage overflows, basement backups, washout of treatment processes, property damage, human health risks and serious adverse effects on the receiving environment (Sheppard, 2012).

Depending upon the land use in the watershed, nutrients and toxics can be scrubbed off roadways and parking lots and transported overland and through storm drains into waterways causing toxic loading of the stream (Thurston, 2006). The contaminants in urban runoff include toxic metals, hydrocarbons, nutrients and pesticides.

Many of the contaminants in road runoff are associated with particulate material and accumulate in the sediments of receiving waters. The organisms most at risk, therefore, will be members of the benthic community as they are exposed to both dissolved and deposited contaminants (Betton, Boxall, Calow, Forrow, & Maltby, 1995). These play an important role in energy flow and nutrient processing in freshwaters, as well as providing prey for vertebrates such as fish and birds (Betton, Boxall, Calow, Forrow, & Maltby, 1995). Essentially, once stormwater runoff enters receiving waters, contaminants can be easily spread throughout the entire human and animal food chain and across multiple ecosystems. Due to the geographic situation of Halifax, contaminated stormwater runoff poses serious biophysical threats to the surrounding environment that need to be managed with the utmost importance.

### 3.1.3 Green Roofs as a Solution to Stormwater Management

The current trend in urban stormwater management systems advocates a hierarchy of preferred alternatives: Source Controls, Conveyance Controls, End of pipe Controls, and Miscellaneous Controls. Source controls are on-site measures that control runoff at the source of generation. These include all measures that treat and/or control the runoff before it reaches the conveyance system.

With nearly a third of the horizontal surfaces in urban areas being rooftops, green roofs provide a potential remedy for this problem. Establishing plant material on rooftops provides numerous source control ecological and economic benefits, including stormwater management, energy conservation, mitigation of the urban heat island effect, and increased longevity of roofing membranes, as well as providing a more aesthetically pleasing environment in which to work and live (Getter & Rowe, 2006). Green roofs reduce the amount of run-off after rain events by temporarily storing water on the roof and releasing it slowly over time.  A green roof also returns moisture to the atmosphere by evapotranspiration. Green roofs are an ideal stormwater management technology because, unlike surface-area intensive storage reservoirs, constructed wetlands and sand filters, they require only existing roof space (Oberndorfer, 2007).

### 3.1.4 Dalhousie University Sustainable Building Policy

The implementation of green roofs on Studley campus is a reasonable proposal and fits within Dalhousie's current "green-minded" development trajectory. In 2011 Dalhousie University passed a Sustainable Building Policy. It stated that new construction must obtain LEED Gold certification or higher, and existing buildings must be retrofitted to improve their overall sustainability. The goals of this policy were to: lower the total cost of building ownership, improve workplace well-being and productivity, reduce environmental and health impacts, support sustainable transport and landscapes, demonstrate reputational and community leadership, and support teaching and research (Green Building: Existing Buildings and Operations and Maintenance, 2011).

Building principles should take into consideration maintenance costs and time along with system complexity and longevity of systems and products. Alongside financial feasibility, building design must also take into account more environmental factors including the capture of waste energy and water. Some of the other key focus areas identified included consideration for reducing light and heat from buildings and managing the building site for erosion control as well as reusing grey and rain water and reducing total water consumption. In terms of energy and atmospheric aspects, this policy includes reducing carbon emissions and air contaminants. The Sustainable Building Policy includes the commitment of becoming a leader by implementing new systems to achieve the best performance in green building (Green Building: Existing Buildings and Operations and Maintenance, 2011).

### 3.1.5 Dalhousie University Master Building Plan

Dalhousie's 2010 Master Plan mapped out a vision for Dalhousie's physical space over the next 10 years, anticipating development to address unmet needs and future challenges. The plan identified priorities for maintenance and new construction to ensure that facilities renewal funds are spent effectively. The Master Plan document focused on identifying improvements and efficiencies in managing the physical environment and its further development (Dalhousie University, 2010).

#### *3.1.5.1 Deferred Facilities Maintenance*

The University maintains an inventory exceeding 100 buildings totalling some 4.8M square feet, of which many were constructed in the early years of the last century. Replacement value of the campus buildings is assessed at a cost in excess of $1 Billion. Although deferred maintenance has been seriously underfunded for some years, the Board of Governors has recently recognized this problem and has adopted a policy of increasing the annual deferred maintenance allocation by $1M per year up to a cap equal to 2% of the assessed replacement value of the campus building inventory. Even once this cap is reached, the challenge will be (a) to determine what levels of attention should be given to which buildings and (b) how the annual budget is to be allocated in doing so, using three basic criteria: building condition, importance of the building to Dalhousie, and return on investment (Dalhousie University, 2010).

### 3.1.6 Water Issues

As per the Dalhousie Sustainable Building Policy, issues surrounding water are of the utmost importance. Portions of the municipal system handling storm and sanitary sewer drainage generated by University facilities are undersized and do not meet current Halifax standards; further campus facilities development is expected to require corrective investments in the municipal drainage systems (Dalhousie University, 2010).

#### *3.1.6.1 Sustainability Issues*

Another major development issue for Dalhousie is regarding sustainability. Their goal is to minimize the extent of impermeable surfaces by utilizing permeable pavers and soft landscaped areas which will reduce the amount of stormwater runoff and subsequent pressure on municipal systems. The plan also included reducing the urban heat island effect by minimizing the extent of paved surfaces as well as managing rainwater and snowmelt on-site with designs that encourage infiltration, evapotranspiration and water reuse such as bio-retention areas and bio-swales. It is specifically stated that green roofs should be incorporated where feasible to improve building, insulation, reduce surface runoff and minimize discharge into the storm drainage system (Dalhousie University, 2010).

## 3.2 Scope

We decided to focus our scope to include only Dalhousie's Studley Campus (See Figure 1). As the largest section of campus and a significant portion of the Halifax peninsula, we thought installing green roofs on Studley campus would have the greatest impact on stormwater management.

Although extensive green roofs can be installed on sloped surfaces, again we decided to focus our attention to include only flat roofs for easy, budget-conscious installation.

*Figure 1: Ariel View of Studley Campus*

### 3.3 Project Goals and Objectives

On top of the long lifespan, green roofs have all the added environmental, economic and social benefits that may not necessarily become quantified. Nonetheless, many municipalities like Halifax, and organizations such as Dalhousie University, are beginning to realize the tremendous benefits that green roofs have to offer and are now developing policy around new building standards (Getter & Rowe, 2006).

The focus of this study is to analyze the potential for green roofing at Dalhousie as a solution to stormwater management, as well as the associated costs. Our objective is primarily transformative, because we wish to inspire change with our research. Using comparable green roof installations within Halifax, as well as reputable research, we will forecast the potential for change in quantity of stormwater runoff at Studley campus. It is our objective that our research is incorporated into Dalhousie's maintenance plan for future changes.

This report will cover all of the methods used for data collection, a step by step procedures guide listing how we determined the correct composition for a green roof in Halifax, the results of implementing green roofs on Studley campus and our recommendations for the future.

## 4 Research Methods

### 4.1 Overview of Study Design

Due to our limitations as outlined below, we were unable to conduct a significant amount of primary research, and instead had to rely on secondary research for the majority of our technical information. In order to get the most comprehensive information, we took a mixed methods approach to our study design collecting both qualitative and quantitative data. This will allowed us to not only gather reliable, valid and trustworthy quantitative information through accurate methods such as GIS, but we were also able to conduct a more in-depth qualitative approach to the issue through the examination of case studies and interviews with industry professionals. In order to develop a comprehensive methods section we needed to apply a well-rounded approach that can back up the research data with solid analysis.

