Going Green:

Design proposal for vertical planting in the Bioresource Engineering alcove on McGill, Macdonald Campus

Prepared by:
Janette Kwan and Emily McGill
Bioresource Engineering
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Submitted to:
Dr. Grant Clarke
Dept. of Bioresource Engineering
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1.0 Executive Summary

The installation of a living wall in the Bioresource Engineering alcove can be expected to bring many benefits. This includes, based on the literature review of the previously submitted design proposal, minor air quality improvements, psychological improvements and aesthetic improvements, amongst others. This paper presents the final design for the living wall, with the ultimate goal of improved aesthetic appeal in the alcove, taking into account the imperative concerns of safety, low maintenance, and budget limitations.

The presented design consists of two industrial metal shelving units, modified to securely hold 2 rectangular plant pots per shelf. Each of these pots will contain 3 circular pots, each containing their own plant. This configuration allows for easy maintenance of the wall, if any of the plants require replacing. A water reservoir tank will be on the top shelf of both racks, with a specially designed mechanical system to fill the tank and release the water to each plant via drip line. There will be a drip line running through every pot, with the amount of water released being adjustable. This tank will be secured in place to prevent the tank from tipping over.

The shelf as a whole will be bolted to the wall to prevent it from falling over. Wooden planks will be used to enclose the storage cabinets at the bottom of the wall. Rope mesh will be used between the two racks, as well as on the exposed end of the wall, to allow climbing plants to cling to.

A specific LED array design will be installed on the ceiling of the alcove. These panels will be donated, so the specifications of the LEDs are still to be determined. These panels will be set to a timer, whose schedule can be adjusted based on the plants‟ moisture levels.

A computer program will be implemented to record the moisture level of the plants over time, and compare this to the watering and lighting schedule. This will be useful for adjusting the schedules to ensure the plants are receiving the proper amount of watering and lighting. The total amount of water and electricity used by the wall can also be recorded. With two pH sensors in the wall as well, this can be used to further the analysis of the plants‟ health progress.

The data recorded and analyzed by this computer program can be presented in an educational or more interactive manner, by installing a monitor on one of the walls of the alcove. The conceptual model of the program has been presented here, though any further design is the responsibility of the next design group to take on this project.

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1.0 Introduction

1.1 Objectives

This project"s intent is to propose an appropriate design for the creation of a living wall in the alcove of the Bioresource Engineering Department. Ideally this design is implementable within the next 4 months, providing the basis for continuation of study in the fall semester by two incoming Design III students, Katherine Bergeron and Alice Chow.

1.2 Parameters and Constraints

Design necessities which acted as guidelines without limiting the design are the parameters. The primary parameters for this design were aesthetic appeal and educational content – the ability of this project to provide learning opportunities for both those directly involved and those observing.

The constraints on the design are those specifications which acted as limiting factors; these include functionality, safety, low maintenance (i.e. least amount of human intervention to keep the system running), and budget feasibility. As the project progressed the balance of these factors pushed the design towards its final incarnation.

The main role that safety played was that every aspect of the design must take into consideration that the entire installation is within arm"s reach of children, students, and the general public.

Low maintenance entails limiting the reliance the design would have on human hands to keep it functioning. This factor served as the main compromise when considering budget feasibility; as low human maintenance entails a highly computerized regulation system, which increases budget considerably.

1.3 Implications

The implementation of indoor plants to improve indoor air quality and overall well-being of building occupants has been receiving widespread attention.

This is a timely project at McGill as there are two other student groups working on developing larger living wall and bio-wall installations on the downtown campus. By catching the wave and implementing this design on Macdonald Campus this project is keeping pace with the movement towards greener building alternatives at McGill.

2.0 Design Progression

2.1 Overview

2.1.1 Stage 1: BREE 490 Bio-Wall Proposal

This design was quite complicated to design, build, and implement. Safety precautions against tugging or bumping against the wall were not adequately addressed. Since a hydroponic system was used, plant turnover would be much more frequent. The initial stages of wall operation would require a decent amount of tweaking, due to the complexity of the design. Ideally, though, once fully set up, the wall should be fairly self regulating and self sustaining. Taking into account the many components of the design, the budget was very high.

2.1.2 Stage 2: PVC piping shelving unit

This design was proposed for the preliminary report, consisting of single PVC piping based support frame. The reservoir in the bottom would require a submersed pump to supply the drip lines. One major problem noticed soon after presenting the design was that the pots would not be able to be removed with the dense piping configuration. Even though a decent amount of time was placed on this design concept, it had to be discarded.

2.1.3 Stage 3: Reduced PVC piping shelving unit

The design from stage 2 was altered to allow sufficient plant container removal space. Through this improvement, almost half of the piping required was removed. Since the frame was to be made complexity from PVC, though, the multitude of specific joints and gluing required made the construction process quite difficult. Hand-formed steel mesh shelving would be used to hold the plant containers. These were only decently stable in holding the containers back from falling over. Since a pump was still required for the reservoir tank, the budget was still quite high, though already significantly lowered from the design from Stage 1. This pump would also have to be in use for many hours of the week, and the multitude of electrical components made the design quite technically complicated, as well as pricey.

