

# *Living Wall*

## *A Feasibility Study for the SLC*



Final Report  
ERS 250



In conjunction with

**WATgreen**

Lauren Knowles, Paige MacLean, Melissa Rosato  
Conrad Stanley, Stefania Volpe, Dave Yousif

Professor  
Susan Wismer

## **SUMMARY**

The purpose of this study was to assess the feasibility of installing a living wall in the Student Life Center at the University of Waterloo, in accordance with the WATgreen mandate to create more environmentally sustainable campuses. This study used a triangulation research method that employed a literature review, key informant interviews and a questionnaire. After analyzing these results, this study concluded that based on the inherent benefits, a living wall should in fact be installed. Associated recommendations included that the wall have a biofilter, that it be integrated into the HVAC system, that it be large scale, that it be maintained by the UWSP Landscaping Group, and that it be located in either the Great Hall or the Atrium.

## TABLE OF CONTENTS

	Summary	
<b>1.0)</b>	<b>Introduction</b>	<b>P. 4</b>
<b>2.0)</b>	<b>Purpose of the Study</b>	<b>P. 6</b>
<b>3.0)</b>	<b>Research Question / Objectives</b>	<b>P. 7</b>
<b>4.0)</b>	<b>Key Terms</b>	<b>P. 7</b>
<b>5.0)</b>	<b>Boundaries of the Study / Scope of Research</b>	<b>P. 8</b>
	-Geographic Boundaries	
	-Time Boundaries	
	-Units of Analysis	
	-Target Groups	
<b>6.0)</b>	<b>Boundaries / Scope of proposed Living Wall</b>	<b>P. 9</b>
	-Geographic Boundaries	
	-Time Boundaries	
	-Input / Output Boundaries	
	-Actor Boundaries	
<b>7.0)</b>	<b>Limitations</b>	<b>P. 12</b>
<b>8.0)</b>	<b>Significance</b>	<b>P. 12</b>
<b>9.0)</b>	<b>Conceptual Framework</b>	<b>P. 13</b>
	-Actor Systems Diagram	
	-Physical Systems Diagram	
	-Positive Feedback Loops	
<b>10.0)</b>	<b>Proposed Research Methods</b>	<b>P. 14</b>
	-Approaches and Objectives	
	-Methods	
	-Triangulations	
	-Site and Population	
	-Sampling Methods	
	-Data Collection Tools	
	-Pre-testing	
	-Data Analysis Strategy	
	-Reliability Validity and Anonymity	

<b>11.0) Survey Results</b>	<b>P. 19</b>
- Questions 1 to 10	
<b>12.0) Contingency Tables</b>	<b>P. 31</b>
<b>13.0) Interview Analysis</b>	<b>P. 34</b>
-Overall opinions	
-Benefits of having a living wall	
-Air quality	
-Cost savings	
-Concerns with having a living wall	
-Preferred location	
-Preferred type, components and scale	
-Funding	
<b>14.0) Case Studies</b>	<b>P. 42</b>
<b>15.0) Conclusions</b>	<b>P. 55</b>
<b>16.0) Recommendations</b>	<b>P. 56</b>
-Key decisions and concerns	
-Future research	
<b>17.0) Sample Budget</b>	<b>P. 60</b>
<b>18.0) Bibliography / Literature Cited</b>	<b>P. 61</b>

## LIST OF FIGURES

<b>1.0) Schematic Diagram of a Biofilter</b>	<b>P. 5</b>
<b>2.0) Canada Life Environmental Room</b>	<b>P. 43</b>
<b>2.1) Canada Life Environmental Room</b>	<b>P. 43</b>
<b>2.2) NORCAT Living Wall</b>	<b>P. 47</b>
<b>2.3) NORCAT Living Wall</b>	<b>P. 47</b>
<b>2.4) Niagara Under Glass</b>	<b>P. 49</b>
<b>2.5) Niagara Under Glass</b>	<b>P. 49</b>
<b>3.0) Small Scale Biofilter</b>	<b>P. 60</b>
<b>3.1) Large Scale Biofilter</b>	<b>P. 60</b>

## **LIST OF TABLES**

<b>1) Contingency Questions of 1 &amp; 3</b>	<b>P. 32</b>
<b>2) Contingency Questions of 1 &amp; 8</b>	<b>P. 33</b>
<b>3) Contingency Questions of 6 &amp; 8</b>	<b>P. 33</b>
<b>4) Contingency Questions of 6 &amp; 4</b>	<b>P. 34</b>
<b>5) Benefits from respondents</b>	<b>P. 41</b>
<b>6) Concerns from respondents</b>	<b>P. 41</b>

## **LIST OF CHARTS**

<b>1) Frequency of Visitors in SLC</b>	<b>P. 21</b>
<b>2) Main Uses of SLC</b>	<b>P. 22</b>
<b>3) Aesthetic Rating of SLC</b>	<b>P. 23</b>
<b>4) Previous Knowledge of Living Wall</b>	<b>P. 24</b>
<b>5) Specific Concerns of Living Wall in SLC</b>	<b>P. 26</b>
<b>6) Ranking the Benefits of Living Walls</b>	<b>P. 27</b>
<b>7) Position of having a Living Wall in the SLC</b>	<b>P. 28</b>
<b>8) Cost and Position</b>	<b>P. 29</b>
<b>9) Proposed Location of a Living Wall in the SLC</b>	<b>P. 31</b>

## **LIST OF APPENDICES**

**Appendix 1) Task Calendar**

**Appendix 2) Schedule of Tasks**

**Appendix 3) Definition of a Living Wall**

**Appendix 4) Questionnaire**

**Appendix 5) Verbal Recruitment Script for Students in the SLC**

**Appendix 6) Questionnaire Participation Letter**

**Appendix 7) Template Interview Questions for Professionals**

**Appendix 8) Interview Raw Data**

**Appendix 9) Questionnaire Raw Data**

**Appendix 10) Map of the University of Waterloo Campus**

**Appendix 11) Ethics Form**

**Appendix 12) Photo Gallery**

## 1.0 INTRODUCTION

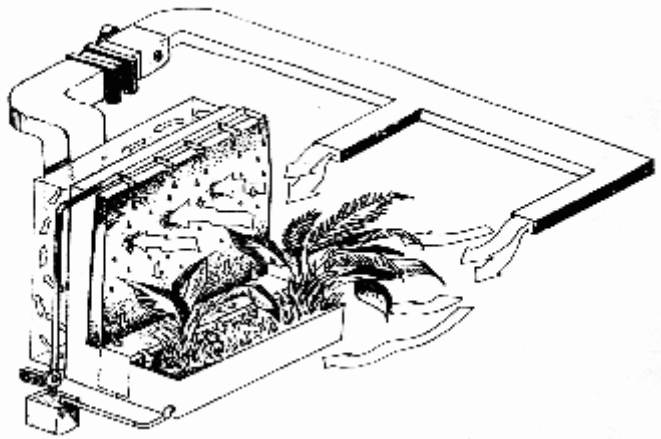
Indoor air quality is becoming a major health concern as North Americans spend over ninety percent of their time indoors. To express this growing awareness, the Environmental Protection Agency cited indoor air quality (IAQ) as one of the top five public health concerns (Llewellyn, 2001). Public awareness of indoor air quality has been enhanced by increased cases of human illness associated with poor air quality in schools, homes, and office buildings. Because modern buildings are designed to be sealed from the outdoors and to reduce both passive leakage and active ventilation (Llewellyn, 2001), there is an increased risk for the development of fungicide, and a greater potential for illnesses such as Sick Building Syndrome (SBS). NASA has estimated that SBS negatively affects workforce production by \$60 billion per year in the United States (Niagara Under Glass, 2002). On a local scale, Brother Andre High School in Markham Ontario recorded high numbers of student illness attributed to the formation of mould in the school's ventilation system. As a result, the affected portion of the school was closed, and a new system installed.

Due to health related epidemics in the past 10 years, studies of indoor air quality are increasingly important in determining the possibility for alternative ventilation systems. One prospect is the implementation of a living wall to act as a natural filter for indoor air. The University of Waterloo, Federation of Students recommended a living wall for the Student Life Center as one such alternative.

The involvement of our project group in this study was to determine the feasibility for the implementation of a living wall in the SLC. As part of our investigation, we addressed living walls as a potentially effective method for improving air quality, and lowering energy costs. To this end, the new technology biofiltration can be applied.

To clarify, living walls can be composed of plants on their own, serving to filter the air through their leaves and surface area. However, living walls with biofilters increase the capacity of air filtration. Biofiltration is defined as the process of drawing air in through organic material (such as moss, soil, and plants) resulting in the removal of organic gases (volatile organic compounds) and contaminants. Micro organisms inherent within the

biofilter absorb, minimize, separate, break-down and transform dangerous compounds so as to re-circulate clean air. Up to 80% of dangerous compounds in indoor environments can be eliminated through the use of a biofilter (University of Guelph, 2002). The schematic diagram (Figure 1.0) below shows air being drawn into the plants and porous organic matter lining the biofiltration wall. As it filters through this organic matter, microbes break down harmful compounds and fresh air is drawn into a ventilation system and re-circulated into the room. This is where the cost savings are derived from. Besides cost savings, there are other numerous benefits to be had.



**Figure 1.0 Schematic Diagram of a Biofilter**  
(University of Guelph, 2002)

There is a possibility for increasing the aesthetic value of the SLC, providing a better working and learning environment, while simultaneously furthering the WATgreen mandate. In keeping with the goals of WATgreen, our rationale for this project is to promote environmental research and initiatives at the University and to help facilitate the formation of interdisciplinary research within the community and other academic communities around the world (WATgreen, 2002). Waterloo students and staff spend a significant amount of time in the SLC. As a center for congregation, the group found it important to assess the feasibility of a living wall at this location.

To determine the viability for a living wall in the Student Life Center, data was collected and analyzed. However, alternative ventilation systems are a new and developing technology, and the secondary data associated with previous studies is limited

to a small number of documented cases. To build knowledge of living walls including the mechanics, costs and benefits associated with their implementation, the group used triangulation to investigate case studies, conduct questionnaires and interview experts in the field.

The Canada Life Center Environmental Room (CLER), based in Toronto has been the main case study for this report. This room was created approximately eight years ago, and contains a fully operational living wall to date. Interviews with professionals and student questionnaires gave an indication of the scientific and social acceptability associate with living walls. Input from Waterloo students and staff who frequent the Student Life Center gave an indication of the need for, and response to the project. In addition, peer reviewed journals, newspaper articles, and reliable web sources surrounding current data and knowledge were utilized for learning about alternative filtration systems.

By implementing a living wall in the Student Life Center, the University of Waterloo would be unique among Canadian universities. In addition, a living wall would be a distinct contribution not only to the school but for future research development in the areas of ecology, building design, and green initiatives. By researching literature associated with the aforementioned technologies and through conducting this study, the creation and enhancement of knowledge in this field have improved the validity of previous studies. The potential benefits of generating awareness, improving air quality, promoting environmental education, and improving aesthetics, rendered this study as an innovative and valuable project.

## **2.0 PURPOSE OF THIS STUDY**

The purpose of this study was to examine the feasibility of executing a living wall in the Student Life Center at the University of Waterloo. The study applied to a methodological framework based on quantitative and qualitative research, and a combination of exploratory and descriptive approaches.

### **3.0 RESEARCH QUESTION/OBJECTIVES**

The main objective of this study was following: to determine the feasibility of a living wall in the Student Life Centre.

The supporting objectives were twofold:

- 1) To conduct a detailed analysis of the economic, social and environmental benefits and costs of a living wall in order to help determine the overall feasibility.
- 2) To recommend the type, size, layout and location of the living wall if the possibility of a wall in the SLC is proven to be a viable undertaking.

### **4.0 KEY TERMS**

#### *Definition of Key Terms*

*Absorption* – The process of one substance entering into the inner structure of another.

*Acceptable Indoor Air Quality* – Air in which there is not known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.

*Biofilter* – A filter which uses natural processes such as bacteria and micro-organisms to clean indoor air of harmful compounds improving overall air quality.

*Contaminant* – An unwanted airborne constituent that may reduce acceptability of the air.

*Environmentally friendly* – An action or characteristic that promotes the future sustainability of natural resources.

*FEDS* – University of Waterloo Federation of Students.

*Living Wall* – Loosely defined, any man-made three-dimensional vertical surface covered in vegetation. The illusion of a natural, wild surface is created. It may serve a number of aesthetic and environmental functions.