The main source of empirical data for this study will come from the usage of geographic information systems (GIS), which was utilized to determine the ideal location of the green roof to maximize the amount of water that is absorbed by the extensive green roof. In order for a space to be utilized for extensive green roofs, the building must meet various physical criteria, such as structural stability, the steepness of the incline, the orientation relative to the path of the sun (in order to determine the amount of solar radiation received), the amount of annual rainfall, etc.

As another method of data collection, peer-reviewed academic journals provided information on fundamental building information critical to green roof installation, green roof efficiency in terms of water capture and loss regarding specific plant species, ideal green roof composition, average costs of green roof installation maintenance and historical precipitation levels in Halifax to use as an average in our models.

| | Data Required | Collecting Method |
|---|---|---|
| **Fundamental Building Information** | Total Number of buildings with a flat roof on Studley campus. | Survey with GIS tool |
| | Total/individual flat roof area of buildings. | Survey with GIS tool |
| | Professional Opinion on which buildings would be the prime initial candidate for installation as a "test case" | Interview |
| **Efficiency of Green roofs** | Water Retention Capability of plant species | Interview<br>Journal review<br>Case studies |
| | Stormwater Runoff flow values | Interview<br>Journal review<br>Case Studies |
| | Financial costs of installing and maintaining a green roof. | Interview<br>Journal review<br>Case studies |
| **Weather Effects Consideration** | Annual precipitation of Halifax (mm) | Journal review |

*Table 1: Total Quantitative Data and collection methods required for research topic.*

## 4.2 Justification of Specific Collecting Methods:

### 4.2.1 Surveying with GIS

We decided that using the GIS database was the best way to get accurate first-hand information on the buildings within our pre-determined scope. Using GIS, we were able to quickly and easily determine the total number of buildings on Studley campus with flat roofs, as well as their individual square footage. This would translate into the potential areas in which our proposed green roofs would be installed. GIS was the best method in this study because it allowed for easy modification of up to date building information in which we were able to pick and choose the criteria we wanted to satisfy with the survey.

Other methods would have been too timely and complicated for the overall objective of the research project which was focused on the stormwater mitigation potential of green roofs on Studley campus as a theoretical proposal for further study and consideration.

### 4.2.2 Interview

Again, since we could not conduct a significant amount of primary research, we looked for ways in which we could achieve a similar result. We decided that interviewing key industry professional in the local Halifax area was a good way to receive credible quantitative as well as qualitative data. We targeted local architects who worked on comparable green roofs within the city and were able to ask them directed questions to which we were given specific answers.

One of our main contacts was Keith Tufts, an architect working for Lyndon Lynch the minds behind the extremely successful green roof on the Halifax Seaport Market. Tufts is currently working on the plans for the proposed Student Union Building renovation and has an abundance of knowledge relating to the University's structures and political workings. We were able to ask his professional opinion on our proposed project and any thoughts he had to help us move forward. This is not the kind of customized information you could find from reading a journal, and is something that helped us confirm the potential and validity for this project.

### 4.2.3 Journal Review

Due to our time constraints and inability to conduct primary research and experiments, we decided that peer-reviewed academic journals were the best method to increase the validity, reliability and trustworthiness of our research. We reviewed papers and reports by various authors, including

Jeremy Lundholm from Saint Mary's University's Biology Department, who published journals such as *Annals of Botany, 2011*, *Ecological Engineering, 2010.* The close proximity to Dalhousie made the research and findings very relatable.

### 4.2.4 Case Studies

In order to make the best case for our research project going forward, we decided to draw on the best practices employed by green roofs already in existence within Halifax. We looked at the Mona Campbell Building, the Halifax Central Library and the Halifax Seaport Farmers Market (See figure2). This helped us to determine some of the most effective plant species for the climate, expectations for installation costs and challenges as well as the level of public support for green roofs. When proposing a project, it is always best to have something comparable to relate to, and the method of case studies provided this comparison.

*Figure 2: The Mona Campbell Rooftop (left), The Halifax Central Library Rooftop (middle), Halifax Seaport Market Rooftop (right)*

## 4.3 Procedures

### 4.3.1 Information Collection

In order to make informed decisions regarding our research project, we first had to gain a more sophisticated understanding of the current issues surrounding stormwater within the city and university, as well as the best practices and potential of green roofs to mitigate such risks. To do this we explored various academic journals via Dalhousie research databases such as Web of Science.

After gaining this crucial base layer of knowledge, we were able to narrow our research needs, allowing us to reach out to relevant professors and professionals in the Halifax area. Meeting with Keith Tufts an architect at Lyndon Lynch and corresponding with Jeremy Lundholm from Saint Mary's Biology Department afforded us the opportunity to collect personal insight from leaders in the field of green roof development. This information collection procedure is what led to the development of our next steps.

### 4.3.2 Case Study Comparisons

In order to determine some of the common methods and best practices that prove successful on extensive green roofs in Halifax, we studied comparable buildings. First, we looked at extensive green roofing on the Studley campus itself; the green roof on the Mona Campbell building incorporates a small variety of commonly used species in green roofing, such as chives, sedums and other creeping shrubs (Dalhousie University, 2014). Following the initial installation and sprouting times, this extensive green generally requires minimal maintenance, such as watering and occasional weeding. Excess rainfall captured by the building is collected in a 77,000L cistern in the basement of the building (Dalhousie University, 2014). The water is then used internally in the building systems, as well as for watering the green roof during a drought.

Hereupon, we extended our research to green roofs elsewhere in Halifax, which led us to one of the largest roofs in the city, the Halifax Seaport Market. We had the opportunity to meet with Keith

Tufts, the lead architect of the LEED certified Halifax Seaport Farmer's Market, built in 2010 by Lydon and Lynch's architectural firm which is now located within the market itself. He stated that the green roof is approximately 16,000ft$^2$ and has 3 inches of soil. There were on average 4 plants per square foot, and at \$20/ft$^2$he estimated that the total cost was \$366,000 (with the geotextile being the most expensive portion). According to Tufts, 50% of the stormwater received by the green roof is collected by the soil and the plant's roots, and the remaining 50% is collected in the buildings water cistern to use as grey water.

Another benefit that Tufts is proud of is the fact that the roof has only required minimal maintenance once per year for weeding, and no additional irrigation was necessary once the plants had established their canopy and root base after the first year. Tufts also mentioned that some extra costs to consider when looking into green roofs include reinforcing the structure of the building to be able to hold the weight of the green roof. Although the actual green roof on the top of the market is an extensive one, which typically does not weigh very much, the large patio next to it and the windmills lining the side make it an intensive green roof because of the increased structural support required. On the plus side, these energy saving features are very helpful in the summer time to keep the building cool without the need for air conditioning, and the patio serves as a scenic location brought to life by the green roof's multi-coloured plants.

### 4.3.3 Determining Water Retention Capabilities of Particular Species

In order to estimate the capability of our proposed green roofs to mitigate stormwater runoff, the water retention and loss potential of different plant species needed to be determined. Again, since we were unable to perform our own research, we based our plant choices off of research conducted by Scott MacIvor, Melissa Ranalli and Jeremy Lundholm in 2010 at Saint Mary's University. Due to the close proximity to Dalhousie, we believed that mimicking the study model results would act as a reasonable substitute to our own primary research findings.

#### *4.3.3.1 Model Analysis*

To create the model for this system, this study needed to process data from alternate reports. By combining characteristics such as species of plants, total volume of water captured by the green roof, total volume lost through evaporation as well as overall rate of evaporation. Also, these characteristics must be ideally suited for Halifax's wet and windy climate.