2.1.4 Stage 4: Two pre-fabricated shelving units, suspended reservoir

This design was completed for the final presentation. Since the reservoir tank was elevated, the need for a pump was removed, thus significantly reducing the budget. Many electrical components were removed, since the irrigation system as a whole was essentially mechanical. The pre-fabricated shelves made construction significantly simpler, though this would be slightly more costly if industrial quality and strength. The irrigation design was addressed to be slightly flawed during the presentation, though, and the truly „self-regulating‟ character of this design was questionable.

2.1.5 Stage 5: As above, with altered irrigation and planting system design

This design is much like that of stage 4‟s, except with an irrigation system that tackles the issue with buoyancy balancing out when the tank fills up. This design is ultimately more self-sustaining than it is self-regulating. The safety issue of plants falling over is very well addressed with the restraining wires. The overall minimalistic involvement of electrical components keeps the budget quite low. The plant selection was altered to reflect the heights that the plants are expected to grow to.

2.2 Design Evaluation and Selection

Rated on the following scale:
Aesthetics: ratio of plant foliage/visible structural components. Higher ratio of plant foliage to visible structural components favoured.

Safety: relative assurance of structural strength without physical prototyping

Maintenance: A lower level of human intervention for the system to function properly yields a positive maintenance rating.

Budget: The lower the value relative to the other designs, the higher the budget rating.

Functionality: The chosen design must have all components: structural, planting, be feasible when all design parameters and constraint are taken into consideration.

Technical: Ease of installation – leading to timely installation, i.e. within a reasonable time period to become functioning.

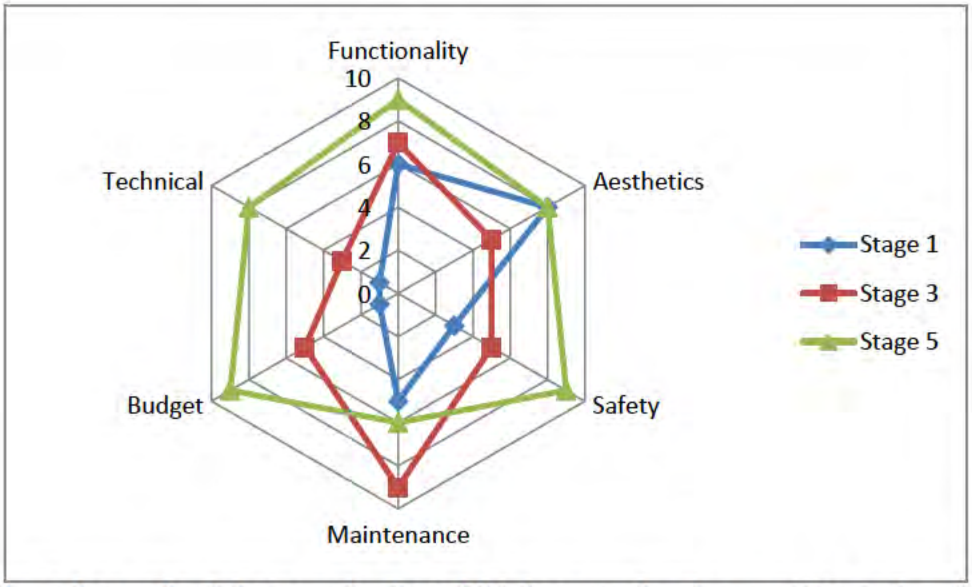

Fig. 1 Spiderweb graph of design selection. A higher number is a positive rating for any of the parameters and constraints listed. Stages 2 and 4 are omitted since they were non-functional designs; functionality being the ultimate limiting factor it is not worthwhile to rate them in other respects. This graph shows how Stage 5 of the design achieves the best balance.

2.3 Terminology

For the duration of this report the following terms will be used:

Reservoir – the container which acts as a reservoir for the irrigation water
Pot – an individual plant pot
Box – a rectangular plant container holding 3 individual pots
Unit – one of the two shelving units, labeled as in Fig. 2

2.4 Support Structure

2.4.1 Ensuring sufficient strength of selected shelving units

Each shelf will have 6 pots weighing ~14g each

Each shelf holds 2 boxes ~32g each

Each pot will be 8" (diameter), 8" deep, 7" full of soil

Assuming the soil is saturated, i.e. density 2000kg/m3

~62L of water will be held in each reservoir tank

A filled 20 gallon (75L) tank weighs around 225lbs (102kg)

Weight per shelf:
$[\ \pi\ (4")^2 \times 7" \times 6 \text{ pots} \times 2000\text{kg/m}^3 \times (0.0254\text{m}/1")^3\ ] + [\ 6 \times 14\text{g/pot}\ ] + [\ 2 \times 32\text{g/pot}\ ]$
= 69.2kg + 84g + 64g
= 70kg

Weight of top shelf with reservoir:

[70kg] + [102kg * 62L/75L]
= 155kg

Carrying capacity of individual shelf:
= 363

Each shelf has a 363kg capacity, both if the shelves are available online from either of two suppliers:

Metro: http://www.metro.com/catalog/commercial/files/cp-catalog-%202011-np.pdf

Leggett & Platt: http://www.rackandshelf.com/WireShelving.aspx

The above calculations show that the expected weights to be held by the shelves are well below the capacities of the shelves themselves.