*Sick Building Syndrome* – Impacts on human health, mainly in office buildings, due to poor air quality in a hermetic environment.

*SLC* – Student Life Centre at the University of Waterloo.

*Sustainability* – Meeting the needs of the present generation without compromising the ability of future generations to meet their needs. In terms of this study, sustainability includes the promotion of economic, social and ecological factors.

*UW* – University of Waterloo.

*VOC* – Volatile Organic Compounds. A type of pollutant in the air.

## **5.0 BOUNDARIES / SCOPE OF RESEARCH**

### *A) Geographic Boundaries*

The known geographic boundaries of this study include the Region of Waterloo, Guelph and downtown Toronto, Ontario. Interviews with experts and field trips to other cities have broadened the geographic scope. Most primary and secondary data collection were conducted on the University campus.

### *B) Time Boundaries*

The time boundary for this project was limited to the 2002 fall term of study. More specifically, it lasted for approximately two and a half months from October to early December 2002.

### *C) Units of Analysis*

The units of analysis for this study are:

- Prominent experts in the field of creating and maintaining living walls
- UW safety Office, UWSP and the SLC Board
- All UW students and staff who frequent the Student Life Center

### *D) Target Groups*

The target groups of this study included those in a decision making position with the ability to affect the future installation of a living wall in the SLC. This includes those with the capacity or authority to provide assistance, financial or otherwise. Members of the Federation of Students, SLC management board, and other constituents of UW administration were involved. An additional target group consist of the entire UW student population. Their support was fundamental in effecting the outcomes of this study.

## **6.0 BOUNDARIES / SCOPE OF THE PROPOSED LIVING WALL**

### *A) Geographic Boundaries*

Due to the proposed location already specified in the request for an audit, the geographical boundaries of the living wall were set to be within the Student Life Center on the campus of the University of Waterloo. Possible locations of the wall within the SLC have been determined in the audit process.

### *B) Time Boundaries*

Conceptual planning of a living wall in the SLC began in October 2002. The estimated time to complete all components of creating a living wall would be approximately two to five years. Following this, the lifecycle of the wall could be indefinite given proper maintenance is ensured.

### *C) Input/Output Boundaries*

#### Inputs:

*Biological/Abiotic Factors:* plants, water, rock, air, solar energy, insects, amphibians, nutrients, and any other biological or abiotic components of the living wall.

*Social Factors:* involvement of students/staff/faculties/classes in the creation, maintenance, and study of the living wall.

*Economic Factors:* initial capital investment (money) in construction materials, labour, expert advice, and long-term maintenance costs.

#### Outputs:

*Biologica/Abiotic Factors:* purified air, the decomposition of the plants and the production of organic material.

*Social Factors:* increased understanding about sustainable campuses, ecosystems, green building technology etc., heightened reputation for the university as an environmentally friendly campus, and emotionally uplifting aesthetic outputs to people who frequent the SLC.

*Economic Factors:* savings in electrical energy costs and air filtration benefits.

### *D) Actor Boundaries*

There are three types of actor groups incorporated in the study boundaries. A visual actor systems diagram is located on the following page. The actor groups can be separated into two subcategories, 1) Decision Makers and 2) Use of the living wall. A summary of the actors is as follows:

## 1) Decision Makers:

### *Core Actors:*

- The SLC Board (Ann Simpson and Nancy O'Neil)
- Plant Operations: Involved in integration of the system, and monitoring of air quality levels

### *Supporting Actors:*

- University of Waterloo students, staff and administration, who are in favour of implementing a living wall
- This includes questionnaire and interview respondents who's opinions can influence decision makers

### *Shadow Actors:*

- Other University of Waterloo students
- Those involved in maintenance of the wall

## 2) Use of the Living Wall

### *Core and Supporting Actors:*

- University of Waterloo staff and administration: Use the wall for faculty research and promotion of Waterloo's innovation
- University of Waterloo Students: benefit from the improved air quality, aesthetics, and psychological effects. In addition, benefit through the use of the wall in course curriculum.
- Visitors to the University of Waterloo: Visitors to the SLC for special events including presentations and meetings.

### *Shadow Actors:*

- Waterloo Community: Benefit from the improved reputation of the University
- Academia: Benefit from the study of the living wall, including research, and the prospect for implementing similar projects in other institutions

## **7.0 LIMITATIONS**

This study was limited by a short time frame, the acute lack of financial and academic resources, and the limited experience of the researchers in this field. These limitations affected the quality and size of the sampling population available for participation in the questionnaire. Additional limitations existed in the ability of the researchers to actively investigate all possible case studies and consult all relevant experts on living walls.

## **8.0 SIGNIFICANCE**

This audit for the Federation of Students could prove to be quite significant. Although approximately 190 WATgreen projects have been completed at the University of Waterloo, none have reflected upon the topic of living walls. This study may have a direct impact on future prospects of a living wall in the SLC. It will also impact the probability of further pursuit and research by other individuals and groups at UW. This audit has the potential to influence relevant decision makers at the University of Waterloo towards the notion of installing a living wall. The creation of a living wall will have direct impacts on a large proportion of the staff and student body at the University. Members of the local community who frequent the SLC will also be affected. Finally, the knowledgebase of UW academia and outside researchers will be expanded. If this study is not implemented, then the students and staff who frequent the SLC will not experience the potential environmental, social and educational benefits of a living wall.

## 9.0 CONCEPTUAL FRAMEWORK

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## 10.0 PROPOSED RESEARCH METHODS

### *Approaches and Objectives*

After careful consideration, the various approaches to research were decided upon. An inductive and integrated approach to the research was determined due to the broader framework that depicts inductive approaches. It is precisely this inductive approach that appears relevant to our topic because theory arises from the exploration of data, of which most is qualitative (Wisner Sept. 24, 2002). Our main research objective was a combination of exploratory research, because our project aimed to gain familiarity into the specific phenomenon of the feasibility of a living wall (1997, p.77), and descriptive, in part, because we hoped to portray the characteristics of the phenomenon (Palys, 1997, p. 80).

### *Methods*

The integrated and inductive approaches required triangulation. Triangulation is the use of at least three methods of research (Wisner, Oct. 1, 2002). For this reason, the intent of our research was to pursue various methods of data acquisition. These methods are extensive. Firstly, the use of case studies of three other living walls currently in existence, (in close proximity to Waterloo), were pursued, as well as other case studies through literature reviews. Interviews with experts that have helped design, build, monitor and maintain living walls were also be conducted. The use of a questionnaire will be useful to gauge the position of students and staff, people who might one day be the primary beneficiaries of a living wall. And lastly some possible field trips enabled the group to obtain primary data in observing a living wall. There is an emphasis on qualitative data due to the criterion for understanding, *verstehen*, understanding behavior in meaningful terms to the involved actors (Palys, 1997, p.22). Quantitative data was obtained through monitoring air quality, and in analyzing the questionnaires.

### *Site and Population*

The selection of the SLC as a potential location for a living wall was a result of a proposal put forth by the FEDS. The decision to pursue this location was justified by the group members due to the fact that the SLC is a true hub of student activity. Also, a living wall in the SLC would be equally accessible to the entire student body. Our research interest was to consider those students and staff that frequent the SLC (at least once a month), as our human population for the questionnaire portion of this study. In terms of the interview component of our sampling, the population consisted of two main categories. First, any and all available experts in the field of living walls. This includes those who have designed, built, monitored, or maintained living walls. Second, UW employees who have a stake in the implementation of a living wall, such as future maintenance personnel, members with decision making power and others. For both the questionnaire and interview populations, it is impossible and impractical to attain a sampling frame. This was in part due to the constant fluctuating attendance in the SLC, and the snowball sampling discussed in the next section. However, the group recognizes that the lack of a sampling frame is often the case with certain kinds of research, and that sampling should still be pursued (Palys, 1997, p.125). The group decided to sample approximately 90 UW students and staff using the questionnaires, 6 key informant interviews. These numbers were derived by estimation of time and available resources.

### *Sampling Methods*

Non-probabilistic sampling techniques were utilized in this study because “acquiring a formally representative sample may be impossible and even undesirable” (Palys, 1997 p.135). Purposive sampling seemed to be the ideal procedure for our study. Purposive sampling takes into account the fact that the ideal candidates for a study are “sought because they meet some criterion for inclusion in the study”, in this case, attendance in the SLC (Palys, 1997 p.137). It is for this reason that the group members distributed themselves in various areas of the SLC and simply approached people who appeared to have the required 5 minutes to spare for completing the questionnaire.

For the interview participants, intensity sampling was deemed appropriate because the group was looking to sample people who have experience with living walls, and as Palys states, the interests (and in our case *role*) of the participants make them ‘experiential experts’ (1997, p.138). Also related to the interview participants, snowball sampling is expected to occur. This was due to the relatively small community of people, organizations and literature available in this new topic. It was unavoidable that the chosen participants would likely be able to provide new contacts (Palys, 1997, p.139).

List of potential interview participants:

<b><u>Name</u></b>	<b><u>Area of Specialization</u></b>
Ian Fraser	UW Safety / Environmental Health Coordinator
Chris DiLulo	UW FEDS – VP Administration and Finance
Ann Simpson	UW SLC Manager
Crystal Legacy	UW – Environment Commissioner
Alan Darlington	University of Guelph – Plant Agriculture Prof.
Jeffrey Mallany	Air Quality Solutions – Biofilters

### *Data Collection Tools*

The data collection tools used were categorized according to the population and sampling methods defined. In terms of the purposive sampling of participants in the SLC, a self-administered questionnaire was utilized for various reasons. Face-to-face contact has been determined to increase response rates, as well as allowing the members of the group to clear up any ambiguities (Palys, 1997, p.146). There is also the benefit of privacy, as opposed to group administered questionnaires (Palys, 1997, p.148). The only limitation of this tool is that an unanswered or improperly answered question will not likely be caught until it is too late to fix (Palys, 1997, p.148).

Included in the questionnaire are single response items, (questions 5, 4, 9, and 10), categorical response items, (questions 1,2,6,7), rating scales, including a Likert-type scale (question 3 and 8), (Palys, 1997, p166-169). The group was cautious with the

formulation of the survey. Particular attention was paid to the choice of wording, including the use of loaded terminology, any bias involved in the questions, ambiguity with questions, asking for meaningless responses, and double-barrelled items (Palys, 1997, p.174-175). Lastly, the group tried to give the survey aesthetic appeal to “increase the likelihood of snagging respondents” (Palys, 1997, p.177).

In terms of the intensity sampling and snowball sampling methods for the interview participants, telephone, face-to-face interviews were pursued. This was due to the fact that there is an 80 – 90% response rate with person to person contact (Palys, 1997, p.154). Also according to Palys, face-to-face interaction offers “benefits that can enhance the quality of the data gathered” (Palys, 1997, p.154). The disadvantage of time is one the group has decided to concede.

Sampling of living walls themselves were done through simple first-hand observation, recording any information on a standard observation form, included in the appendices. The required field trips for this sampling to occur were arranged with the owners (companies, stores, etc.) of the existing walls. Lastly, case studies were another sampling tool used in the form of literature reviews. All of the above sampling tools ensured that triangulation of the information was possible.

### *Pre-Testing*

With questionnaires, pre-testing is recommended (Palys, 1997, p.176). It is for this reason that the group asked various friends or roommates to complete the original version of the questionnaires. This was done to minimize surprises before distributing the questionnaires to participants in the SLC. Depending on the reaction and suggestions from this pilot study, the revision of certain questions was necessary, and changes edited accordingly. In the case of the interviews, the first interview served as the test case, although it was in fact an interview that was used. Again there were editing and tweaking of questions according to the results of the first interview.

### *Data Analysis Strategy*

To analyze the qualitative data of our questionnaires, interviews, field observations and literature reviews, the group decided to try to identify patterns to help distinguish the connections between variables (Palys, 1997, p.299). Another strategy that was used included comparing and contrasting cases, again to help isolate and identify the required information needed to answer our research question (Palys, 1997, p.300).

In terms of quantitative data analysis, different strategies applied. Descriptive statistics were used to summarize and present the data (Palys, 1997, p.320). This was done through the use of pie charts, and column graphs. Also, to help determine relationships among variables, Inferential statistics were employed (Palys, 1997, p.320). In this strategy, “correlation helped to determine the degree of association between variables” and contingency tables aided in differentiating among variables (Palys, 1997, p.354).