The *MacIvor et al*. model was conducted over two growing seasons, 2007 and 2008 on top of the Patrick Power Library at Saint Mary's University. 190 free-draining plastic square modules were employed each measuring 36 cm by 36 cm module (about 1.395 ft$^2$) to act as individual samples. First, each sample was weighed individually to determine a pre-test weight. Next, simulating a 10mm rain event which was determined by historical rain data to be the amount of an average local rainfall, 1.30 kg water was applied per species, over a period of 45-60 seconds. The samples were then weighed 5 times over the following 24 hour period to determine the water capture and water loss for each sample and species.

We applied the same technique with average precipitation records current to 2014. During a four month period (May to August) average rainfall was 6.1mm (Figure 1). Results from *MacIvor et al.* study in 2011 provided data to model a suitable simulation.

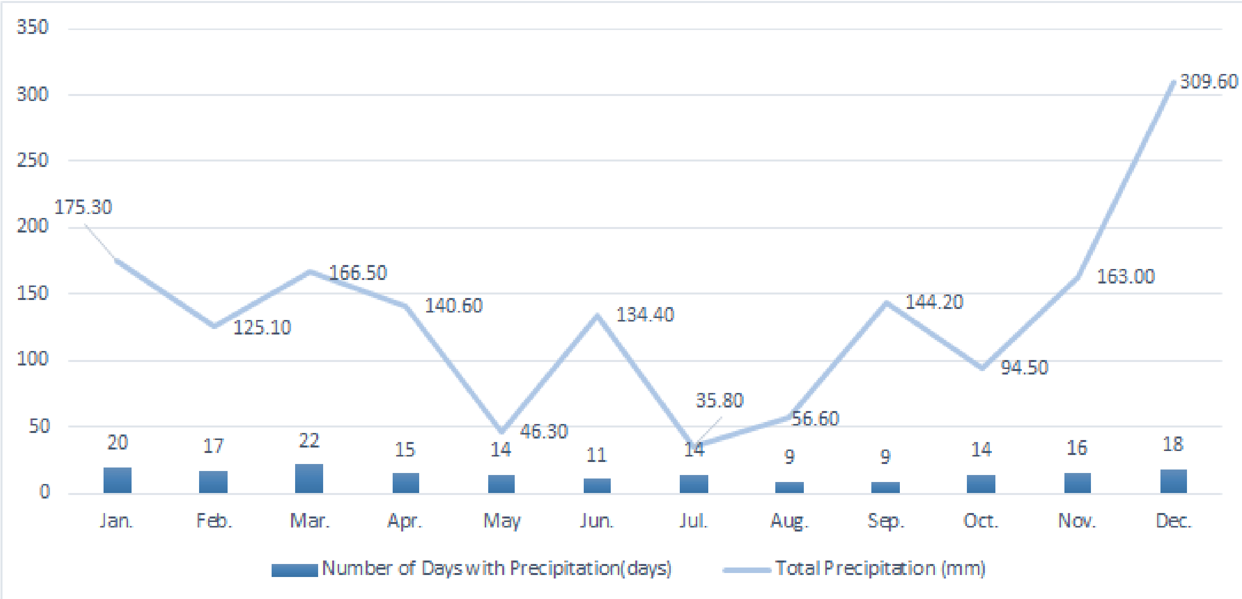


*Figure 3: The Precipitation Recording of 2014, Halifax, Nova Scotia (Retrieved from: http://halifax.weatherstats.ca/)*

### 4.3.4 Creating a Campus Connection

After the crucial gathering of data and information from the various sources mentioned above, we then had to determine the key connection between our research and the University. At this point we looked into the 2010 Dalhousie Master Plan as well as relevant policies such as the Sustainable Building Policy which was ratified in 2011 as described above in detail in sections 3.1.4 and 3.1.5. Finding this link to Dalhousie's desire to create a more environmentally sustainable campus by implementing green roof technology was a vital procedure in the formation of our conclusion and ultimate reasoning for our project moving forward.

## 4.4 Validity, Reliability and Trustworthiness

Due to the complex amalgamation of characteristics that produce an extensive green roof such as degree of roof slope, temperature, wind, hours of sun, soil composition, materials used in roofing membrane and geotextile, number and intensity of rain events, there are many factors that can be changed, even incrementally, to drastically alter results. Nonetheless, since the purpose of this project was to investigate mitigating stormwater runoff, the most important variable to measure was the water retention capability of the green roof. Since we were working with quantitative data such as rainfall, soil density and water capture rates, the validity of our results was high.

Again using a variable such as rainfall, the reliability may at first appear low. However, for our study, we tried to mitigate variance by using the average of many years of historical rainfall data for Halifax. This average volume was used during testing to determine which plants retained the most water. For this reason, excluding external factors such as storm and drought events, the plants themselves should retain the same volume of water in every study in the future proving our results reliable.

Along with being valid and reliable, our results are also highly trustworthy. Using a mix of academic journals, interviews with distinguished professors and researchers in the Halifax area, informal talks with award winning architects and case studies of similar buildings our results are transferable, dependable, confirmable and credible.

## 4.5 Limitations

For our project, the greatest limitation was time. From agreeing on a topic of interest, to formulating a research question, to conducting research, to submitting the report, we had just over two months. The accelerated timeline resulted in many limitations with the level of research we were able to conduct. For instance, we could not get accurate average rainfall data for the area and had to rely on historical records instead. Also, we were not able to set up meetings with all of the key personnel we targeted due to scheduling limitations, forcing us to rely more on academic journals for trustworthy information.

Similarly, due to the high variation in the total cost of installing a green roof, we were limited in our financial analysis. Again due to the time constraint, we were unable to obtain a quote from a professional company in Halifax on the price of installing an extensive green roof on one of Studley campuses buildings. Instead we had to rely on information from academic journals, case studies and the informed opinion of the architect of the Seaport Market's green roof, Keith Tufts for our cost range estimate.

Additionally, one of our methods of research was based around observing comparable green roofs already installed in the Halifax area. However, due to uncommon weather patterns such as the high volume of snowfall and long winter season, we were unable to see the plants first-hand and had to rely on old photographs and data reports.

## 4.6 Delimitations

One of our calculated delimitations was the scope we set for our project. Deciding to examine only buildings with flat roofs on Studley campus provided us with a small area of study with a limited the level of variance in green roof installation time and cost. Having comparable surfaces will ease the implementation process because risks and best practices can be established early on and copied for maximum installation efficiency. We believed this made the project much more reasonable for the University to pursue.

A second delimitation that we imposed upon our project was focusing on a primary benefit that green roofs afforded. This allowed us to keep our research straightforward especially within the time constraints. It also allowed us to more easily tie the project proposal into a campus issue as well as a municipal issue which only furthers the potential support for this project. Essentially, we made this a political issue, as well as a scientific one.

Although the cost of project implementation was one of our supporting arguments for installing green roofs on Dalhousie campus, we knew that due to the large variability in potential buildings and the complexity of each individual installation, we decided not to do a formal cost-benefit analysis saving us a significant amount of time for other research.

# 5 RESULTS

## 5.1 Extensive Green Roof Design

From our research, we found that there were two distinct types of green roofs, which are categorized as "intensive" or "extensive" systems depending on the plant material, soil depth and the planned usage for the roof area.

Intensive green roofs are so named because of their "intense" maintenance needs. They are designed to be similar to landscaping found at natural ground level. Typically these installations use a wide variety of plant species that may include trees and shrubs and thus require deeper substrate layers than extensive roofs (usually >15.2cm). Since they are often park-like areas accessible to the public, they are generally limited to flat roofs and require significantly more maintenance to keep up the pristine appearance.