2.4.2 Final Frame Design

The frame consists of two essentially identical metal shelving units, denoted as A and B in Fig. 2. Each will be a total of 4 feet across, 1.5 feet deep, and 8 feet tall. The 5 shelves containing the plants will each be 14 inches apart from each other. The bottom shelf which is enclosed to store monitoring components and maintenance inventory, will be 1 foot tall. There are 4 inches between the top of this storage compartment and the first shelf to help plants grow uninhibited. If the brand Metro is used for the metal rack, a choice of having the posts and shelves be coated with a special corrosion resistant antimicrobial epoxy is available. Leggett & Platt also offers the required parts at appropriate sizes but without the epoxy option.

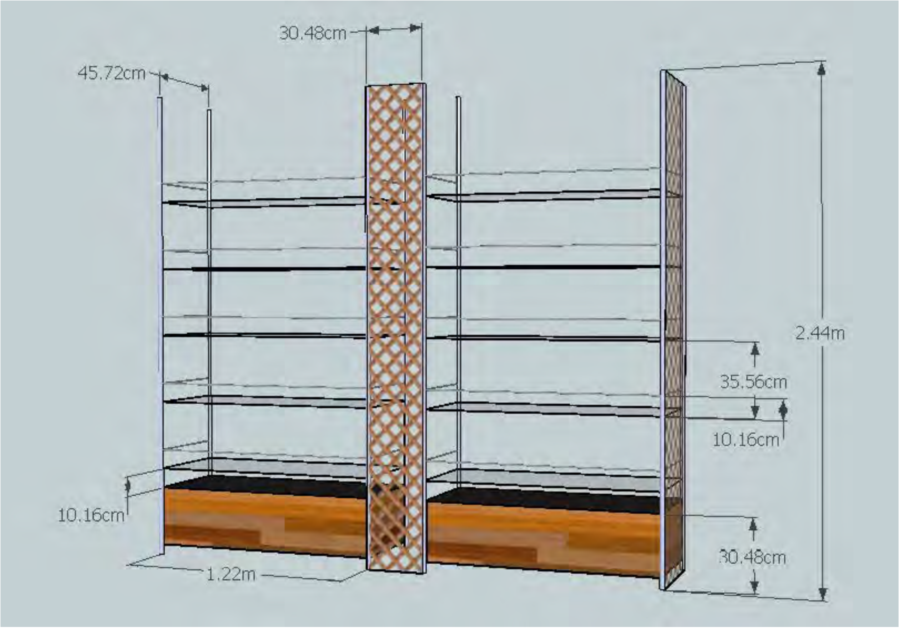

Fig. 2 Structural frame with dimensions

Each plant shelf will have a retaining wire running across to help prevent the pots from falling off the wall - these will be 4 inches up from the bottom of each shelf. A generic wire tension clamp will be used to tighten each wire, which can be loosened during maintenance, when plant pots need to be removed from the shelves.

Fig. 3 Tension clamp to allow the tightening and release of the retaining wires for placement and removal of plant boxes. Picture courtesy of http://www.aerialsuperstore.co.uk

The two metal racks will be 1 foot apart, and the aggregate wall will be placed essentially flush against the back and left wall or corner. A few inches of leeway are available for the living wall positioning. The 1 foot spacing between the two racks will be connected with a rectangular rope mesh, as will be the exposed right side of the rack wall. This will allow strategically placed climbing plants to create a green facade on these 2 surfaces.

For the reservoir tank that would be sitting on the top plant shelf, 2 posts will be placed vertically in front of them, running through the mesh shelf, to help hold the tanks in place.

There is a certain amount of wood available from the previous shelving unit that existed in the alcove. This will be used to aesthetically enclose the bottom storage compartments of the racks. The front panels will be hinged to the top of the compartment, so that the cabinet can be easily opened and closed, and locked. Two generic hinges will be bolted to the top mesh shelf of the cabinet, and the flaps of the hinge bolted to the front panels of wood. A simple hoop will be added to the bottom of the two front panels, to allow a chain and lock to loop the panel to the cabinet‟s bottom mesh shelf. The top of the cabinet compartment will be covered with a slanted water proof lining to protect the stored items from water damage. These will be slightly raised at the front so that any water that may fall on the surface will roll off the back of the compartment.