### *Reliability, Validity and Anonymity*

Reliability was achieved through a variety of ways. The questionnaires used in the study are standardized, ensuring consistency. Careful measures were taken to record each procedure that was undertaken. This enabled easy repetition of the methods used. Lastly, the fact that there are six group members, all whom contributed opinions and

decisions also account for consistency in observing the same phenomenon through different perspectives (Palys, 1997, p.69).

Validity was achieved through many means. Ecological validity stemmed from the fact that the undertaking of this project, and the results, dealt with a real life case analysis (Palys, 1997, p.414). In this respect, this study could be used to generalize findings by other institutions, organizations and even other schools who wish to perform an audit or feasibility study of living walls, also pertaining to external validity (Palys, 1997, p.258). This was accomplished by posting the finished study on the internet easing accessibility concerns.

Anonymity was assured through the questionnaires by various means. Firstly, the participants' name, age, program or other identifiable personal information was not requested. Secondly, the questionnaires were be coded by letter for identification purposes during the analytical phase of the study. The interviews remained anonymous unless the participant indicated permission to use specifics including name and opinions in the study.

## **11.0 SURVEY RESULTS**

The purpose of the questionnaire and the surveying in the Student Life Center (SLC) was to find whether the general population in the SLC was in favour of having a living wall. We employed a purposive-accidental sampling technique of 90 people in the SLC using face-to-face surveying methods. The respondents included students, staff and visitors.

This method of administering the survey was chosen because of the higher response rate associated with face-to-face contact. Palys states that individuals are more inclined to participate in a study if they are in personal contact with the evaluator and can clarify uncertainties and reservations that they might have (1997, p.148). The higher percentage of responses increases the internal validity of the study and is therefore desirable (Palys, 1997, p.146). In cases where it was believed there was a threat to validity, these are noted in the question analysis. Because purposive-accidental sampling was used, this may

have lowered the representativeness of the population sample. However, it is fair to assume that due to the 100% response rate, we have a reasonably representative response rate.

The types of questions in the surveys varied greatly. The questionnaires were designed in this way to analyze the numerous benefits and concerns that might arise if a living wall were to be implemented. To do this, we structured the majority of our questions to encompass quantitative data. According to Palys, quantitative data can be easily analysed with the help of a computer, and as a result, the reliability of the survey answers is amplified (1997, p.187). The range of questions also allowed us to determine the opinions regarding the optimal location for a living wall.

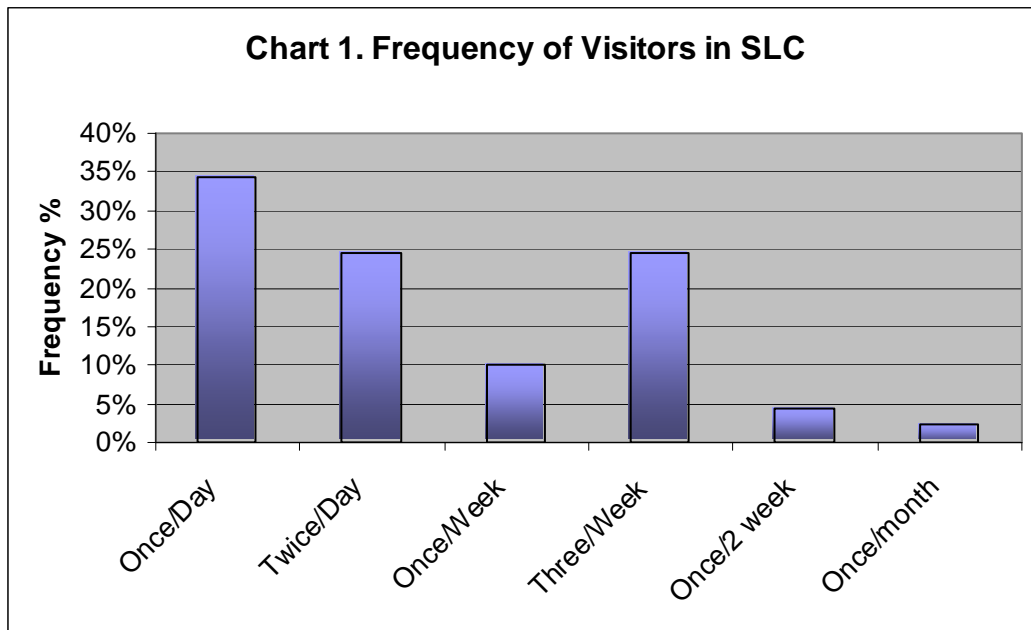
### **Question #1**

**How many times a week do you frequent the SLC? (check one)**

- Once a day**
- More than once a day**
- Once a week**
- Three times a week**
- Once every two weeks**
- Once a month**

This question was included in the survey as a way of measuring how often an average visitor makes use of the SLC. This is important to know when assessing whether a living wall would be worthwhile – if the average person only frequents the SLC once a week, then the noticeable benefits of a living wall for that person would probably be minimal. Likewise, the amount of time they spend in the SLC might have a direct impact on whether or not a person would be in favour of having a living wall installed. This question, when examined together with the results from question 3, was also intended to provide an indication of whether visitors and employees become bored and dissatisfied with the SLC's interior aesthetics the more often they frequent the building. If this were the case, it would possibly reveal the need for a continuously evolving wall of plants that will help improve the decorum.

Of the people surveyed, 58% said they frequented the SLC at least once a day. 24% said they go to the SLC three times a week; 10% once a week; 4% once every two weeks; and 2% of the people frequented the SLC once a month (see Chart 1). Thus, because the majority of people were found to frequent the SLC on a daily basis, the benefits of a living wall would be appreciated on a frequent basis by most of the population that frequent the SLC.



## Question #2

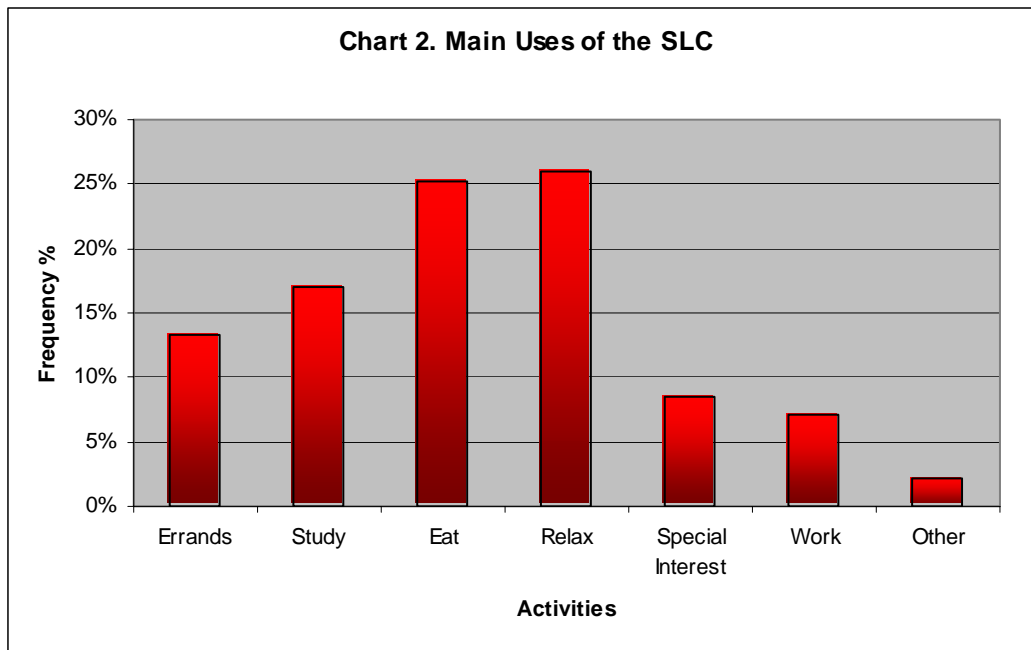
**What are your three main uses of the SLC?**

**(rank your choices, 1 = most important)**

- Errands (eg. Bank, Pharmacy, Used Bookstore, etc)**
- Studying**
- Eating**
- Relaxing / Leisure Time (eg. Great Hall, Bomber)**
- Special Interest (eg. Clubs, Meetings, Events, Presentations etc.)**
- Work**
- Other: \_\_\_\_\_**

As another background question, this was intended to establish the primary uses of the SLC, information that would factor into a final decision about the feasibility of a living wall. A living wall would be more beneficial and conducive to some uses (such as studying and relaxing, which involve remaining in one location over a long period of time) than to other uses (errands). Determining which are the primary uses has helped reveal whether the benefits of a living wall would be fully appreciated by the majority of those who frequent the SLC.

The majority of respondents said they mainly used the SLC to relax and eat, 26% and 25% respectively. 17% of the respondents were at the SLC to study, 13% to do errands and 17% for special interest, work and other (see Chart 2). Special interest includes meetings, clubs, events, et cetera. Also, 31% of the people surveyed said that relaxing was their number one activity at the SLC. Eating, working and studying then followed it (See Chart 2).



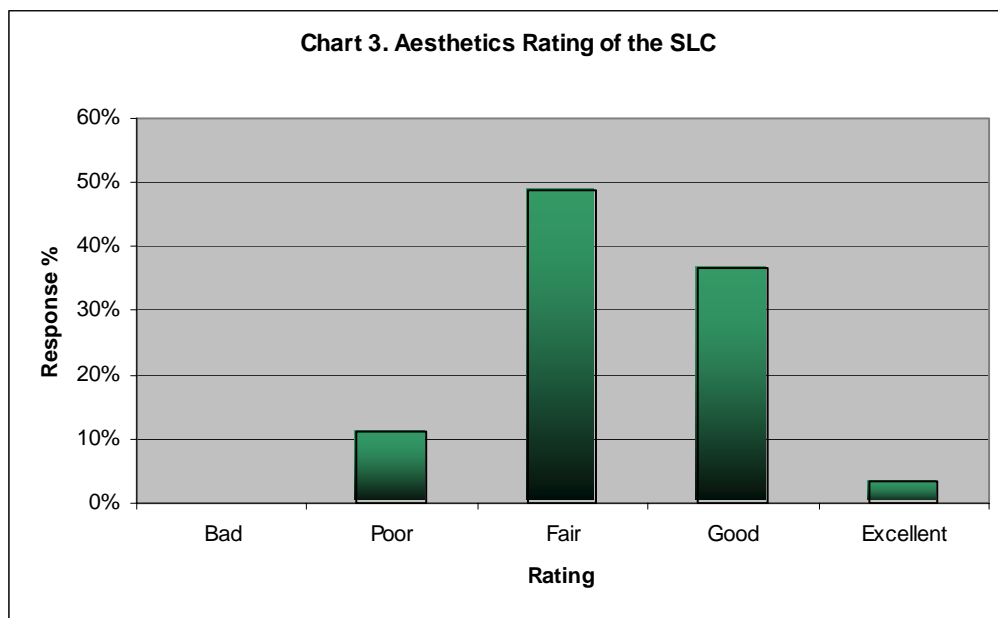
**Question #3**

**How aesthetically pleasing would you currently rate the SLC? (circle one)**

**Bad                  Poor                  Fair                  Good                  Excellent**

This question was designed to determine how aesthetically pleasing the majority of respondents felt the SLC to be. This would establish whether there existed a need for the aesthetics of the SLC to be improved, and possibly indicate that the visual and psychological attributes of a living wall would be of some benefit in the SLC. One downside to this question was that it was a relative one based on personal opinion without a defined set of criteria for respondents to use in order to judge the aesthetic appeal. Respondents might have rated the aesthetics of the SLC in comparison to other buildings on campus, other buildings they have been in during their lifetime, or what they thought an ideal building should look like inside. As such, this question had reduced internal validity.

The majority (60%) rated the SLC as fair or worse. Only 3% of the participants rated the SLC as excellent – the highest rating. This question and its responses clearly show that there is room for improvement in the aesthetics of the SLC (See Chart 3).