In contrast, extensive roofs generally require minimal maintenance generally limited to annual weeding to ensure maximum efficiency. This green roof style is typically not accessible to the public and may not even be visible. Due to their shallower media depth (<15.2cm) plant species are limited to herbs, grasses, mosses and drought-tolerant succulents such as Sedum. In addition, extensive green roofs can be built upon a sloped or flat surface drastically increasing their installation potential. Despite the seemingly large differences in the two types of roofs, most green roofs have similar construction components. A root barrier installed on top of the normal roofing membrane protects the roof from root penetration damage. A drainage layer above the root barrier allows excess water to flow away from the roof. On top of the drainage layer is a geotextile filter fabric, which keeps silt and particulate matter in the media from clogging the drainage layer.

Moving forward, we determined to focus the rest of our results on characteristics associated with extensive green roofs exclusively. We believed installing extensive green roofs was a much more reasonable project with a higher likelihood of implementation. This is due to the facts that extensive green roofs are the most budget friendly alternative, allowing for a higher number of roofs to be installed within the University's allocated budget. Essentially extensive green roofs provide the most bang for their buck.

## 5.2 Rooftop Characteristics for Best Performance

After reviewing and synthesizing our research, we determined that there are several factors which influence green roof water retention capacity and runoff dynamics. These characteristics include: the number of layers used and the type of material used for the roofing membrane.

When we spoke to Keith Tufts, architectural designer for the Seaport Market green roof, we were told that the quality of the membrane material determines the lifespan and efficiency of the installation. Green roofs also contain several layers of soil, suited to the choice of plants. The selection of plant species for a green roof corresponds to the local environment and amount of annual precipitation. It is also important to consider the length of dry and wet periods in the area when choosing plants for green roofing. Other factors which contribute to the performance of the roof include the roof's geometric characteristics including slope, length of slope, and total surface area available. (Berndtsson, 2010).

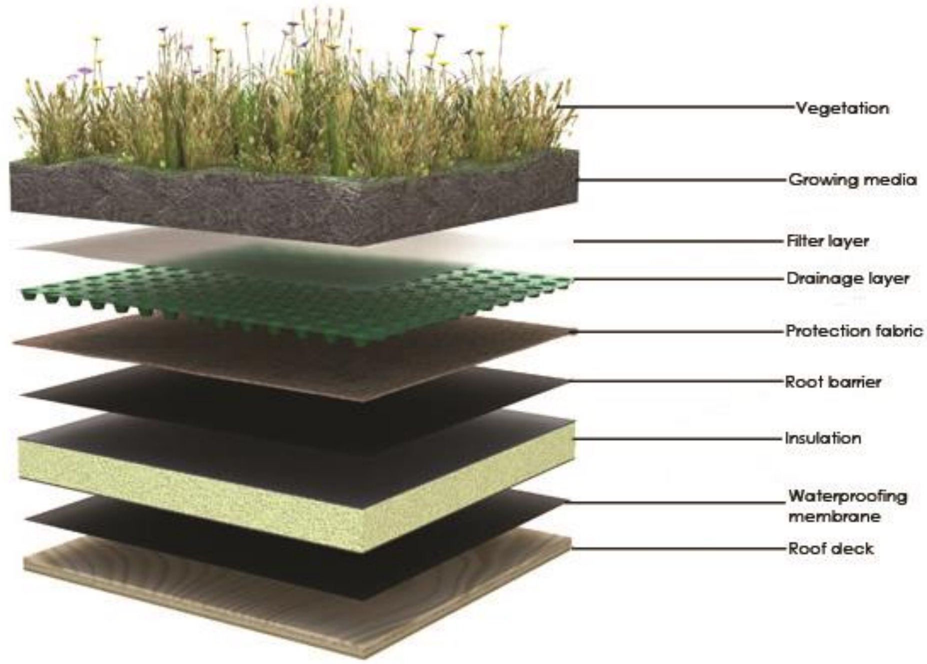


*Figure 4: Typical Green Roof Layers*

## 5.3 Available Surface area for green roof

Using GIS, we were able to determine that there is approximately 250,000ft2 of rooftop that exists on Studley campus. In reality this number would be reduced due to factors such as rooftop utilities or access ways taking up square footage, as well as changes in roof level, or slope.

Moving forward, 250,000ft2 was an easy reference number to use when making calculations in the future and will be considered our estimated capable area.

## 5.4 Plant Species and Retention Rates

For the full benefit of green roofs to be realized, specific factors must be considered including: aesthetic appeal, environmental conditions including micro- and macro-climate, substrate composition and depth, plant selection, installation methods and maintenance. (White & Snodgrass, 2003).

More importantly, extensive roofs require plants that propagate easily and establish themselves in the substrate at high rates and within great density. Selected plant species should have high water retention rates and be ideal for climate conditions experienced in Halifax. Green roof plants do not require routine maintenance and are hardy during periods of drought. The most common plants used in Halifax are: Sedums, Tall Forb, Creeping forb, Grasses and succulents.

Although a monoculture is often the simplest way to install the plants, the optimal extensive green roof would use a combination of multiple types of plants in order to improve the overall functioning of the green roof. For example, during a study done in 2011 by MacIvor and Lundholm, a monoculture of *D. Spicata* was shown to perform badly at water capture, but when it was mixed with other species, such as *S. Tridentata* & *E. Nigrum*, it was very beneficial for the green roof's ecosystem, which greatly helped increase water retention rates (Lundholm, 2011).

### 5.4.1 Model Results

From *MacIvor et al*.'s research, eight species of plants native to Nova Scotia were singled out as having the greatest efficiency in the growing medium (Table.2). To receive the highest return for the initial cost of installation it is extremely important that plant selection is done to maximize water runoff as total roof efficiency is dependent on top plant choices.

To determine what was considered high efficiency in water retention and evaporation rates, the average percent of water capture was calculated amongst intercropped species and 69.81% of water was captured. The plant species which had the greatest retention efficiency were: New York aster (*Symphyotrichum novi-belgii*), hay sedge *(Carex argyrantha Tuck),* wild strawberry (*Fragaria vesca)*, black crowberry *(Empetrum nigrum)*, and three-toothed cinquefoil (*Sibbaldiopsis tridentata*), with an average water capture value of 71.85% (Table 1).

| Plant | location[a] | Survival rate | Life-from Group[b] | Water Capture[c] | Water Capture % | Water Loss[d] | Water Loss % |
|---|---|---|---|---|---|---|---|
| **New York Aster** | PP | 80.00% | TF | 0.91 | 70.00% | 0.92 | 70.77% |
| **White Goldenrod** | SMU | 99.05% | TF | 0.89 | 68.46% | 0.91 | 70.00% |
| **Hay Sedge** | RH | 99.44% | GR | 0.98 | 75.38% | 0.96 | 73.85% |
| **Wire Grass** | SMU | 100.00% | GR | 0.84 | 64.62% | 0.76 | 58.46% |
| **Wild Strawberry** | MB | 99.44% | CF | 0.93 | 71.54% | 0.90 | 69.23% |
| **Black Crowberry** | SMU | 99.44% | CF | 0.92 | 70.77% | 0.88 | 67.69% |
| **Three-tethered Cinquefoil** | SMU | 99.33% | CF | 0.91 | 70.00% | 0.90 | 69.23% |
| **Large Cranberry** | SMU | 99.38% | CF | 0.88 | 67.69% | 0.87 | 66.92% |

*Table 1: Basic data for 8 local vegetation species for green roof.*

[a] The location of plants can be found; PP: Point Pleasant Park; SMU: the Saint Mary's University Green Roof Testing Facility; RH: Residential House, Halifax, NS; MB: MacDonald Bridge, Dartmouth, NS.
[b] Life-form Group: TF: tall forb; GR: graminoid; CF: creeping forb.
[c] In unit of kilogram (kg); with an even standard error of ±0.02.
[d] In unit of kilogram (kg); with an average standard error of ±0.03.