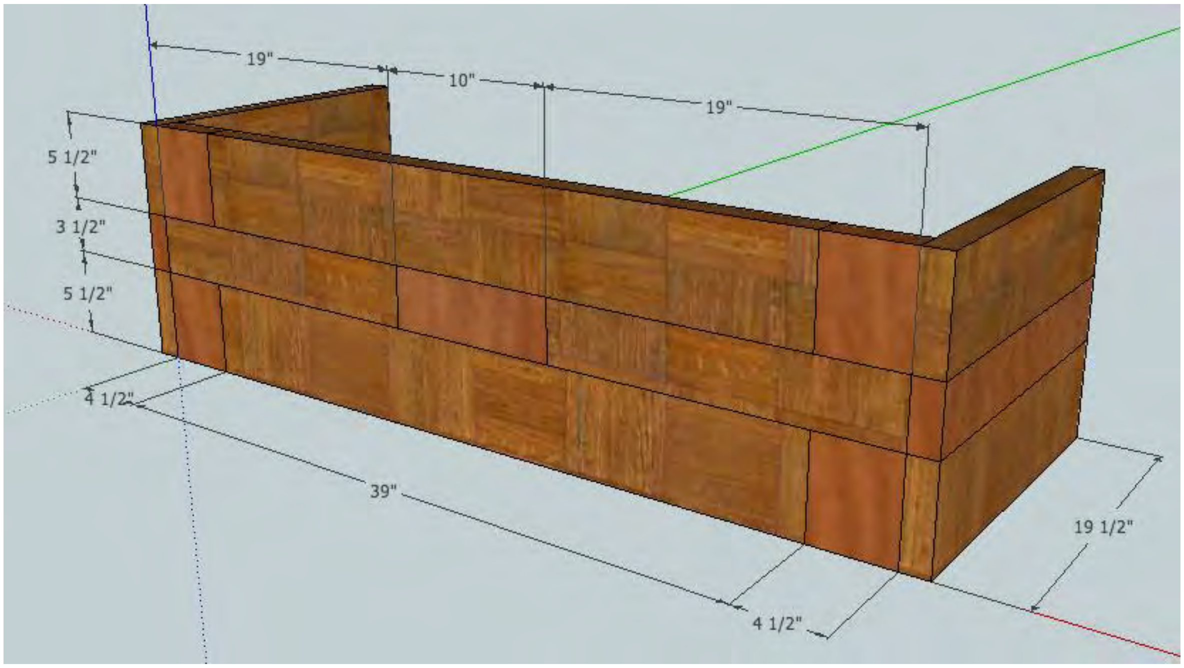

Fig. 4 Depiction of storage compartment in bottom of structure, using available wood from the previous alcove construction.

2.5 Planting System

The irrigation system is designed to fill each pot with 150% the volume which would satisfy the water holding capacity of the soil. This will effectively fill the pots to saturation, at which point gravity will bring some water out of the pot until the water holding capacity is reached. This is in line with the recommended watering methods for most of the plants chosen.

To avoid this water from gathering in the boxes and restricting the aeration of the plant roots, the plant boxes will have a 2 cm layer of expanded perlite within the boxes, below the pots. Expanded perlite has a very high absorbency and this volume of perlite should absorb all of the leftover water. The slow rate of evaporation from the perlite will help raise the relative humidity in the alcove, positively impacting plant stomatal responses, and potentially improving the environs for the human occupants as well.

Any water which overflows or which cannot be absorbed by the perlite will drain through the tube placed 1.5cm up each plant box. This tube leads directly to the drain hole.

2.5.1 Plant Selection

The main criteria for selecting plants for the wall include:

- Hardiness/survivability
- pH tolerance
- Variety of foliage
- Life span
- Similar fertilizer and watering requirements

All of the plants chosen have appropriate characteristics that make them suitable for this kind of installation; notably, reputations as very easy houseplants.

Details to increase the longevity of the plant‟s lives will be included in the Maintenance Guide to be developed over the coming months. Aspects of plant care include occasional misting/wiping of leaves, checking for salt build-up in soils, fertilizing, pruning and re-potting.

The soil to be used can be a typical potting soil, which resembles a basic loam as it would be described in a field.

Table 1. Plant type and characteristics

Plant type	**Height**	**Light**	**Watering**
Philodendron scandens	Vining; low; can be trained high	Mid / low	Drench, and dry
Philodendron Domesticum	Vining; low; can be trained high	Mid / low	Drench, and dry
Chlorophytum elatum “Spider Plant”	Varies; Flexible	Mid	Drench, and dry
Hedera “English Ivy”	Vining; low	Mid / low	Avoid under watering
Scindapsus aereus “Golden Pothos”	Vining; low	Mid	Drench, and dry
Aglaonema modestum “Chinese Evergreen”	20-150cm	Low	Avoid under watering
Zebrina pendula “Wandering Jew”	~15cm; wanders	Mid / low	Drench, and dry

2.6 Irrigation System

2.6.1 Overview

The irrigation system functions on robust mechanical components and the elements of natural siphoning actions, and does not require any electrical parts to function. In this, the design limits the failure component of electrical pumps and valves which were present in previous designs. Any caretaker of the system will be able to fix and control the irrigation system with tools available at any typical hardware store.

The reservoir is designed to take in distilled water via an inlet tube at a very low rate, gradually filling the tank to the necessary capacity. Once it reaches capacity the siphoning action is triggered via the siphon bell/outlet tube, and the reservoir drains, watering the plants and beginning the cycle again.

The basic principle is that the inlet tube will always be filling the reservoirs, with the reservoir mechanism controlling how often the reservoirs empty into the planting system. The rate at which water reaches each plant is controlled per plant using individual dripper heads. An initial setting of 2.0 L/hr is recommended, and methods for assessing the appropriateness of these settings will be included in the Maintenance Guide.

2.6.2 Plant Water Requirement

The water requirements of the plant are a function of the soil‟s water holding capacity. The following calculations were carried out in Microsoft Excel and the related spreadsheets are available for quick modification of design components.