**Question #4**

**Before today, had you ever heard of a living wall? (circle one) Yes No**

**Question #5**

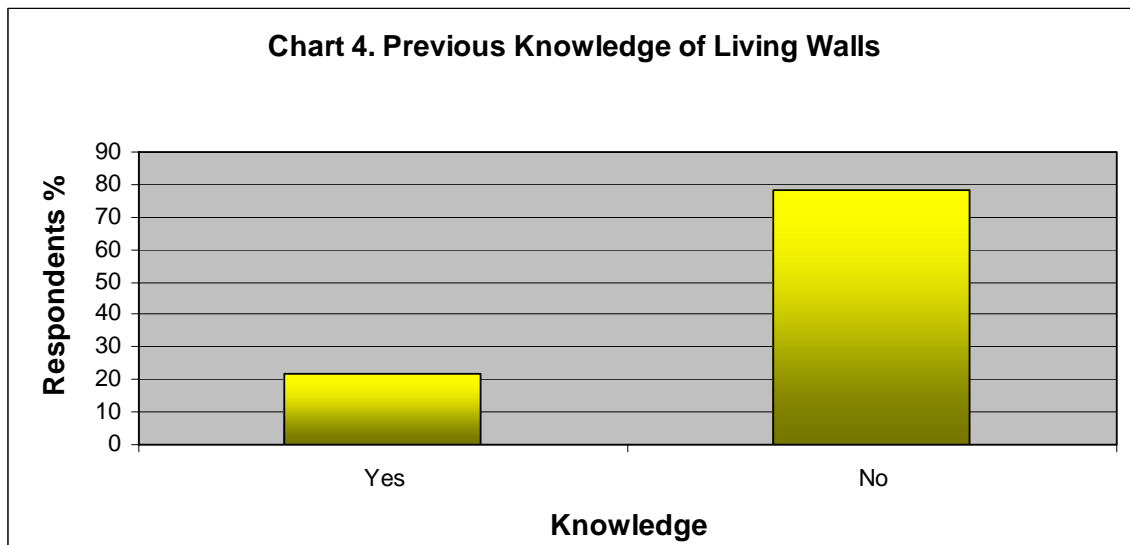
**If yes, where and how? \_\_\_\_\_**

The purpose of question 4 was to discover how many individuals had prior knowledge of living walls. Such knowledge might impact what benefits and concerns they listed and

whether they agreed with having a living wall in general. This question would also provide insight on the importance of the educational benefits of a living wall in the SLC. If few university students had ever heard of a living wall, then building one in the SLC could be construed as important if for no other reason than to provide these students with the opportunity to learn about this technology through a functioning example.

A continuation of question 4, question 5 again attempted to uncover the educational benefits of actual functioning living walls by asking respondents in the SLC whether their knowledge of living walls came from a textbook or other second-hand source or whether they had had actual first-hand exposure to the technology through an existing example like the Canada Life Building.

The results confirmed our suspicions that the majority (78%) of participants have never had any previous knowledge on what a living wall was (See Chart 4). This illustrates the need for a living wall in the SLC purely from an educational perspective, in order to provide a hands-on introduction to this relatively new technology.



#### **Question #6**

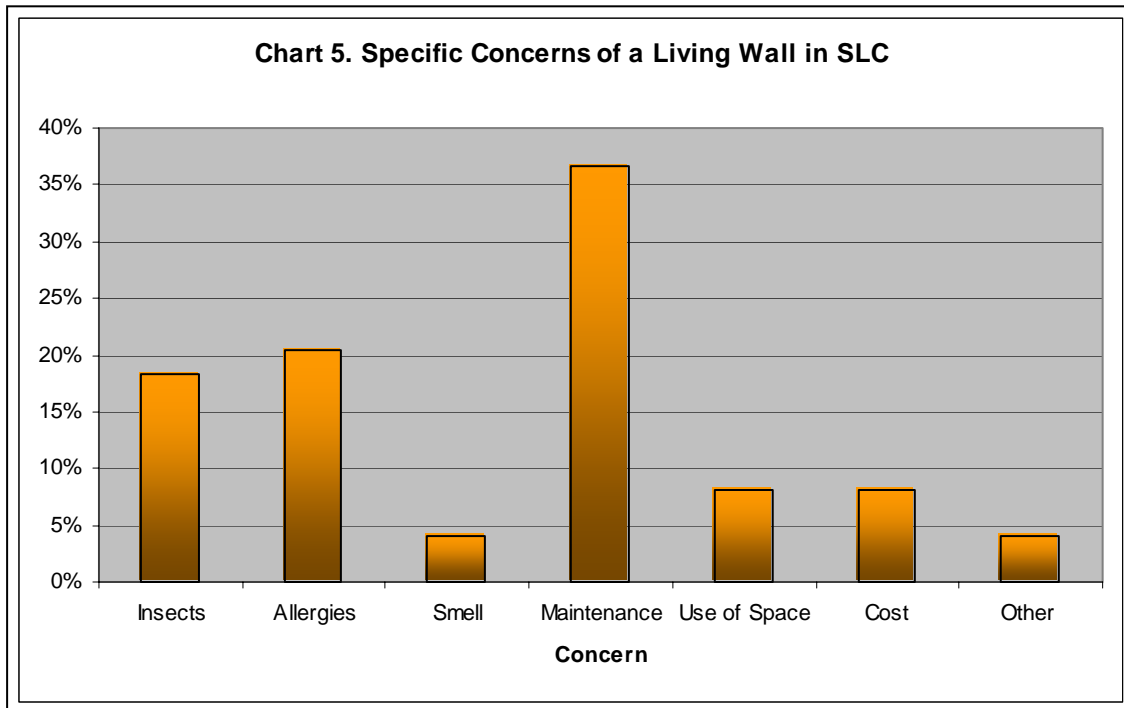
**Do you have any concerns about having a Living Wall in the SLC? Yes or No**

**(If yes rank your choices, 1 = most concern)**

- Insects**
- Allergies**
- Smell**
- Maintenance**
- Use of Space**
- Associated Economic Costs**
- Other:** \_\_\_\_\_

This question was included in the survey in order to evaluate what the most common concerns with a living wall were among those who frequented the SLC. This information would be important when composing an evaluation of the pros and cons of a living wall, and would also provide valuable suggestions on what concerns need to be thoroughly addressed should the university move ahead with the construction of a living wall. A limitation of this question was that most respondents probably had limited background knowledge on living walls in order to make an informed judgment on which factors were of concern. We refrained from providing such information at the time when the survey was conducted in order to avoid biasing the respondent's answer with information from outside literature sources.

54% of the participants showed concerns with having a living wall in the SLC. Of those who had concerns, 37% of them said they worried most about the maintenance of the wall most. Allergies and Insects were the next top concerns with 20% and 18% respectively. An economic cost was the top concern for only 4% of the people who had some concerns with living walls. Of all the concerns, maintenance was ranked first followed by insects (See Chart 5).



**Question #7**

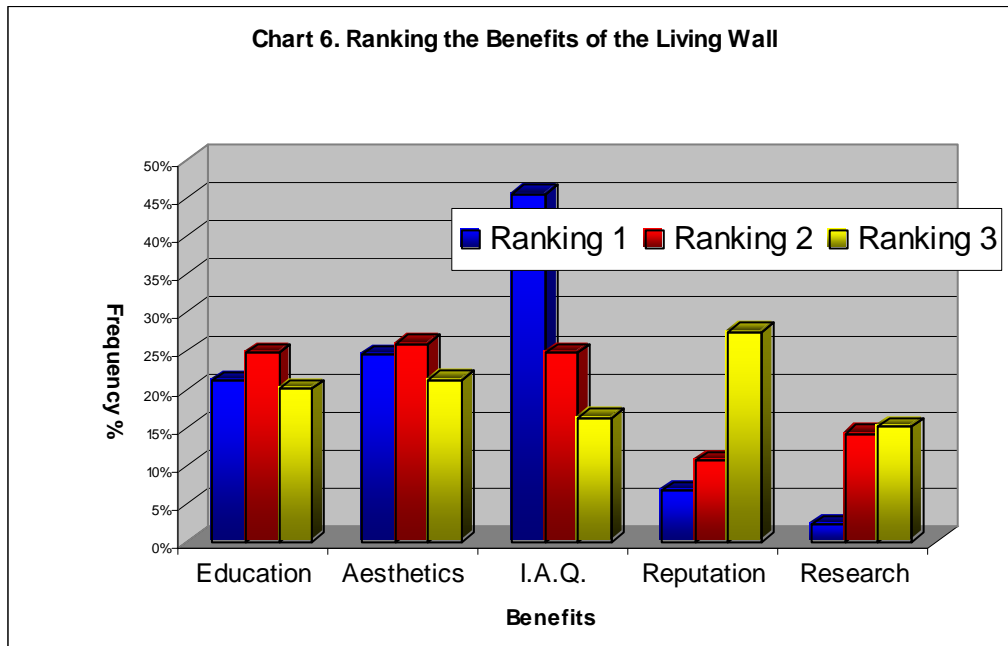
**What do you believe the benefits are of having a Living Wall?**

**(Rank top 3 choice, 1 = most beneficial)**

- Environmental / Sustainable Campus Education**
- Aesthetics**
- Improved Air Quality**
- Reputation of Waterloo's Innovation**
- Research / Student Involvement**

This question was designed to reveal the main benefits of a living wall from the perspective of those who would be the beneficiaries if one were to be installed. These answers would be important when creating an analysis of benefits versus costs, and also when evaluating what components to emphasize during the actual design of a living wall for the SLC – should a large biofilter be built because air quality was rated the most important or should the wall merely consist of plants with no biofilter because aesthetic appeal was seen to be the primary benefit? Again, the internal validity of this question was somewhat hampered because respondents did not have equal prior knowledge regarding the possible benefits of living walls.

Almost half (46%) of the people surveyed said that indoor air quality is the top benefit generated from a living wall. In relation to all rankings, 29% of the people surveyed felt that indoor air quality was an important benefit. 24% believed that aesthetics was important, followed by education (21%) and school reputation and research (See Chart 6).



**Question #8**

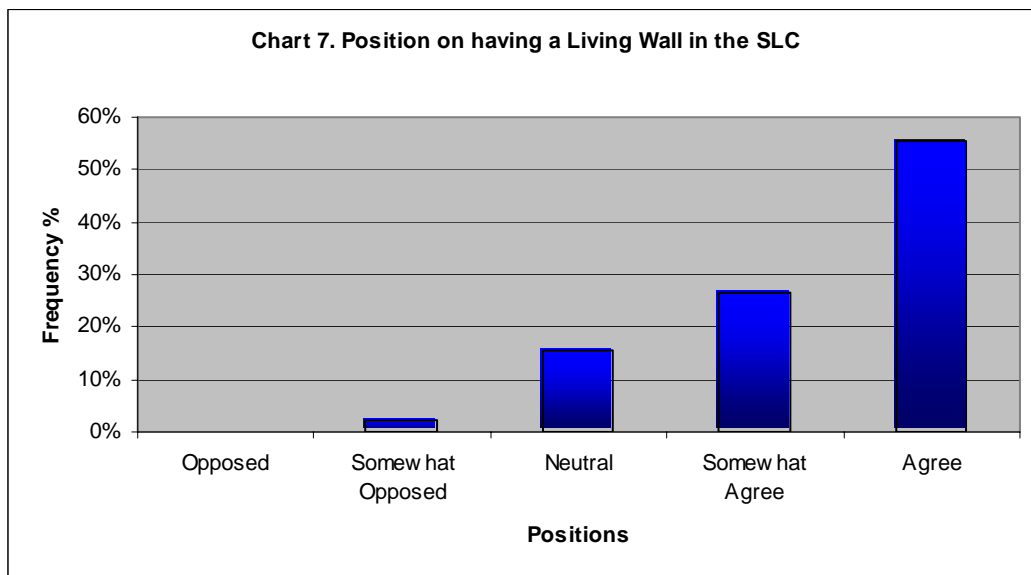
**What is your position on having a living wall in the SLC? (circle one)**

**Opposed      Somewhat Opposed      Neutral      Somewhat Agree      Agree**

This, the most important question on the survey, was chosen to determine the overall opinion of those in the SLC on whether a living wall should be installed. This question thus paralleled this study’s overall objective of determining the feasibility of constructing a living wall. Answers to this question could be related to previous questions using contingency tables in order to establish relationships between respondent’s position on having a living wall and answers to previous questions. There were a few threats to the internal validity of this question. First, respondents would have had varying degrees of background knowledge regarding living walls, and in some cases a lack of knowledge

may have hindered their ability to properly answer the question. As well, the simple act of filling out the previous questions on the survey, as well as an innate desire by some respondents to give the “proper” answer to please the surveyor may have impacted the validity of the answer (testing validity – Palys, 1997, p.248).

83% of those surveyed either agreed or somewhat agreed with having a living wall in the SLC. 16% of the respondents were neutral on the issue and 2% somewhat opposed to having a living wall in the SLC. It should also be noted that none of the students surveyed strictly opposed to having a living wall (See Chart 7). Clearly then, the vast majority of people who frequent the SLC are in support of a living wall, lending strong weight to the argument that one should be installed.