## 5.5 Retention Rates

Depending on substrate depth, green roofs have been shown to retain 25-100% of rainfall and reduce annual total building runoff by 60-79%. Many studies agree that the green roofs influence runoff dynamics by lowering and delaying the runoff peaks as compared to the precipitation, or hard roof runoff peaks. Green roofs reduced the peak intensities from an average rainfall intensity of 4.3 mm/h to an average green roof runoff rate of 2.4 mm/h. The green roofs delayed the start of runoff by average of 5.7 h and delayed the peak runoff response an average 2.0 h (Berndtsson, 2010).

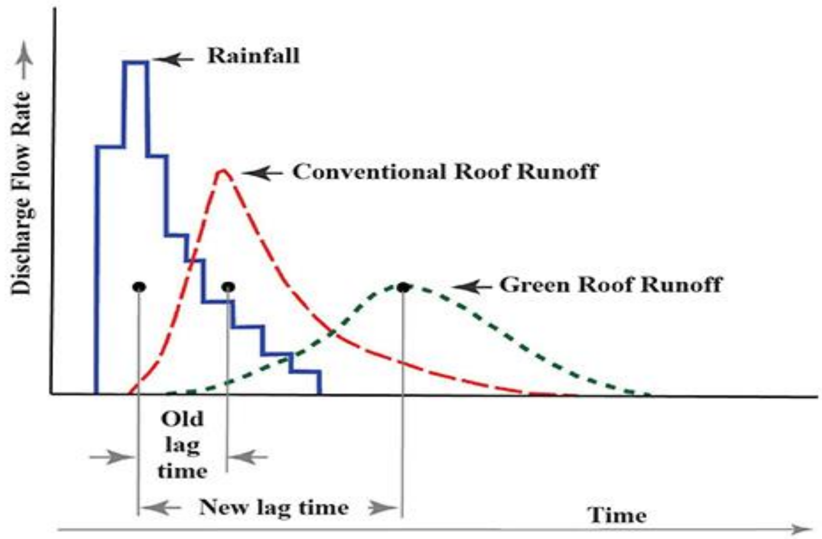


*Figure 5: Depiction of Typical Stormwater Delay (http://www.ianrpubs.unl.edu/epublic/live/g2244/build/graphics/g2244-5.jpg)*

### 5.5.1 Model Results

We were able to combine *MacIvor et al.*'s research findings, with our own research to theorize the results of the same study on Dalhousie's Studley campus. We were able to construct a basic model green roof for the buildings on Studley campus using MacIvor's 36 x 36cm$^2$ or 1.395ft$^2$ model, which was found to have the ability to capture 71.85% of rainfall during an average storm event.

Using the estimated capable surface area available on Studley campus in the original model, of an estimated 23,5297.5 kg of stormwater entering into the green roof system, about 16,739.2 kg of water, will be retained and either evaporate back into the atmosphere or slowly leak out after the peak rainfall has ended.

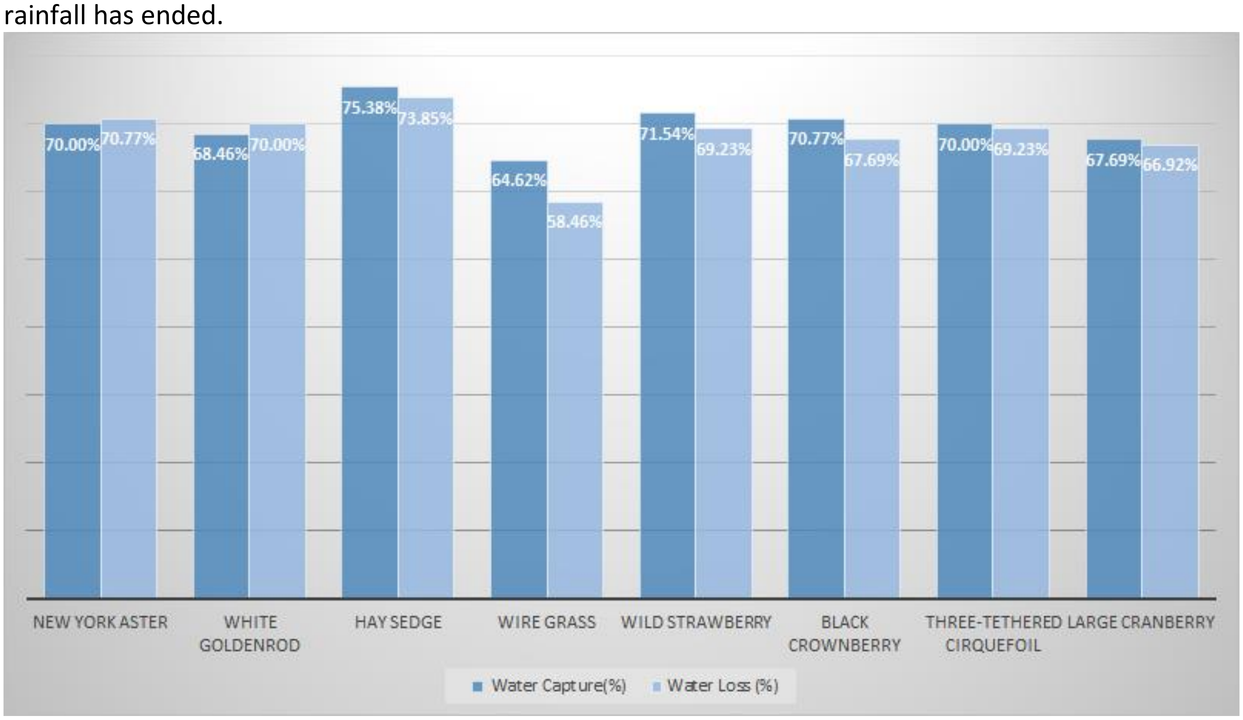


*Figure 6: The percentages of water capture and water loss of 8 local plants.*

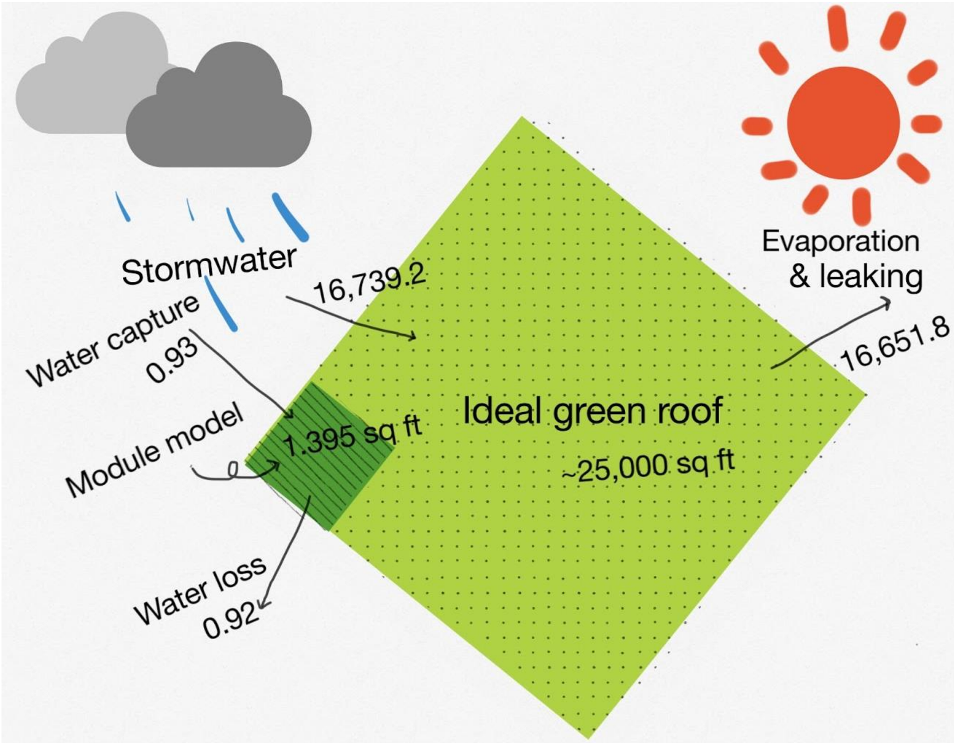


*Figure 7: Model of Water Capture and Loss Rates Experienced on Basic Green Roof*

## 5.6 Installation and Maintenance Costs

The average cost of installation typically ranges between $14-$25/ft$^2$. As a comparison, the Halifax Seaport Market's green roof cost approximately $20/ft$^2$. Keith Tufts claimed the higher price was due to the fact that the roof was visible to special care was taken to beautify the appearance of the extensive roof. He went on to say that every project is unique and there are always many ways to lower the costs. Economy of scale for example is very relevant for a project of this size. Costs can be reduced to as low as $8-$10/ft$^2$for a 3" growing media and sedums.