WATERING REQUIREMENTS

Assume: negligible loss of evaporated air from closed reservoir

WATER HOLDING CAPACITY OF SOIL	2.7	mm/cm	*for loam*		
DEPTH OF SOIL	20.32	cm			*dependent on pot size*
DEPTH OF WATER HELD IN SOIL	54.864	mm	5.49	cm	*dependent on soil depth*
APPROX VOL OF H20 HELD IN SOIL	1362.2	cm^3	1.36	litres	
x 1.5 to ensure thorough saturation			2.04	litres	
WIDTH OF SINGLE SHELF	121.92	cm			
POT DIAMETER	17.78	cm			
NUMBER OF POTS PER SHELF	6.0	actual value (rounded down)			
NUMBER OF SHELVES/UNIT	5				
NUMBER OF UNITS	2				
NUMBER OF POTS PER UNIT	30				
NUMBER OF POTS TOTAL	60				

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TOTAL AMOUNT OF WATER TO SATURATE ALL POTS	122598	cm^3	122.60	litres
AMOUNT OF WATER TO SATURATE ONE UNIT	61299	cm^3	61.30	litres
HYPOTHESIZED TIME: SATURATION TO COMPLETELY DRY	2.00	days	48	hours

DESIRED TIME TO FILL RESERVOIR TO SIPHON POINT	5.00	days	120	hours
REQUIRED FLOW FROM INLET	0.51	L/hr		

2.6.3 Flow From Source

An average household can expect to have a water pressure of above 300kPa. A pressure of 10kPa corresponds to a head of 1m. The maximum height that the water needs to reach for this design is 2.5m to reach the reservoir inlet tubes. Thus, the assumed water pressure supplied by the wall source is 30 xs that which is required to bring the water through a tube to the two reservoirs.

2.6.4 Reservoir Functionality

Similar to an automatic flush urinal, the reservoir system utilizes the principles of siphon pressure with a “siphon bell” (Fig.).

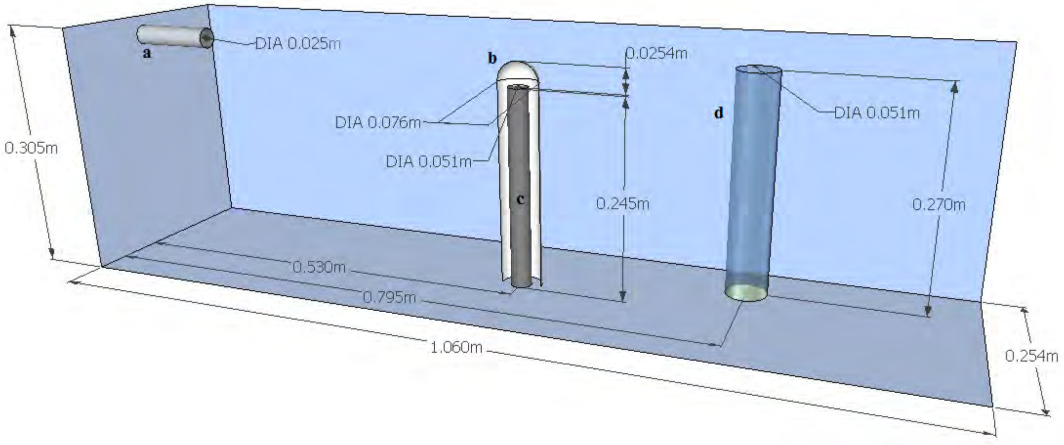

Fig. 5 Overview of one reservoir unit.
a. Inlet tube; b. Siphon bell; c. Outlet tube; d. Overflow tube

The outlet tube penetrates the bottom of the reservoir. The siphon bell has slits cut about 0.5cm deep in its bottom and otherwise must be watertight for the system to work. The siphon bell sits over the outlet tube. As the inlet slowly lets water into the reservoir the water starts rising up the bell column.

Once the reservoir is filled to the desired volume (61L) the water level should be 25cm. At this point the water level will have reached the top of the outlet tube within the siphon bell. The siphon created will serve as sufficient suction to drain the reservoir until the water level is again as low as the cuts in the bottom of the siphon tube and the air pressure breaks the siphon.

In the case of unanticipated high inlet flow or siphon bell blockage not allowing water to enter the bell column the reservoir contains an overflow tube of 5.08cm diameter 27cm high within the reservoir. If the water level in the reservoir reaches this height the excess water will spill into the overflow tube. The overflow tube leads directly out of the reservoir towards the drain. It joins with the overflow tube of the other reservoir via a Y-junction stepping the tubes down to 2.54cm diameter before reaching the floor drain.

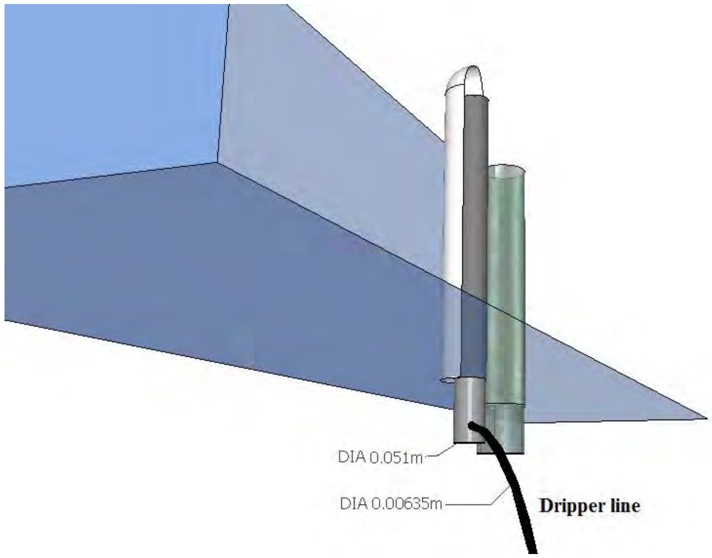

Fig. 6 Detail below the reservoir showing the outlet and overflow tubes penetrating the base, and a representative dripper line

Fig. 7 A representative dripper. A single dripper will be placed in each pot. Photo provided by http://www.amazon-irrigation.com.