### Question #9

**If the cost of a Living Wall were not an issue, would your desire to have one change?**

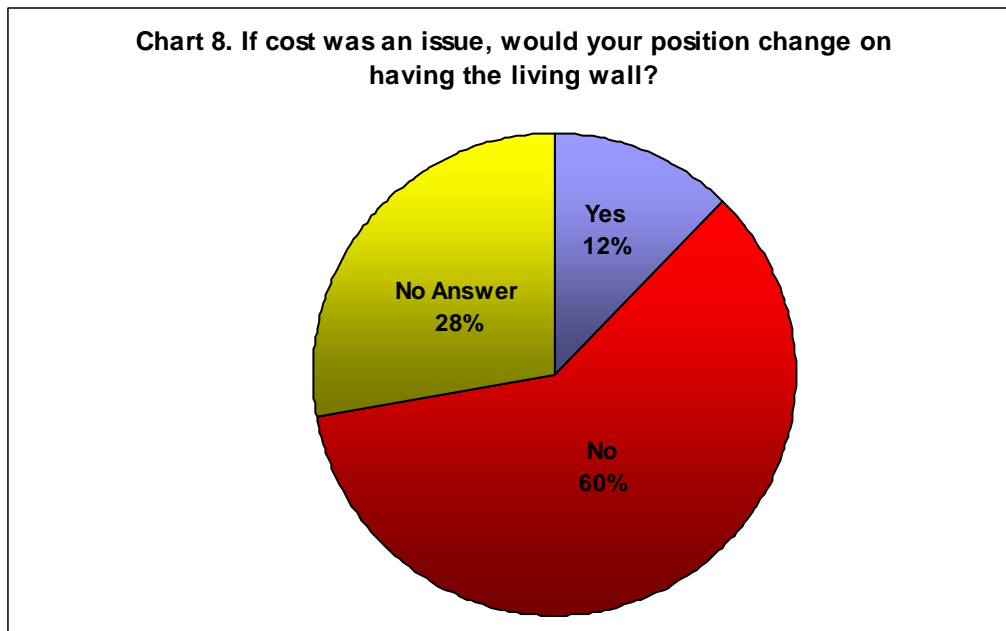
**If yes, why?**

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The purpose of this question was to isolate economic cost as an issue and determine the desire of having a living wall if this concern were removed from consideration. It was intended to help judge the importance placed on the issue of economic cost without directly asking the question in a way that might bias the rest of the survey by

overemphasizing the importance of cost to the respondents. This question was somewhat hampered by the fact that respondents were not told the final cost in dollars of installing a wall prior to filling out the survey (since this information was not available). Additionally, upon actually conducting the survey, this question was found to be poorly worded and confusing to some respondents, which resulted in it being left blank in a number of instances. Unfortunately this problem was not caught in the pre-test phase of the instrument design.

Due to the problem that arose from the wording of the question, the numbers represented are inconsistent and incomplete. Nevertheless, 60% of the people surveyed said that economic costs were not a factor in their desire to have a living wall or not. However, 12% of the people said their desire would change if economic costs were an issue. Finally, 28% of the answers did not meet the proper requirements of YES or NO; therefore, they were not counted (See Chart 8).



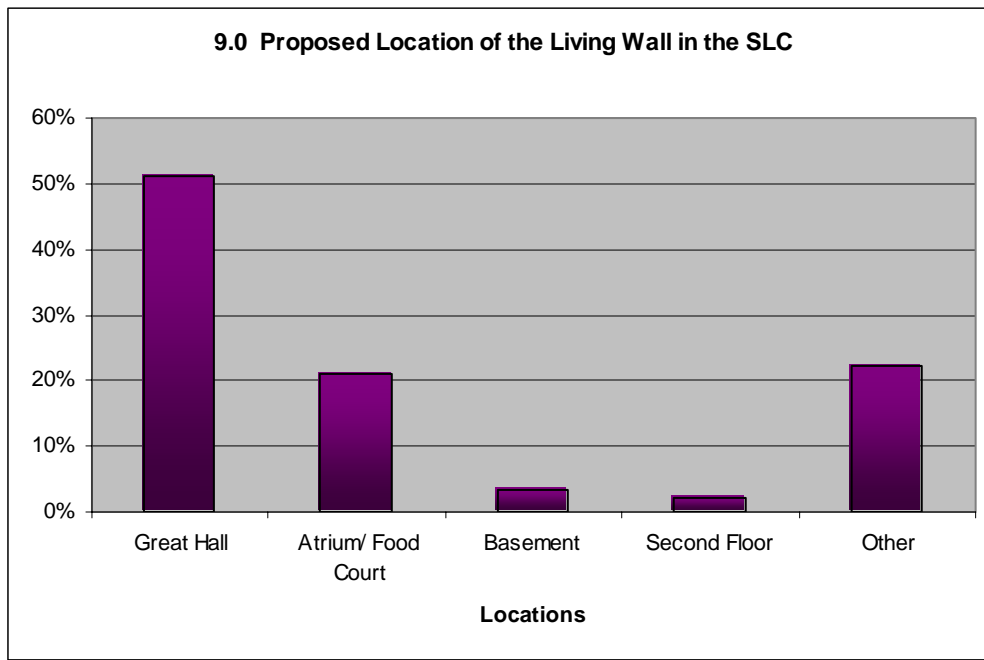
### **Question #10**

**If you agree with having a Living Wall, where in the SLC do you feel would be the optimum location for it? Why?**

---

This question was designed to have respondents provide feedback on the best location in the SLC for a living wall to be installed. While respondents may have had limited knowledge regarding the ideal location of a living wall from a technical perspective, they could certainly provide this study with first-hand insight into which areas in the SLC they would be able to derive the most benefits from having a living wall installed. One limitation of this question was that in many cases respondents conversed aloud regarding the best location for a living wall, which may have influenced some of the results. This disadvantage of group-administered questionnaires was most prevalent with this particular question (Palys, 1997, p.148).

Over half of the participants said that they would like to see a living wall in the great hall. The reason provided by most of the great hall answers was that there was not enough light. A concern some students had for not wanting a living wall in the great hall was that there was not enough room. 21% of the people surveyed said that atrium/ food court is an ideal place to have a living wall because of the abundant amount of sunlight received. Other responses include those that did not favour a living wall in the SLC.



## 12.0 CONTINGENCY TABLES

### Question #1 and #3 – Frequency in the SLC and aesthetics in the SLC

Contingency Table 1. reveals that there is a loose inverse relationship between how often people frequent the SLC and how they rate it aesthetically. Of those who rated the aesthetics as being poor, 60% frequented the SLC once a day or more than once a day, whereas the aesthetics of the SLC were rated poor by only 10% of the people who frequented the SLC once a week or less. This relationship holds somewhat true as well among those who rated aesthetics as fair. This relationship can likely be attributed to the fact that people who are in the same building on a consistent basis tend to grow bored and tired of its indoor appearance after a while.

The contingency table does reveal conflicting figures among those who rated the aesthetics as excellent; however, the small number of respondents who thought that the aesthetics were excellent diminishes the value of these figures relative to the number who thought the aesthetics were poor or fair.

Therefore, the findings of this contingency table point to the value in installing a living wall because it would notably alter the familiar aesthetics of the SLC, not only

immediately following its installation, but also on a continuous basis because of the constantly evolving nature of the plants growing on the wall. This would minimize the degree to which daily visitors become bored and dissatisfied with the indoor aesthetics of the SLC.

*Table 1. Contingency of questions 1 and 3*

	Once a day	More than once a day	Once a week	Three times a week	Every two weeks	Once a month
Bad	0	0	0	0	0	0
Poor	50%	10%	0%	30%	0%	10%
Fair	34%	30%	9%	25%	2%	0%
Good	33%	18%	15%	21%	9%	3%
Excellent	0%	67%	0%	33%	0%	0%

**Question #1 and #8 – Frequency in the SLC and position on having a living wall**

This contingency table (Table 2) reveals that there is a fairly consistent level of agreement/disagreement with the proposal of having a living wall regardless of how often the respondents frequented the SLC. This runs contrary to our expected result that people who frequent the SLC on a consistent basis would be more in favour of having a living wall installed because they would be the ones who would most enjoy the benefits.

While on one hand this result would seemingly discredit the relationship found by comparing question 1 and 3 (that those who frequent the SLC a lot would be more in favor of installing a living wall to improve the aesthetics that they find lacking), this result also illustrates that the perceived benefits of implementing a living wall accrue nearly equally to all who visit the SLC, regardless of how long they spend in the building. This reinforces the notion that the benefits of a living wall are universal and far reaching across a wide spectrum of the people who frequent the SLC.

**Table 2. Contingency of questions 1 and 8**

	Once a day	More than once a day	Once a week	Three times week	Every two week	Once a month
Opposed	0	0	0	0	0	0
Some	50%	0	50%	0	0	0
Neutral	57%	7%	21%	7%	7%	0%
Some	25%	29%	8%	29%	4%	4%
Agree	67%	58%	13%	58%	8%	4%

**Questions #6 and #8 – Concerns and position on having a living wall**

Contingency Table 3 reveals that those who had concerns with insects, allergies, maintenance, use of space, costs and other still tended to agree or somewhat agree with having a living wall. We had expected that the majority of those who had concerns would not agree with having a living wall. Only people who have issues with smell tended not to agree with having a living wall. Also, 86% of the people surveyed who had no concerns agreed with or somewhat agreed with having a living wall. Interestingly, 100% of those who had concerns with economic cost still agreed or somewhat agreed with having a living wall.

**Table 3. Contingency of questions 6 and 8**

	Opposed	Somewhat Opposed	Neutral	Somewhat Agree	Agree
Insects	0%	11%	11%	0%	78%
Allergies	0%	0%	30%	40%	30%
Smell	0%	50%	50%	0%	0%
Maintenance	0%	0%	11%	39%	50%
Use of Space	0%	0%	25%	25%	50%
Cost	0%	0%	0%	75%	25%
Other	0%	0%	0%	50%	50%
No	0%	0%	15%	20%	66%

## Questions #4 and #6 – Previous knowledge and concerns

This contingency table (Table 4) reveals that 83% of the people surveyed who have never had prior knowledge of living walls also had no concerns. It also shows that most of those respondents who had concerns with insects, allergies, maintenance and other issues had no prior knowledge of living walls. The only concern found to be higher among those who had prior knowledge of living walls was smell. These respondents may have had prior contact with a living wall where they noticed the difference in odor upon entering an area with the living wall. From first-hand experience gained from visiting the Canada Life Building in Toronto, we could understand that some people might not prefer the “outdoors” smell around a living wall, even though others might find it refreshing.

*Table 4. Contingency of questions 6 and 4*

	Yes	No
Insects	0%	100%
Allergies	30%	70%
Smell	100%	0%
Maintenance	22%	78%
Use of Space	50%	50%
Cost	50%	50%
Other	0%	100%
No	17%	83%

## 13.0 INTERVIEW ANALYSIS

The following is a summary analysis of the five key informant interviews which were conducted for this study. For the complete interviews, please see the appendices.

The internal validity of these interviews is reasonably high because the respondents provided direct answers to the research questions which were posed. However, the internal validity may have been reduced because we chose which respondents to interview, allowing bias to enter the research. As well, their responses may have been affected by the way in which the questions were framed, along with a desire for the respondents to “please” the surveyors with positive answers.

The external validity of these interviews is high because of the general nature of the questions that were asked, but it varies based on the particular respondent. General information on living walls provided by Jeff Mallany and Alan Darlington can be generalized to any living wall installed in any building. Information provided by Ian Fraser and Crystal Legacy can be generalized to most buildings on campus, and information provided by Ann Simpson is mainly specific to a living wall installed in the SLC.

### ***Overall Opinion on having a living wall in the UW SLC***

All interview respondents thought that building a living wall in the SLC would be very worthwhile, and that it would make a positive overall contribution.

### ***Benefits of having a living wall***

#### *Air Quality*

Jeff Mallany discussed the ability of living walls to remove over 300 contaminants at low concentrations. Formaldehyde levels can be reduced by 80%, though chlorinated compounds and halogenated materials are not removed as effectively. Alan Darlington commented that living walls act as humidifiers during the winter.

The SLC Manager felt that the air quality in the SLC was not that good, particularly in the “old” side of the building which gets very dusty and dry in the winter. Ian Fraser thought that the SLC already had good air quality. He did think that a living wall would help in removing food odours.