Maintenance for a typical extensive green roof involves irrigation, fertilizer and weeding which can cost approximately $0.50-$0.75/ft$^2$, however; due to Halifax's moist climate, maintenance only requires annual weeding costing approximately $0.30sqft.

The initial extra short-term capital costs of green roof construction can be offset through long-term energy and maintenance savings experienced by the university. In comparison, the expected life-cycle costs and benefits of green roofs versus conventional roofs found that while a green roof initially costs approximately 25% more to install, it would save close to 50% of the initial investment over its lifetime compared to the conventional roof. Nearly one third of those savings would be from improved water management. With 250,000 ft$^2$of capable rooftop multiplied by the $8-$10 /ft$^2$ installation cost, retrofitting the entire campus would cost the University around $2-2.5 Million.

# 6 DISCUSSION

The purpose of our study was to determine whether the installation of green roofing was an economical and sustainable solution to the existing flaws in the municipal stormwater management. Dalhousie University, specifically Studley campus was the focus of our study, being the largest university campus in Halifax, and already a community leader in sustainable development. Thanks to LEED certified buildings on the Studley campus such as the Mona Campbell (gold), the Le Marchant Multi-use building (gold) and the Ocean Sciences building (silver) Dalhousie sets a community standard for new developments to achieve high energy efficiency which reduce costs to heating and cooling, as well as structural maintenance. To help raise the efficiency of existing buildings, we proposed the installation of green roofing on Studley buildings that could theoretically support this addition.

We primarily relied on scientific literature to collect information regarding materials required for green roofing and the associated costs. Also, using GIS we were able to identify roughly the total flat roof surface area which we was used as our study sample. Our goal was to apply the known benefits of green roofs when used to mitigate stormwater runoff and build a model to work with Halifax conditions. After examining the characteristics of other green roofs within the city we were able to determine several species of plants suitable for the moist climate experienced year round. This lead to findings that gave us an idea of the cost of installation and maintenance. The average cost is $\$20/ft^2$ which includes all layers and plants but excludes the roofing membrane. Since we are proposing a project of great scale we estimated that due to economy of scale, costs could be reduced to $\$8\text{-}10/ft^2$, half the original market price. With this in mind, we were able to estimate the cost to the university. Results were an average cost of $2-2.5M which is well within the allocated budget indicated in the Master Plan.

These findings corresponded with much of our research. In short, it is widely agreed upon by several experts that the incorporation of green roofing has a wide range of benefits not only for the structure itself but for surrounding wildlife. Green roofs are now becoming increasingly more common on new developments, because they are aesthetically pleasing while offering areas of greenery in urban settings. For our study, we specifically looked at the function of mitigating stormwater runoff and found that during periods of peak rainfall, a well-engineered green roof can capture 90% of water. Water may be delayed for up to six hours before reaching storm drains, these processes help significantly in reducing the pressure on municipal system in a way that returns the water to the environment in a cleaner state. Halifax being located next to the Atlantic Ocean experiences high rates of annual precipitation and stormwater is deposited into the harbour. When the rain reaches the ground, often chemicals from vehicular traffic and salting are taken up and end up being output into the ocean. This method of stormwater management will only further contribute to ocean degradation if a new system is not developed soon.

Our results were based on estimated values from research done on Halifax green roofs and finding the total study area on the Studley campus. We experienced limitations in time and resources therefore were not able to produce our own values. Several of our findings advocated the installation of green roofing for reasons other than our area of focus. These included the reduction of cost to heating and cooling as well as roof maintenance. Keith Tufts informed us that the addition of a green roof can actually extend the lifespan of the roof because of the quality materials used to anchor the garden. All of these extra finding were supported our research question and we were able to state that green roofs not only improved stormwater management but reduce maintenance costs.

# 7 CONCLUSION

It is clear that green roof technology offers an economically feasible alternative to spending millions of dollars to renovate and maintain outdated stormwater infrastructures. Green roofs involve growing plants on rooftops and thus replace the vegetated footprint that was destroyed when the building was constructed.

Overall, one of the main deterrents of green roofs becoming widespread in North America is the initial cost of installation. On top of the long lifespan, green roofs have all the added environmental, economic and social benefits that may not necessarily become quantified. It is clear that this project should be integrated into Dalhousie’s Maintenance plan and implemented immediately.

## 7.1 Recommendation for further research

The purpose of this project was to focus our efforts on installing green roofs on Studley campus as a source control measure for stormwater. We mostly investigated the positive impacts that green roofs could provide regarding water management and did not analyze other benefits in-depth. For example, the concept of installing green roofs on Dalhousie campus could be altered to suit research looking into improving urban air quality, biodiversity or even mental health. Furthermore, a comprehensive study could be conducted from our current research to include all the benefits green roofs hold.

Alternatively, our project only looked into rooftops on Studley campus that were flat for easy installation. However, extensive green roofs can be installed on sloped surfaces too, at an additional cost for more complex engineering. This research can broadened to include all rooftops on Studley campus, both flat and sloped which would expand the square foot potential drastically capturing more benefits. To do this, pricing models would have to be altered.

Similarly, the scope of the project could also be expanded to include other Dalhousie campuses such as Carlton, Sexton and the Agricultural Campus in Truro. Again this increase in square footage would dramatically increase the measurable benefits of green roofs.