The outlet tube shown has a representative dripper line leading from it. Reservoir A will have 7 dripper lines leading from it while Reservoir B will have 6. The 6 lines lead to the 6 plant columns per shelving unit, and are split into sections as detailed in the Bill of Materials (Appendix A) to reach each individual plant.

DIAMETER OF DRIP LINE	0.635	cm
RADIUS OF OUTLET TUBE	2.54	cm
CIRCUMFERENCE OF OUTLET TUBE	7.98	cm
CIRCUMFERENCE - 7(DRIP LINE DIAMETER)	3.53	cm
NO. OF SPACE BETWEEN DRIP LINE HOLES	8	
CIRCUMFERENCE ROOM BETWEEN HOLES	0.44	cm

This would mean that if the openings for the drip lines in the outlet tube were placed in a line about the outlet tube there would only be space for 0.44 cm between each hole, which might alter the integrity of the tube and thus its lifespan. For this reason the drip line openings should be staggered along the bottom 4cm of the outlet tube with a minimum of 1cm in between their openings.

2.6.5 Drip System

The drip irrigation system consists of six drip lines leading from the reservoirs down the plant columns in each unit. For ease of material calculation, a grid system can be applied to a unit. The shelves can be labeled 1 to 5, and the 6 “columns” of plants can be labeled A, B and C based on the distance of their 1st tier pots from the reservoir outlet (Fig. 8).

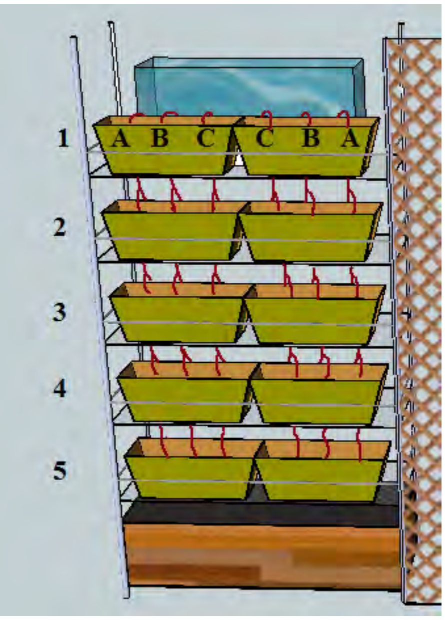

Fig. 8 Depiction of the drip lines and labeling of pot columns and shelves for clarity of material calculation.

REQUIRED MATERIALS FOR DRIP IRRIGATION SYSTEM

Conversion	**"n"**	
1 foot = "n" metre	0.3048	
1 inch = "n" metre	0.0254	
1 inch = "n" cm	2.54	
1 litre = "n" cm^3	1000	
1 cm = "n" mm	10	
safety factor	1.15	in case of errors: cutting, looping, etc

DISTANCE

R being the reservoir:					*safety factor*	
FROM R TO C	10	inches	25.4	cm	29	cm
FROM R TO B	13	inches	33.02	cm	38	cm
FROM R TO A	19	inches	48.26	cm	55	cm
BETWEEN POTS	8	inches	20.32	cm	23	cm
between shelves	14	inches	35.56	cm	41	cm

DISTANCES FROM R SUMMARIZED

		COLUMN									
		A	B	C	D	E	F				
	1	55	38	29	29	38	55				
	2	96	79	70	70	79	96				
SHELF	3	137	120	111	111	120	137				
	4	178	161	152	152	161	178	SUM			
	5	219	202	193	193	202	219	3680	cm	3.68	m

T JOINTS

		COLUMN						
		A	B	C	D	E	F	
	1	1	1	1	1	1	1	
	2	1	1	1	1	1	1	
SHELF	3	1	1	1	1	1	1	
	4	1	1	1	1	1	1	SUM
	5	0	0	0	0	0	0	24

L JOINTS

		COLUMN						
		A	B	C	D	E	F	
	1	0	0	0	0	0	0	
	2	0	0	0	0	0	0	
SHELF	3	0	0	0	0	0	0	
	4	0	0	0	0	0	0	SUM
	5	1	1	1	1	1	1	6

Thus, for one unit, 3.68m of drip line, 24 T-joints and 6 L-joints are necessary. The structure as a whole, then, requires 7.36m of drip line, 48 T-joints, 6 drip L-joints, and 60 individual dripper heads.

2.7 Soil Moisture Monitoring

The sensors come into play in reducing the amount of maintenance time spent on the wall. Once a week, the computer program will generate graphs to record the soil moisture content fluctuation throughout the week, relative to the watering periods. For the first few months of the wall‟s operation, a caretaker will have to look at these graphs to see if the watering schedule matches the plants‟ needs. The watering and lighting schedule can be tweaked throughout this period, until the graphs show that the plants are hydrated ideally. After this point, the wall can be considered fairly „self-sustaining‟.

One moisture sensor will be placed at the upper portion of the wall near the water reservoir, and the 2nd sensor will be placed near the bottom of the wall, furthest from the water tank and light source. This should give a good idea of the wall‟s aggregate moisture content, while remaining within a manageable budget of 2 moisture monitors.