#### *Cost Savings*

Alan Darlington discussed the utility savings derived from not having to bring in outside air that must be warmed up or cooled down to room temperature. He commented that 40% of a building’s utility costs are for ventilation. Based on utility savings, a living wall

would pay for itself in about 10 years if sunlight provides 50% of the light. Once this technology is perfected the payback may be under 5 years. By improving worker productivity, a living wall could pay for itself in 2 years. Jeff Mallany commented that Canada Life Insurance Company have made back their construction costs five fold through the public relations and advertising benefits of their living wall.

### *Aesthetics/Psychological*

Ian Fraser felt the boost to the SLC aesthetics made the wall worth having. Crystal Legacy said that the wall would look amazing if constructed. Alan Darlington noted that people like to be in rooms with plants, and Jeff Mallany commented that employees of Canada Life often came down to eat lunch in the Environmental Room. Alan Darlington discussed the benefits of greening spaces on worker productivity, citing several studies.

### *Education*

The Environmental Commissioner had never heard of a living wall before, but Ian Fraser had prior knowledge of the Canada Life Wall. This reveals that a living wall is still new and somewhat unknown technology, and thus has educational benefits.

Ian Fraser believed the living wall would be great for student research. Alan Darlington expanded on this by explaining that through a living wall, people can be thought about photosynthesis, nutrients and ecology all in one location.

### *Reputation*

Ian Fraser thought that a living wall would provide a boost to the university's public relations. The Environmental Commissioner noted that a living wall was an innovative idea that would attract the eye of decision-makers. Alan Darlington listed a number of other schools that currently have living walls in the planning stage: Seneca College (10 square meter biofilter), Queens University (30-50 square meter biofilter), Guelph Humber (200 square meter biofilter), and Durham College (125 square meter biofilter). For reference, the Canada Life wall is 10 square meters (Biofilter wall only). The fact that all

of these comparable schools are looking into building their own living walls is proof of the reputation benefits they can provide.

### ***Concerns with having a living wall***

#### *Economic Costs*

Jeff Mallany stated that the cost of a biofilter is \$2.00 per square foot, and that one square meter of biofilter would be needed for every 100 meters of floor space. The cost of the Canada Life Living Wall was about \$180 per square foot, which includes one air change through the wall per hour.

Alan Darlington said the cost of a living wall depends on its size. Costs can be reduced by using a modular system such as the one Air Quality Solutions has developed (6 x 2 ½ feet modules with separate troughs). These can be easily incorporated into a building while giving the illusion that the wall was custom built.

Alan Darlington mentioned that even with a living wall, outside air still needs to be brought into a building in order to keep carbon dioxide levels down and oxygen levels up. In order to supply enough oxygen, 10 square meters of plants would be required per person, which is impractical. Thus ventilation utility costs can never be fully eliminated even with a living wall. Also, air leaving a biofilter might be close to 100% humidity, and dehumidifying this air also costs money.

Crystal Legacy commented that a living wall would need to be “sold” to decision makers in order to gain approval. Jeff Mallany likewise noted that a few employees of Canada Life have resented the cost involved in building their living wall.

#### *Maintenance*

Ian Fraser was concerned with maintenance, especially the need to find someone on campus to oversee and look after the wall. He suggested plant operations or the person who looks after the biology greenhouse. Ian felt that volunteers could handle the physical

maintenance components. Crystal Legacy noted that many people may consider a living wall to be more of a hassle than it is worth. Ann Simpson also felt that maintenance was a concern, but she brought up the idea that the UWSP Landscaping group would very likely agree to maintain the wall. This would ensure maintenance would be done even during university holidays.

Alan Darlington stated that maintenance was not much of a problem. He estimated that 70% of maintenance was basic horticultural maintenance and the other 30% was standard mechanical upkeep that most building mechanics could handle. Alan commented that 20 square meters could be done by one person every 3-4 hours. Jeff Mallany estimated that about 3 hours per week of maintenance is spent on the Canada Life Living Wall, and that this number would be much lower without the fish (as low as 5 hours per month). Jeff also noted that there is a 10% plant turnover per year, and that the main systems breakdowns relate to failure of the water pump. According to Alan, backup mechanical systems could be incorporated to deal with this.

### *Insects*

A concern with insects was raised by Crystal Legacy. Alan Darlington and Jeff Mallany both noted that no pesticides are needed for the Canada Life Living Wall and that natural predators are relied on to control pests (though mild soap is occasionally used to control outbreaks). They found that most insects actually stay close to the wall where the food is located, except for fruit flies.

### *Moisture/Humidity*

The Environmental Commissioner raised the concern of excess moisture. Ian Fraser believed some might worry that humidity would cause problems with the lights, but because the SLC is so large that this would not in fact be a major problem. Alan Darlington noted that any excess humidity can be removed if a living wall is tied into a building's HVAC system, and that moisture is not a threat to nearby computers.

### *Bacteria/Moulds/Spores/Allergies*

Ian Fraser felt that people's fear of indoor mould growth would present a problem, even though it is not a problem in reality. Likewise, he thought that fear of allergies would be an obstacle, though in actuality it would also not be an issue because normal allergens outdoors would be worse. Alan Darlington and Jeff Mallany said the notion that plants can lower air quality by producing spores, fungus or Legionnaire's disease is a myth that they have disproven through research. Nevertheless, Alan noted that the idea of bacteria in a room scares some people. Jeff also said that some people may still be turned off by the somewhat musky, outdoor smell around a living wall.

### *Space*

Crystal Legacy was concerned about the space a living wall might take up in the SLC, possibly causing congestion in a hallway.

### *Vandalism*

Ann Simpson noted that vandalism would be a concern.

### *General Resistance to Something "New"*

The SLC Manager believed that some people's traditional perceptions would need to be changed for them to agree to accept a living wall. Helping them to visualize the wall would help in this endeavour. Ian Fraser agreed that the biggest challenge would be public relations.

### *Preferred Location for a living wall in the SLC*

Jeff Mallany recommended that the wall be located near windows to provide natural radiation because this is more efficient than artificial lights, making a living wall more cost effective. However, household plants (which are typically used in living walls) would be tolerant of low light conditions, so fully artificial light would be acceptable.

Ann Simpson believed that the wall should be kept out of the line of heavy traffic, but in a public location for the benefit of more people. She recommended that a living wall should be placed on the 2<sup>nd</sup> level of the SLC in front of the large windows, or in the new reading room on the 3<sup>rd</sup> floor. Or, it could be a 3 storey structure all along the windows. Ian Fraser agreed that the atrium would be ideal because of the light levels and the capacity of the wall to eliminate food smells from Brubakers. The Environmental Commissioner felt that the best location would be in the multi-purpose room.

### ***Preferred Type, Components and Scale of a living wall***

Alan Darlington stated that a living wall with a biofilter is much better than one without one because biofilters greatly enhance the wall's ability to improve air quality. Without a biofilter, a living wall serves purely an aesthetic function. He noted that the larger the size of the living wall, the more effective it would be at filtering the air. A living wall could be constructed as a free-standing unit in a building (but this wouldn't work as efficiently because the unit wastes time purifying the same air), or it could be linked into the building's duct system to distribute the purified air throughout the building. Alan Darlington noted that a biofilter could run without plants but at reduced efficiency. Native plants would be acceptable to use but they only live about half as long as tropical ones. Larger organisms such as fish and frogs would provide an aesthetic benefit but would serve no other function and require extra maintenance, so they were not recommended.

Crystal Legacy recommended starting off small so as not to initially scare people off. Ann Simpson said the size would depend on the cost.

### ***Funding***

The SLC Manager said the SLC Board could provide funding ranging from \$100 to \$20,000 if the wall appeared to be beneficial. Another option would be the Student Life Endowment Fund through FEDS, or the Health and Safety Committee if it could be proven that there were health benefits to having a wall.

As well, Ann suggested that funding could come from corporate partners and local environmental groups, and that the biology department could donate plants.

Table 5 summarizes the benefits which interview respondents felt would be derived from having a living wall in the SLC.

Table 5 Possible Benefits	Respondents				
	Environmental Commissioner	SLC Manager	Health & Safety	Jeff Mallany	Alan Darlington
Air Quality	No	Yes	No	Yes	Yes
Cost Savings	No	No	No	Yes	Yes
Aesthetics	Yes	No	Yes	Yes	Yes
Education	No	No	Yes	Somewhat	Yes
Reputation	Yes	No	Yes	Yes	Somewhat

Table 5: Benefits from respondents

Table 6 summarizes the concerns of interview respondents to having a living wall in the SLC.

Table 6 Possible Concerns	Respondents				
	Environmental Commissioner	SLC Manager	Health & Safety	Jeff Mallany	Alan Darlington
Econ. Cost	Somewhat	Somewhat	Somewhat	Somewhat	Somewhat
Maintenance	Yes	Yes	Yes	No	No
Insects	Yes	No	No	No	No
Moisture	Yes	No	Somewhat	No	No
Spores/Mould	No	No	Somewhat	No	No
Space	Yes	No	No	No	No
Vandalism	No	Yes	No	No	No
P. Relations	Yes	No	Yes	No	No

Table 6: Concerns from respondents

## 14.0 CASE STUDIES

To form a complete research strategy using triangulation, we chose to apply an inductive case study approach as one method of research. This involved using individual case studies in context, trying to understand each situation in its own terms, and connecting these concepts to a grand theory (Palys, 1997, p.19). The goal of these case studies is to attempt to understand the functionality of living walls with respect to improving air quality as the main beneficiary for implementation. We chose this topic, as it was a common theme that emerged during preliminary literature reviews, and through data collection with questionnaire responses. In addition, indoor air quality is a well-documented subject matter. However, improved aesthetics, education, economic, reputation, and psychological benefits will also be addressed. Multiple qualitative case-study analysis is useful in that a consideration of how the cases are similar or different from one another may help attune us to useful explanatory concepts (Palys, 1997, p.300). The study of the relationships among these themes within outside case studies and relating them to our study is called nomothetic analysis (Palys, 1997, p.420). By analyzing functioning living walls, we became better informed of their ability to improve indoor air quality, and thus we were able to make appropriate recommendations for implementing a similar project in the Student Life Center. The three case studies we looked at in our research include the Canada Life Environmental Room (CLER), The Northern Center for Advanced Technology (NORCAT), and Niagara Under Glass. All three walls were constructed and monitored by Professor Alan Darlington and colleagues from the University of Guelph, Ontario. Most of the information researched was specific to the CLER living wall, however the other examples confirm the results from this study. The information for these case studies came from academic journal articles written by Alan Darlington and colleagues. A final example of psychological benefits from greening indoor spaces will be discussed using information from the *Journal of Environmental Psychology*, and from a study conducted by Oxford Brooks University.

*Canada Life Center Environmental Room (CLER)*



**Figure 2.0 (left) and 2.1(right) Canada Life Environmental Room (CLER)  
(Air Quality Solutions, 2002)**

The Environmental Room pictured above is located in the Canada Life Building in Toronto, Ontario. The system is designed to remove Volatile Organic Compounds from the indoor environment, reducing the need to constantly replenish the space with new outside air while simultaneously decreasing the energy consumption of the building. The wall has been extensively monitored and from these studies, numerous results have been documented. As a part of this case study, the structure, function, and effectiveness of the CLER living wall will be discussed to provide an example of what a living wall is comprised of, how it operates, and the benefits of having a wall this size. Further case studies will be used to reinforce the findings from this study.

*Structure of the wall*

Unless otherwise noted, the following information is summarized from the University of Guelph website, containing information written by Professor Alan Darlington and colleagues, accessed October 2002. For further information please see [www.ces.uoguelph.ca/research/envweb](http://www.ces.uoguelph.ca/research/envweb)

The Canada Life Environmental Room (CLER) is 150 square meters in area and has a 4000 litre aquatic system. The wall is a hybridization between a typical indoor landscaped space and an industrial biofilter. The biofilter is 10 square meters (Mallany, pers com, October 16, 2002), and has three main sections which can be considered unique ecosystems with their own variable conditions, flora, and fauna. The three sections include:

- 1) The terrestrial hydroponic area. This section contains a heterogeneous assortment of green plants such as orchids, mosses, and ivy.
- 2) The aquatic system that serves the needs of the plants both above and below the water line. This system also aids in the dispersal of contaminants to the roots of the plants.
- 3) The scrubber (breathing wall) composed of five fibreglass panels with surfaces of porous lava rock and moss.