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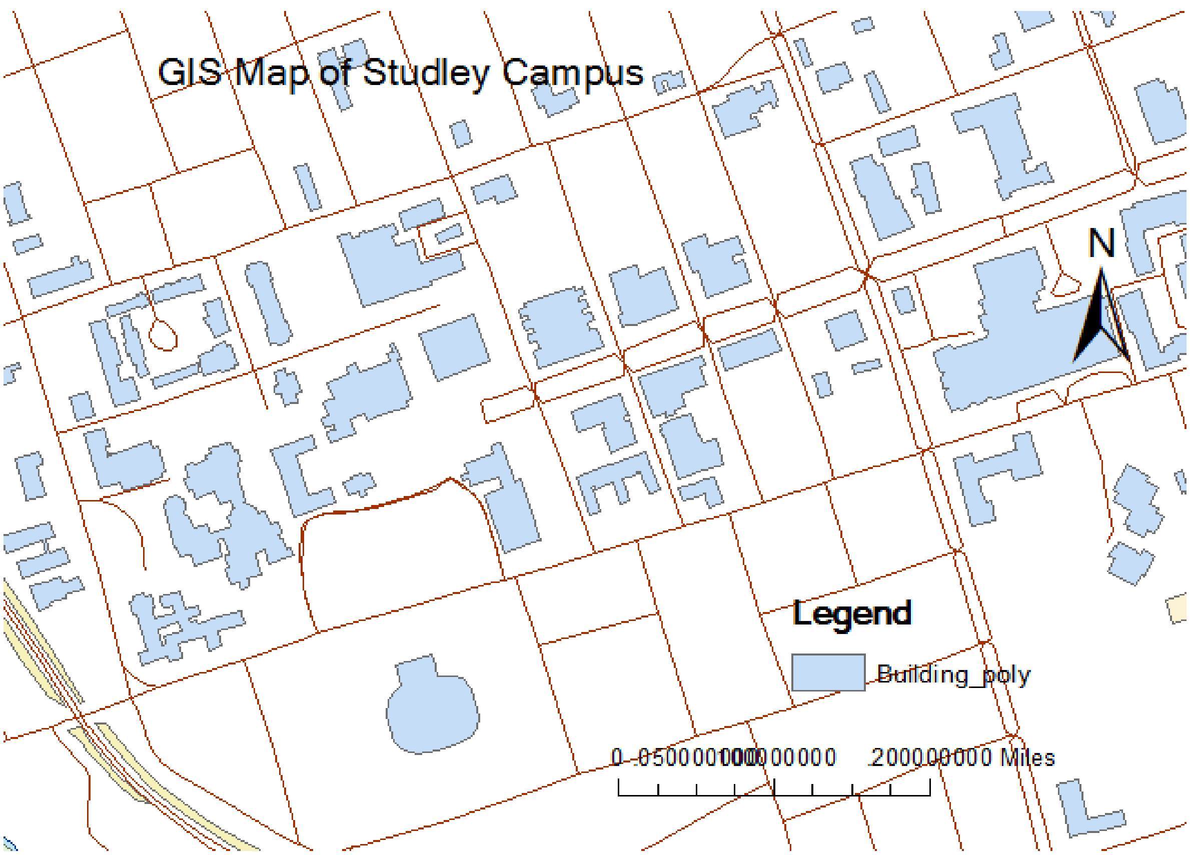
# 9 APPENDICES

## 9.1 SUMMARY OF MOST FREQUENTLY USED STORMWATER MANAGEMENT PRACTICES

| Source Control | Conveyance Control | End of Pipe Control | Misc. Controls |
|---|---|---|---|
| -Rooftop Runoff<br>-Disconnection of Foundation Drains<br>-Catch Basin Restrictors<br>-Lot Control<br>-Rooftop Detention<br>-Porous Pavement<br>-Permeable Pavers<br>-Slope Stabilization and Erosion Control Measures<br>-Compost Berm<br>-Rain Garden | -Vegetated Swales<br>-Channel/Outlet Protection<br>-Pervious Pipe Systems<br>-Pervious Catch Basins<br>-Wet Swale<br>-Permanent Check Dams | -Detention/Retention Facilities<br>-Underground Tanks<br>-Wetlands<br>-Infiltration Basins/ Trenches<br>-Filter/Buffer Strips<br>-Sand Filters<br>-Oil and Grit Separators | -Public Education<br>-Litter Control<br>-Recycling Programs<br>-Animal Waste Control<br>-Spill Response Plans<br>-Proper Storage and Use of Chemicals, Fertilizers and Pesticides<br>-Vacant Lot Clean Up<br>-Street Sweeping<br>-Road Salt Management<br>-Land Use Restriction<br>-Revision of Development Standards |

## 9.2 GIS STUDLEY CAMPUS ROOFTOP MEASUREMENTS



| OBJECT ID | Shape_Length | Shape_Area m^2 |
|---|---|---|
| 105 | 328.97 | 6911.38 |
| 107 | 371.57 | 3952.42 |
| 621 | 74.85 | 293.52 |
| 1325 | 118.91 | 473.28 |
| 1607 | 107.24 | 514.65 |
| 1610 | 89.39 | 492.65 |
| 1615 | 120.27 | 488.78 |
| 2010 | 123.06 | 684.02 |
| 2045 | 113.94 | 645.96 |
| 2339 | 145.40 | 788.28 |
| 2420 | 165.21 | 855.65 |
| 2432 | 129.19 | 878.51 |
| 2446 | 127.07 | 844.96 |
| 2531 | 135.78 | 785.23 |
| 3267 | 169.01 | 1438.59 |
| 3324 | 247.22 | 1800.87 |
| 3525 | 221.71 | 3057.71 |

| OBJECT ID | Shape_Length | Shape_Area m^2 |
|---|---|---|
| 3562 | 400.92 | 5737.41 |
| 3563 | 371.02 | 4416.88 |
| 3577 | 401.27 | 4657.63 |
| 3656 | 235.55 | 2960.15 |
| 3682 | 233.54 | 2136.67 |
| 3698 | 582.29 | 3985.11 |
| 3715 | 134.75 | 1134.60 |
| 3917 | 258.00 | 2813.02 |
| 3959 | 280.84 | 2297.59 |
| 4185 | 232.58 | 1802.04 |
| 4521 | 130.98 | 863.33 |
| 4550 | 288.06 | 3030.33 |
| 4551 | 339.70 | 2241.70 |
| 4552 | 225.68 | 2494.68 |
| 4553 | 234.92 | 2523.76 |
| 4735 | 794.68 | 8530.59 |
|  | **total** | **76531.92** |

## 9.3 Ethics Form

### *9.3.1.1 ENVIRONMENTAL PROGRAMMES*

#### 9.3.1.1.1 FACULTY OF SCIENCE

#### 9.3.1.1.2 DALHOUSIE UNIVERSITY

### *9.3.1.2 APPLICATION FOR ETHICS REVIEW OF RESEARCH INVOLVING HUMAN PARTICIPANTS*

*9.3.1.2.1.1.1 UNDERGRADUATE THESES AND IN NON-THESIS COURSE PROJECTS*

## GENERAL INFORMATION

**1. Title of Project: The Greening of Stormwater**

**2. Faculty Supervisor(s) :** Dr. Tarah Wright **Department:** Environmental Science **e-mail:**

Tarah.Wright@dal.ca

**3. Student Investigator(s) Department e-mail: Local Telephone Number:**

Emma Laing & Sydney Cranstone Environmental Science emma.laing1@gmail.com (613) 650-7380

Sydney.cranstone@dal.ca (902) 999-5072

**4. Level of Project:**

**Non-thesis Course Project** [ ] Undergraduate [ **X** ] Graduate Specify course and number: ENVS 3502.03

**5. a. Indicate the anticipated commencement date for this project:** January 30th 2015

**b. Indicate the anticipated completion date for this project:** April 17th 2015

## SUMMARY OF PROPOSED RESEARCH

**1. Purpose and Rationale for Proposed Research**

*Briefly describe the purpose (objectives) and rationale of the proposed project and include any hypothesis(es)/research questions to be investigated.*

Our project goal was to address the current issues with storm water management on Studley Campus and apply a sustainable solution. By reducing the amount of water on campus from reaching storm sewers, the result is significant reductions in urban road pollution deposited into the harbour. We acknowledged that green roofing is an affordable and effective method for improving current stormwater management, and in helping promote dalhousie's commitment towards a sustainable campus

## 2. Methodology/Procedures

**a.** ***Which of the following procedures will be used? Provide a copy of all materials to be used in this study..***

[ ] Survey(s) or questionnaire(s) (mail-back)
[ ] Survey(s) or questionnaire(s) (in person)
[ ] Computer-administered task(s) or survey(s)]
[ **X** ] Interview(s) (in person)
[ ] Interview(s) (by telephone)
[ ] Focus group(s)
[ ] Audio taping
[ ] Videotaping
[ ] Analysis of secondary data (no involvement with human participants)
[ ] Unobtrusive observations
[ ] Other, specify ____________________

**b.** ***Provide a brief, sequential description of the procedures to be used in this study. For studies involving multiple procedures or sessions, the use of a flow chart is recommended.***

In order to make informed decisions regarding our research project, we first had to gain a more sophisticated understanding of the current issues surrounding stormwater within the city and university, as well as the best practices and potential of green roofs to mitigate such risks. To do this we explored various academic journals via Dalhousie research databases such as Web of Science.