2.8 Lighting

The LED system design has been developing continuously since the actual LEDs to be used are expected to be donated. Since the exact specifications could not be confirmed until final receipt of the arrays themselves, some assumptions have been made in order to make the interim design presented here. Communications with Prof. Mark Lefsrud and student Anthony Rossi have been made to gather whatever information is used in the design considerations.

Anthony mentioned the likelihood of having an 8:1 ratio of red to blue LEDs, plus 1 one LED, per array, and a total of 3 arrays being implemented. The LEDs, requiring 3.3 volts, would be placed on an aluminum sheet with thermal paint to act as a heat sink. This would in total weigh less and cost less than using other types of heat sinks. To account for the amperage capacity of the LEDs, a resister will be added to the circuit. A 12V DC adapter will also be required for the LEDs to be powered by the existing electrical configuration in the alcove‟s ceiling.

It is known that around 200μmol/m^2/s is required for the plants on the wall. An approximate photosynthetic photon flux density of 1000μmol/m^2/s can be expected from average LEDs, with a half-angle of 30 degrees. The wall, in aggregate having 9 feet wide by 7 feet tall of foliaged surface, will have a surface area of 63ft^2, or 5.8m^2.

Until the final LED arrays are received, legitimate calculations for the placement position of the panels are difficult. Once the products are received, using the real half-angle values and PPFD values, the exact distance and angle the arrays are to be placed can be calculated.

2.9 Monitoring Program

Conceptually, the computer program proposed will take the logged information from the moisture and pH sensors, and create a database to store all of this information. It will also store the watering and lighting schedules of the wall, which as of this design must be inputted by the user. Based on the specifications of the watering schedule and LED lights implemented, the program will also record the total amount of water and electricity used by the living wall.

The program will run itself once a week to generate some graphs. These graphs, and the logged and stored information, will be archived. Graphs include ones comparing moisture content to the watering schedule over time, or the pH, moisture content, and lighting schedule over time. The program will offer the user the ability to choose any and all of these data sets to compare, over whatever time period they like. This will be useful for the initial period of the wall's operation, when the schedule for watering and lighting still need to be modified and tweaked.

Finally, an open end to this design is the ability for all of this information to be presented in a way that is educational to those who pass by the alcove. A monitor can be later installed to display the current status of the wall, with some graphs or other interesting facts related to this wall or living walls in general. The final design of the computer program as a whole is within the scope of the next design team to take over this project.

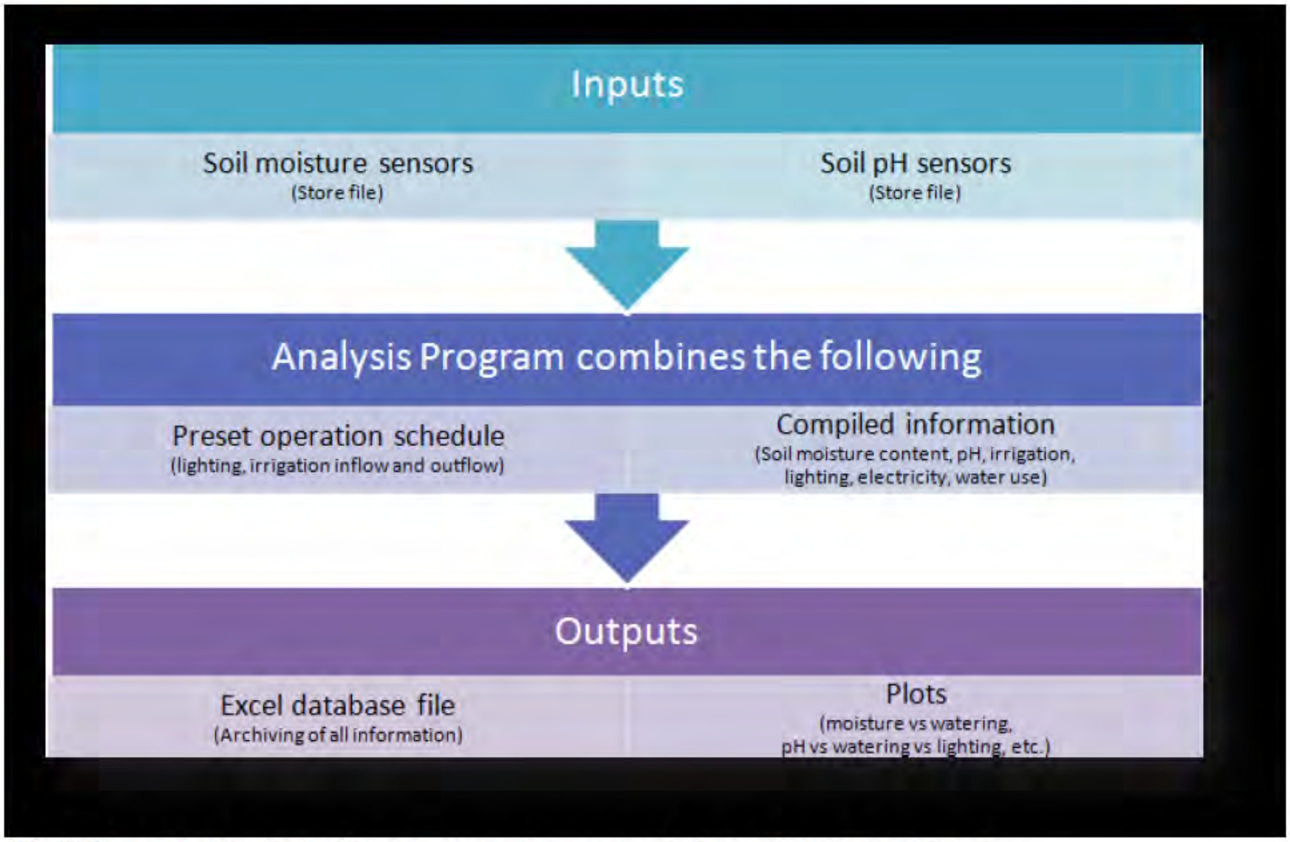

Fig 9 Flow chart of monitoring program concepts from inputs to outputs.