The panels are covered with moss, and are continuously moistened by re-circulating water. Air is drawn through the scrubber and the adjacent hydroponic region by an air handling system including a fan with variable speeds, which helps control the atmosphere in the room. Once the air is drawn through the scrubber, it flows into the general ventilation system, the HVAC (heating, ventilation, and air conditioning) system, and then through the air duct system and back into the room. In addition, the environmental room has a lighting system designed to simulate day and night conditions for the plants when the room is not being used.

The plants for this wall were selected for their ability to adapt and survive in the moderate temperature, humidity, and light conditions typically found in indoor environments. Although there are no endangered species present, the majority of the plants are native to tropical ecosystems. Local plants were not used extensively as the indoor climate would have to mimic seasons to ensure their survival. It was thought that this would make routine use of the Environmental Room difficult, creating irregular conditions for monitoring and research. The diversity of the wall is large as there are hundreds of species of plants which make the room ecologically stable and able to handle a broad range of introduced variables such as pests. It should be noted that pesticides are

rarely used, and pest regulation is achieved through biological controls such as the introduction of predators.

### *Function of the CLER Living Wall*

Unless otherwise noted, the following information is summarized from the professional journal article entitled *The Biofiltration of Indoor Air: Air Flux and Temperature Influences the Removal of Toluene, Ethyl Benzene and Xylene* written by professor Alan Darlington and colleagues. References for this source will include page numbers in the following body of text. For more information, please see bibliography.

Studies from the CLER living wall show that biofiltration can remove Volatile Organic Compounds typical of indoor environments (p. 245). More specifically, it was shown that a biofilter with living botanical matter as the packing medium reduced concentrations of Toluene, Ethyl Benzene, Xylene, and Formaldehyde, currently present in parts per billion in indoor air (p. 240). The studies noted that although concentrations of VOC's typically found in the indoors are very low by industrial biofiltration standards, the fact that North Americans spend in excess of 85% of their time indoors makes these exposure levels an important public health concern (p. 240).

The processes of varying air flux and temperature was used to determine the conditions, which enable the maximum removal of VOC's per time unit, and the influent water temperature was used to regulate the temperature of the biofilter. The Ability of the biofilter to degrade VOC's was found to be dependent on two factors each influenced by temperature (p. 243):

- 1) The absorption of the VOC's into the water from the air and
- 2) The rate at which the microbes can degrade the material

One concern was that biofilters containing plants can actually lower IAQ by releasing spores and other VOC's generated by plant biomass. It is true that green plants such as mosses, are known to create a number of volatile and semi volatile compounds as a part of their natural metabolism (p. 245). With respect to the CLER living wall, along with reduced levels of VOCs and Formaldehyde relative to other rooms in the building, higher

level of aerial spores were found to be present in the Environmental Room. However, Darlington notes that this was well within the limits of what is necessary for high air quality and it was concluded that the large concentrations of biomass in an enclosed area does not have the effect of lowering air quality as some would assume (p. 245).

In addition to improved air quality, the CLER living wall serves an educational purpose. The wall is used for various special interest groups including high school biology and environmental classes, university research, co-op work related projects, and to enhance corporate public image output through environmental education.

### *Effectiveness of the Wall*

Unless otherwise noted, the following information is summarized from the University of Guelph website, containing information written by Professor Alan Darlington and colleagues, accessed October 2002. For further information please see [www.ces.uoguelph.ca/research/envweb](http://www.ces.uoguelph.ca/research/envweb).

When relying almost entirely on biofiltration, the air quality of the Environmental Room was found to equivalent to, or superior than the rest of building which relies on a sophisticated ventilation system that replaces the building air up to 6 times per hour. Final results showed that the filter removed significant amounts of all VOC's, but that these rates were dependent on the individual contaminant. More specifically, Toluene and Formaldehyde were removed effectively, whereas Trichloroethylene (TCE) was not removed with the same efficiency. For example, a single pass of air removed 80% of the formaldehyde, 50% of the toluene and 10% of the TCE. In addition to capturing these compounds, the filter also degraded them into their benign constituents, eliminating the disposal problems associated with other VOC filters and saving the building management significant costs. Traditional filters are composed of Carbon. At the end of their life cycle they are considered hazardous waste and thus disposal methods incur unsustainable environmental and economic consequences.

In terms of cost benefit analysis, Darlington states that the investment towards implementing a living wall is returned in reduced absenteeism, increased productivity,

and decreased utility bills over a two to five year time frame (Darlington, pers com, November 25, 2002).

*Northern Center for Advanced Technology (NORCAT)*



**Figure 2.2 and 2.3 NORCAT Living Wall, 2000.**

Unless otherwise noted, the following information was summarized from the professional journal article entitled *The Biofiltration of Indoor Air II: Microbial Loading of the Indoor Space*) written by Professor Alan Darlington and Colleagues, and will be referenced using page numbers. Additional information was summarized from the NORCAT website, accessed October 2002 at [www.norcat.org](http://www.norcat.org). For further information, please refer to the bibliography.

The living wall module pictured in figure 2.2 and figure 2.3 is located in the inner lobby of the Northern Center for Advanced Technology in Sudbury, Ontario. This living wall was implemented due to the concern for poor indoor air quality. It was thought that this technology might prove valuable especially in Northern Canada where buildings are sealed to increase energy efficiency. The biomass consists of all native Northern Ontario species that were collected from the Sudbury region, and then installed directly into the model. These plants were salvaged from areas of future development (Darlington, pers com,

November 25, 2002), and include species such as bog laurel, blueberries, cranberries, bunchberries, spruce, cedar, poplar, sphagnum, club moss and grass. Over the course of the first winter, the plants acclimatized and are now thriving in their new environment. This model is not as successful at the CLER living wall, as the plants have a higher turn over rate correlated with conditions not suited to seasonal cycles (Darlington, pers com November 25, 2002).

The biofilter within this model has undergone several air quality tests, has been refined, and adjusted by researchers. The project has since moved on to study the ability of the biomass to filter out organic compounds, such as Toluene, Methyl Ethyl Ketone (MEK) and Trichloroethylene (TCE), from the ambient air of the NORCAT building. As such, the living wall at the Northern Center for Advanced Technology provides the same function as the living wall the Canada Life Center. Although this wall has a different design, it serves the same purpose, and studies have shown that it effectively improves indoor air quality (P. 5). The wall was analyzed with respect to its contribution of fungal or bacterial concentrations to indoor air. A conclusion was reached that there was no increase detected in fungal spores or bacteria concentrations. It was determined that any increase in bacterial concentrations was due to the misting system that kept the plants moist (P. 5). However, by modifying irrigation and maintenance schedules, bacterial and fungal concentrations were reduced (P. 5). It was finally concluded that the use of plant biomass does not lower indoor air quality because it doesn't produce significant amounts of bacterial or fungal spores (P. 5).

### *Niagara Under Glass*



**Figure 2.4 (left) and 2.5 (right) Niagara Under Glass, Vineland, Ontario (Darlington, 2002)**

Unless otherwise noted, the following information is summarized from the Niagara Under Glass website, accessed October 2002. For further information please see [www.niagaraunderglass.org](http://www.niagaraunderglass.org)

The images above are pictures of the biofilter that was constructed for Niagara Under Glass by Clean Air Solutions. In addition to this biofilter, Niagara Under Glass also has a living wall without a biofilter, that functions to remove humidity from the air in their greenhouse. The aim of Niagara Under Glass is to let visitors discover the science of growing plants and the relationship between plants and our environment which includes the indoors. Visitors experience an interactive approach to the science of producing plants in an atmosphere of education and entertainment. Niagara Under Glass and its adjoining Discovery Center, is an example of an agri-tourism initiative that has become a showcase for the greenhouse industry. This biofilter is being used by the University of Guelph in relation to the use of plants in space exploration, as a version of this technology is being tested on the International Space Station. The research conducted on this module has produced similar results to other installations from Air Quality Solutions. It is

effective in greening indoor spaces, improving indoor air quality, and in this case, it serves as a unique environmental education tool for the public. The main difference between this wall and those operating at CLER and NORCAT, is its freestanding design, and internal monitoring room (Figure 2.4). This design is easily outfitted into any building, requiring little existing infrastructure.

### *Psychological Case Studies*

Aside from filtration benefits of a living wall, there are psychological benefits associated with natural spaces in workplaces. Interior planting has become increasingly popular in the working environment, and its presence is believed to have physiological benefits (Oxford University, 1999, p.5). Research conducted by Oxford Brookes University suggests that perception of interior planting plays a role in human psychological well-being (1999, p. 6). Green interiors are seen as pleasant compared to those that have not been greened. The study found that buildings with green interiors were perceived as more relaxed than buildings without, which in turn lowers stress and anxiety. The areas were regarded as more welcoming, which is important in areas of high congregation (such as the SLC). Furthermore, green areas were perceived to be more expensive-looking which in many cases, enhanced the feeling of well-being. (Oxford University, 1999, p..5).

Similarly, a study published in the Journal of Environmental Psychology found that the aesthetic quality of a room influenced people's moods. The participants of this study were more energetic and had an overall greater feeling of well-being (Shibata and Suzuki, 2002. p.265).

### *Validity of Case Studies*

Case studies can be analyzed with respect to external validity, which is the generalizability of results beyond the specifics of the study (Palys, 1997, p.414). For example, the compare and contrast nature of the four examples used confirms external validity, as the results from each study are similar. External validity can then be extended to suggest that the improved air quality generated from the use of a living wall in the CLER, at NORCAT, and at Niagara Under Glass, will also be a benefit for other

institutions who chose to implement a living wall.

The bulk of the literature review is covered in the case study and introduction sections of this report. In order to eliminate redundancy we have included a brief summary of the most important literature reviews in the following section. Again, the most relevant data extracted from each of the different sources has been profusely examined in other areas of the report.

#### *Journal Articles and Professional Documents*

#### **American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc (Ashrae Standard)**

##### Ventilation for Acceptable Indoor Air Quality, 1999

This standard's purpose is to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects.

#### **Darlington, Alan, Michael Dixon, and Jeff Mallany.**

##### The Biofiltration of Indoor Air II. Microbial Loading of the Indoor Space 2001

Talks about the impact of indoor air biofilters on selected airborne spore concentrations.

#### **Darlington, Alan and Michael Dixon.**

##### Acclimation and Nutrition of Indoor Air Biofilters. Proceedings: Indoor Air, 2002.

Discusses the removal of toluene and methylethlyketone (MEK) present in parts per billion (by volume) concentrations from indoor space. Compares two species of living moss and a coconut fibre as packing material, as well as the response of biofilters to these materials.

#### **Darlington, Alan, James Dat, and Michael Dixon.**

##### The Biofiltration of Indoor Air: Air Flux and Temperature Influences the Removal of Toluene, Ethlybenzene, and Xylene.

Environmental Science and Technology, 2001. 35, 240-246.

Presents information from the study of indoor air biofilters including the reduction of toluene, ethylbenzene and o-xylene. Also discusses the proper conditions associated with the most efficient removal of such indoor air chemicals.

**Darlington, A., M Chan, D Malloch, C. Pilger, and M.A. Dixon.**

The Biofiltration of Indoor Air: Implication for Air Quality. Indoor Air 2000. 10: 39-46

A discussion of the alternative methods of maintaining indoor air quality. Includes the efforts made to determine whether indoor air biofilters and biomass into indoor space can have a negative impact on indoor air quality.

**Llewellyn, David. Alan Darlington, Michale Dixon and Jeff Mallany.**

The Biofiltration of Indoor Air I: A Novel Reactor for a Novel Waste Gas Stream.2000/2001

A discussion of biofiltration as a means for maintaining indoor air quality (IAQ). Also deals with volatile organic compounds (VOCs), including the benefits of such alternatives in the areas of health, and economic costs. Confers various prototypes and the nature of the materials used.

**Oxford Brookes University.**

Green Plants for the Feel Good Factor. 1999

[www.interiorscape.com/rentokil/](http://www.interiorscape.com/rentokil/)

This paper sets out to establish why people need or want to have interior planting in the present-day buildings and to determine the possible psychological benefits to people of plants inside buildings. Findings were that using plants in indoor space benefits humans in their mood, productivity and anxiety.

**Shibata. Seiji, Suzuki. Naoto.**

Journal of Environmental Psychology Effects of the Foliage Plant on Task Performance and Mood Volume 22. 2002 Elsevier Science pg. 265-272

This study investigates the effect of leafy plants on the subjects task performance and mood. The subjects were subjected to both association task and sorting tasks. It concluded that the presence of the plants affected the association task more than the sorting task, and male subjects more than female subjects. It was also suggested that the presence that the presence of the leafy plants might affect creative work positively.