After gaining this crucial base layer of knowledge, we were able to narrow our research needs, allowing us to reach out to relevant professors and professionals in the Halifax area. Meeting with Keith Tufts an architect at Lyndon Lynch and corresponding with Jeremy Lundholm from Saint Mary's Biology Department afforded us the opportunity to collect personal insight from leaders in the field of green roof development.

## *3. Participants Involved in the Study*

**a.** ***Indicate who will be recruited as potential participants in this study.***

Dalhousie Participants: [ ] Undergraduate students
[ ] Graduate students

[ ] Faculty and/or staff

Non-Dal Participants: [ ] Children

[ ] Adolescents

[ **X** ] Adults

[ ] Seniors

[ ] Persons in Institutional Settings (e.g. Nursing Homes, Correctional Facilities)

[ ] Other (specify) ___________________________________________

b. ***Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. If only one gender is to be recruited, provide a justification for this.***

- Architects and designers involved with green roofing.
- Professional knowledge on the subject matter
- No preference for age/gender/ or any other physical characteristics.

**c.** ***How many participants are expected to be involved in this study?*** *One*

## 4. Recruitment Process and Study Location

**a.** ***From what source(s) will the potential participants be recruited?***

[ ] Dalhousie University undergraduate and/or graduate classes

[ ] Other Dalhousie sources (specify) ________________________________

[ ] Local School Boards

[ ] Halifax Community

[ **X** ] Agencies

[ ] Businesses, Industries, Professions

[ ] Health care settings, nursing homes, correctional facilities, etc.

[ ] Other, specify (e.g. mailing lists) _____________________________________________

**c.** ***Identify who will recruit potential participants and describe the recruitment process.***

*Provide a copy of any materials to be used for recruitment (e.g. posters(s), flyers, advertisement(s), letter(s), telephone and other verbal scripts).*

A simple e-mail was sent to the Halifax Seaport Market requesting information on individuals involved with the green roof project. That is how we got in touch with Keith Tufts.

## 5. Compensation of Participants

**Will participants receive compensation (financial or otherwise) for participation? Yes [ ] No [ X ]**

If **Yes**, provide details:

## 6. Feedback to Participants

**Briefly describe the plans for provision of feedback and attach a copy of the feedback letter to be used.** Wherever possible, written feedback should be provided to study participants including a statement of appreciation, details about the purpose and predictions of the study, contact information for the researchers, and the ethics review and clearance statement.

Note: When available, a copy of an executive summary of the study outcomes also should be provided to participants.

This was not necessary, however an e-mail of appreciation was sent to interviewee Keith Tufts for taking time and discussing green roofs with the group.

## POTENTIAL BENEFITS FROM THE STUDY

1. **Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project**.

Participant has vast knowledge of green roof technology and cost. He has worked on several green roofing projects and was considered an important person of interest in our research.

2. **Identify and describe any known or anticipated benefits to society from this study.**

Interviewing the participant will add to our existing information of green roof benefits to buildings along with the research done.

***POTENTIAL RISKS TO PARTICIPANTS FROM THE STUDY***

1. **For each procedure used in this study, provide a description of any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social, economic, legal, etc. risks/stressors**

[ **X** ] No known or anticipated risks

Explain why no risks are anticipated: No risk associated because the participant is not being asked to demonstrate any physical behaviour or strenuous metal exercises. Participant may be at own risk when commuting to the location of the interview.

[ ] Minimal risk

Description of risks:

[ ] Greater than minimal risk

Description of risks:

9.4

9.52. **DESCRIBE THE PROCEDURES OR SAFEGUARDS IN PLACE TO PROTECT THE PHYSICAL AND PSYCHOLOGICAL HEALTH OF THE PARTICIPANTS IN LIGHT OF THE RISKS/STRESSES IDENTIFIED IN QUESTION 1.**

## 10 INFORMED CONSENT PROCESS

Refer to: http://pre.ethics.gc.ca/english/policystatement/section2.cfm

1. **What process will be used to inform the potential participants about the study details and to obtain their consent for participation?**

[ ] Information letter with written consent form; provide a copy
[ ] Information letter with verbal consent; provide a copy
[ ] Information/cover letter; provide a copy

[ ] Other (specify) ___e-mail

**2. If written consent cannot be obtained from the potential participants, provide a justification.**

The person we chose to include in our study was contacted by request of an interview through e-mail. Keith Tufts is an architect who does a lot of work with green roofing and could share useful information with us. He confirmed our interview also by e-mail, stating he would meet us in the Halifax Central Library.

## 11 ANONYMITY OF PARTICIPANTS AND CONFIDENTIALITY OF DATA

**1. Explain the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.**

There was no need for concealing the identity of our participant, he is locally well known and has contributed to several building projects in Halifax. He was not asked to fill out any questionnaires or surveys and he was asked general questions involving green roof installation.

**2. Describe the procedures for securing written records, questionnaires, video/audio tapes and electronic data, etc.**

Casual conversation, and note taking on a PC.

**3. Indicate how long the data will be securely stored, the storage location, and the method to be used for final disposition of the data.**

[ ] Paper Records
  [ ] Confidential shredding after ______ years
  [ ] Data will be retained indefinitely in a secure location
  [ ] Data will be retained until completion of specific course.

[ ] Audio/Video Recordings

### 11.1 [ ] Erasing of audio/video tapes after ______ years

  [ ] Data will be retained indefinitely in a secure location
  [ ] Data will be retained until completion of specific course.

[ ] Electronic Data

11.2 [ ] ERASING OF ELECTRONIC DATA AFTER _______ YEARS

11.3 [ X ] DATA WILL BE RETAINED INDEFINITELY IN A SECURE LOCATION

[ ] Data will be retained until completion of specific course.

11.4 [ ] OTHER

______________________________________________________________________________

11.5 (PROVIDE DETAILS ON TYPE, RETENTION PERIOD AND FINAL DISPOSITION, IF APPLICABLE)

**Specify storage location:** ______________________________________________________

## ATTACHMENTS

Please **check** below all appendices that are attached as part of your application package:

[ ] **Recruitment Materials**: A copy of any poster(s), flyer(s), advertisement(s), letter(s), telephone or other verbal script(s) used to recruit/gain access to participants.

[ ] **Information Letter and Consent Form(s)**. Used in studies involving interaction with participants (e.g. interviews, testing, etc.)

[ ] **Information/Cover Letter(s)**. Used in studies involving surveys or questionnaires.

[ ] Parent Information Letter and Permission Form for studies involving minors.

[ ] **Materials**: A copy of all survey(s), questionnaire(s), interview questions, interview themes/sample questions for open-ended interviews, focus group questions, or any standardized tests used to collect data.

**SIGNATURES OF RESEARCHERS**

___Emma Laing___________________________________ April 17 2015

Signature of Student Investigator(s) Date

__Sydney Cranstone __________________________ April 17 2015

Signature of Student Investigator(s) Date

__David Watling _____________________________________ April 17 2015

| | |
|---|---|
| Signature of Student Investigator(s) | Date |
| ____Zijin Zhang | April 17 2015 |
| Signature of Student Investigator(s) | Date |
| Skylar Ho | April 17 2015 |
| Signature of Student Investigator(s) | Date |

**FOR ENVIRONMENTAL PROGRAMMES USE ONLY:**

Ethics proposal been checked for eligibility according to the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans

Signature Date