**Valvasori, Joe**

The Living Wall: Urban Biofiltration E-Magazine. Volume X, Number1. (January-February)

[www.emagazine.com/januaryfebruary\\_1999/0199inbrief.html](http://www.emagazine.com/januaryfebruary_1999/0199inbrief.html)

This article found in e-magazine talks about the efforts of various Toronto-based companies to incorporate eco-engineering into office buildings. It touches upon the various applications for living walls, and the general impacts associated with employee contentment and productivity. It also discusses some of the various companies spearheading the eco-engineering industry.

*Books*

**Palys, Ted.**

Research Decisions. Quantitative and Qualitative Perspectives  
Second Edition. Simon Fraser University. Harcourt Canada Ltd. Toronto 1997

A comprehensive guide that delves into the many aspects of qualitative and quantitative research methods and the associated protocols for conducting valid and reliable research, and data analysis.

**Neuman, W, Lawrence.**

Social Research Methods. Qualitative and Quantitative Approaches.  
Fourth Edition. University of Wisconsin at Whitewater.  
A Pearson Education Company. 2000

A guide to social science research in the realm of qualitative and quantitative data acquisition and analysis. Discusses various methods for conducting research and the associated benefits and constraints of each.

### *Educational CD*

#### **Air- According to Nature's Intentions.**

##### Air Quality Solutions Ltd. Natureaire Systems October 2002

Prepared by Alan Darlington, Professor at the University of Guelph, this CD contains information on the company, Air Quality Solutions. Includes pictures of living wall installations, data from living wall studies, background scientific papers, and information slideshows.

### *Websites*

#### <http://www.cape.canterbury.ac.nz/Archive/eco/canadalife.html>

An article found on the University of Canterbury, New Zealand, this site talks about the innovative approach of the Canada Life Building in Toronto to revitalize the office environment by improving air quality and aesthetics through the use of a breathing wall. It also talks about the problems with indoor air quality including sick building syndrome.

#### <http://www.ces.uoguelph.ca/research/envweb/>

This detailed site belongs to the University of Guelph, Ontario. It outlines living walls including background information and in-depth analysis of the functionality of living walls. It uses the Canada Life Building breathing wall as an example of how this new technology can be implemented effectively.

#### [www.livingmachines.com](http://www.livingmachines.com)

A site for the company, Living Machines, Inc. This website talks about living machines as an ecologically engineered machine designed to treat wastewater and air through an interactive and cost-effective natural process. It also includes information on the discussion of education in ecology and sustainability for

businesses and community initiatives. Finally, it compares for clients worldwide, how living machines have been placed into the equation of day-to-day business decisions.

## **15.0 CONCLUSIONS**

Through the case studies, questionnaires and interviews, and by utilizing these three components for triangulation, various conclusions have been made regarding the feasibility of implementing a living wall in the SLC.

There are many benefits derived from the implementation of a living wall with a biofilter. It has been found to be a more sustainable option in dealing with indoor air quality than a traditional ventilation system, as the removal and disposal of hazardous waste is eliminated through a completely natural method. Improved indoor air quality is achieved, along with economic advantages related to savings on utility costs, as well as reduced absenteeism and increased productivity. More so, psychological benefits in the form of stress relief can also be attributed to living walls. Aesthetically, a living wall is extremely pleasing and its benefits are enjoyed not only by the students and staff of the University, but also the academic and Waterloo community. Another advantage of a living wall is the reputation benefits it can bring to the University of Waterloo as an innovator and leader in the way of green building design and technology, and sustainable campuses. Lastly, a living wall can serve as an impressive educational tool. Not only will it fulfill the mandate of WATgreen, to educate others in sustainability concerns, but it will also contribute to academic research. Staff and students from various faculties on campus, including Environmental Studies, Science, Engineering, and even Arts, can conduct research on and with living walls. Examples of promising topics include, but are not limited to ecosystems, plant cycles, air quality, green building design and technology, and the psychological benefits of plants.

Although a considerable number of benefits have been identified, certain concerns regarding living walls also exist. Many of these issues have been resolved in the following recommendations section. Below is a synthesis of the prominent concerns. Maintenance is an issue - not pertaining to the nature of the maintenance, but primarily to the time commitment. Cost has also been established as a barrier to the implementation,

largely due to high start-up costs. To a much lesser extent, the concern of insects, allergies and smell and excess humidity have been raised. However, through triangulation, and in particular the case study analysis, these concerns are easily mitigated, and in some instances, not applicable. Lastly, vandalism and littering have been identified as possible concerns, along with suggestions for educational campaigns to curb such behaviour.

In conclusion, this study has found that the benefits derived from the implementation of a living wall in the SLC largely outweigh the limited and manageable concerns. This conclusion is strongly based on the triangulation method of research conducted through questionnaires, interviews, case studies and literature reviews. Based on our conclusions, numerous options for recommendations found in the following section have been provided, in the hope that the possibility of implementing a living wall could one day prove realistic.

## **16.0 RECOMMENDATIONS**

Based on our extensive research and conclusions, specific recommendations related to the implementation process of a living wall in the SLC are outlined below.

### **Recommendations Relating to Key Decisions and Concerns**

#### **Scope**

Improving indoor air quality is the main function of a living wall. For this reason, as indicated through our report, a living wall comprised of a biofilter is preferred over a living wall without a biofilter due to the increased air filtration capacity. Therefore, the benefits of improved indoor air quality are directly proportional to the size of a living wall, thus a large scale model is recommended. Additionally, larger scale living walls can derive more economic benefits, as reliance on traditional indoor air filters can be minimized according to the size and impact of a living wall. In terms of psychological, aesthetic and reputation benefits, the more extensive the living wall, the greater the benefits. In the case of education gains, scope does not appear to be an issue. It is therefore our recommendation that a larger scale living wall be implemented.

However, since costs will have a large bearing on the decision of scope, an additional recommendation is provided. Darlington has indicated a new development in the manufacturing and structure of living walls. Modular biofilters are being considered to allow for flexibility in scope as well as associated costs. Although limited information was available at the time of the study, it has been learned that the option exists for purchasing and implementing a single biofilter, leaving an option to affix other modules in the future. Our recommendation is that further research be conducted to determine benefits and drawbacks of this implementation method. Please refer to the section on costs and funding for further suggestions relating to scope.

### **Location**

Research has led to several recommendations for the exact location of a living wall. First and foremost, our study has determined the Great Hall as the prime location, due to many factors. A living wall in the SLC's Great Hall would ameliorate the current poor air quality, benefit the most number of people (as per our questionnaire results), and substantially improve the unappealing aesthetics (as per our questionnaire results). The Great Hall also contains ample room for installation. Due to the psychological benefits, a living wall in this location would complement many activities. This includes students studying or convening, employees working on a daily basis, and visitors wishing to get a glimpse of the University of Waterloo's student life.

However, due to the lack of natural light, the Great Hall would limit the economical benefits to be had from a living wall. From a cost savings perspective, the Atrium section of the SLC is also recommended, as it contains large windows, thus reducing the costs of artificial light. The Atrium, much like the Great Hall is also frequented by large numbers of people, although the nature of activities conducted in this section are limited mostly to eating.

The nature of living walls is such that there is an element of flexibility in terms of location. We have recommended two locations, the Great Hall and the Atrium, based primarily on opinions of students and experts, and to a lesser extent case studies and literature reviews. Another factor in determining the location of a living wall is whether the proposed location allows for easy integration with the existing HVAC system. This is

essential because 1) if a connection to the system is not available, additional costs would be associated with integration, 2) a freestanding wall without a connection to the HVAC system would undermine the ability of the system to circulate indoor air. Further study should be conducted concerning the ideal location in terms of specific requirements, as this was outside the scope and time of our study.

## **Maintenance**

In response to the main concern of a living wall, we recommend various options in terms of maintenance. Firstly, it must be stated that according to Darlington, maintenance of a 20 m<sup>2</sup> living wall can be done by one person in one hour every 3-4 weeks. The type of maintenance required is not complex and can be completed by an individual with basic gardening knowledge. In terms of the technical maintenance, this too can be fulfilled by the average maintenance personnel of any building. It is for this reason that the type of maintenance is not a concern. However, the commitment for maintenance has been found to be an area in need of investigation. Our recommendation is to encourage an agreement with the University of Waterloo Sustainability Project, in particular their affiliated Landscaping Group, to commit to the maintenance of the plants. In addition, the UW Grounds Department / Plant Operations should be approached to determine the feasibility of pledging their support. Due to the limited time required to sustain a living wall, this is not foreseen to be a problem. If there are other possibilities within the school community, these should be pursued. As well, contracting out the maintenance remains an option, albeit the least recommended one due to increased costs.

## **Costs and Funding**

Without specifics in terms of exact location and scope, it is difficult to assess the costs of a proposed living wall. Nevertheless, using some general estimates from Darlington, a preliminary budget has been organized. Two scopes are presented as options for a living wall: a large scale biofilter approximately 200m<sup>2</sup> being proposed for the University of Guelph at Humber, as well as a smaller 10m<sup>2</sup> biofilter on the same scale as the CLER Living Wall in Toronto. The following dollar figures were calculated using rough estimates from professor Darlington. Please see the adjoining budget for more information. Note that due to time constraints, no cost was examined for the modular

type of biofilter, although this could be a strong alternative. Please refer to the section on recommendations for further research for more details.

Some possible funding options to cover the costs for a living wall are suggested. These include the SLC Board, the Federation of Students and the Student Life Endowment Fund. As per Ann Simpson's suggestion, funding can also be pursued from corporations, environmental groups, the University of Waterloo's Health and Safety Committee as well as through fundraising. In addition, many options exist for covering part of the costs through more innovative techniques. One such example is by accepting plant donations from the Biology department. It is our recommendation that each of these venues be pursued.

### **Recommendations for Further Research**

This study has succeeded in determining the feasibility of implementing a living wall in the Student Life Centre. More so, the recommendations outlined above initiate the groundwork for the implementation process. However, due to time constraints and limited scope, not all aspects of the implementation process of a living wall were examined. Instead, we recommend additional research be conducted to this end.

In particular, we have concluded that a more extensive economic feasibility study be performed that would, in turn, better determine the feasibility for a particular location. Scope would also be a factor that could be evaluated by a more extensive assessment of the aforementioned factors.

## 17.0) SAMPLE BUDGET

Estimated Base Price: \$1500 / m<sup>2</sup> of living wall

Price includes:

- Plants
- Growth medium
- Support structure
- Plumbing system parts

Possible extra costs:

- Water pumps (dependent on size of unit)

Other requirements:

- A source of good quality water
- A drain
- For multi-storey units: a structure (floor pad) that we can use to support our system on every 12 feet of vertical distance
- A duct work system behind the wall capable of removing up to 0.2 m<sup>3</sup> /s of air per m<sup>2</sup> of biofilter (40 cfm per ft<sup>2</sup>)

Two Proposed Scales:

### **Proposal A**

Small Scale Wall -- 10m<sup>2</sup>

10m<sup>2</sup> x \$1500 =

TOTAL: \$15,000

### **Proposal B**

Large Scale Wall -- 200m<sup>2</sup>

200m<sup>2</sup> x \$1500\* =

TOTAL: \$300,000



Figure 3.0: Small Scale Biofilter  
(10m<sup>2</sup> biofilter at Canada Life Centre, CLER)



Figure 3.1: Large Scale Biofilter  
(proposed 200m<sup>2</sup> biofilter at the  
University of Guelph at Humber)

\* With complex designs (i.e. multi story units), price can increase to \$2000/ m<sup>2</sup>

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Air Quality Solutions Ltd.

Jeff Mallany, MSc

*Personal Interview. October 16, 2002*

Environmental Safety Facility and Safety Office

Ian Fraser, Safety/Environmental Health Co-ordinator

*Personal Interview. November 20, 2002*

Student Life Centre

Ann Simpson, SLC Board

*Personal Interview. November 25, 2002*

University of Guelph

Alan Darlington, Ph.D. Adjunct Professor

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University of Waterloo, Federation of Students

Chris DiLullo, Minister of Finance Internal

*Personal Interview. October 3, 2002*

University of Waterloo Sustainability Project

Crystal Legacy, Environmental Commissioner

*Personal Interview. November 15, 2002*