2.10 Location Modifications

2.10.1 Water Trap Solution to Floor Drain Odour Emission

The floor drain in the alcove will intermittently pollute the area with a foul odour. With a 0.635cm diameter drip tube leading to the drain hole, constricted to allow only a very minor drip, approximately 500mL of water should drain into the U-tube every 5 days as the reservoir flushes.

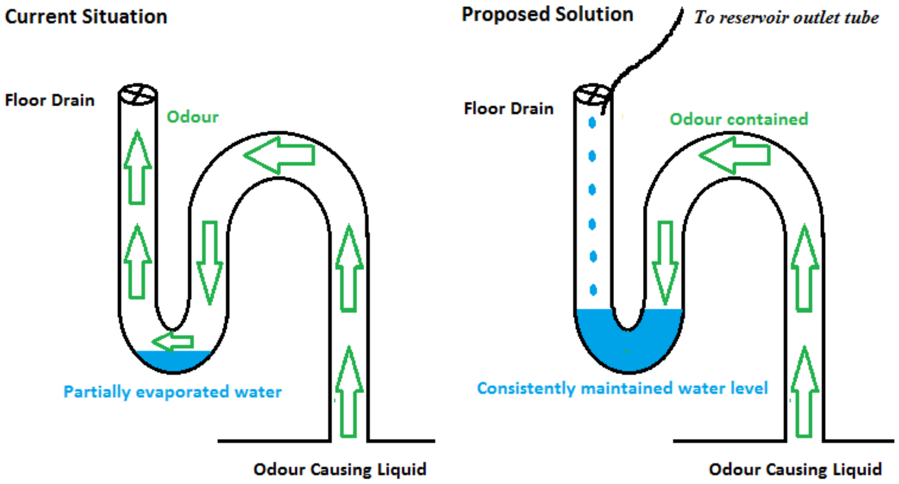

Fig.10 Current situation and proposed solution to odour emission problems from the floor drain.

2.10.1 Barrier Solution to Floor Drain Being a High Point

A drain has been installed in the alcove area to collect any water that may leak in the area. This drain is in fact elevated relative to the rest of the alcove area, so if there is a case of a water burst, the water would leak into adjacent offices before draining. To address this issue, a generic raised rubber barrier should be fixed to the floor, bounding the alcove area to contain any leaked water within the corner to be drained

2.10.2 Removal of shelf adjacent to bench

The 16” by 16” white painted wooden shelf currently exists in the alcove. This is not involved with the design presented here. It is recommended that this shelf be removed to allow moving the ornate bench directly against the column. This would allow for more room between the edge of the bench and the fountain, and provide more movement space, enabling a number of visitors to be in the vicinity of the living wall at once. In lieu of this, the metal wire which was previously used to contain the „eco-sphere‟ should be removed, as it no longer serves a purpose.

2.11 Summarized Budget

A detailed bill of materials for the project can be found in Appendix A. The estimated prices are summarized in groups in the table below. The prices, especially for the planting system and maintenance, are based on assumptions that donation from other departments in the university or otherwise interested parties will contribute.

Table 2 Summarized budget broken into major design components.

Item Group	Price
Structural	$1668
Planting System	$235
Irrigation	$787
Lighting	$150
Monitoring System	$750
Maintenance	$25
Total	$3615

2.12 Timeline of Implementation

Table 3 Timeline from April-September for the next steps in project development.

April	Re-submission of funding application to the Sustainability Project‟s Fund Purchase of base structural materials and construction on site Prototyping of irrigation reservoir Development of basic monitoring system Completion of Maintenance Guide
May	Final material purchases including plants Installation of living components Maintenance and monitoring schedule begins
June	Maintenance and monitoring
July	Maintenance and monitoring

August	Maintenance and monitoring
September	Katherine Bergeron and Alice Chow take over maintenance and optimization of the system

3.0 Next Steps

The design presented here is mostly self-sustaining, with the mechanical irrigation system and scheduled lighting system. There is potential for electrical components to be added to tie into the computer program, to allow this design to be more truly „self-regulating‟. This could involve the computer program responding to the wall‟s moisture content, to either commence or stop watering, or turn the LED lights on or off.

The computer program has been conceptually laid out here. The program itself still has to be written. A more educational way of presenting the work of this program can be designed, to involve say a monitor displaying the wall‟s current or recent status.

The design proposed here is ready to be implemented. The computer program can be written alongside during construction, since the wall‟s operation does not necessarily require the program to be completed immediately.

4.0 Conclusion

The design presented here involves two industrial metal racks, modified to hold plant pots on each shelf in place. A specially designed irrigation system will mechanically water each pot with an intensity controlled drip line. Two moisture monitors will be installed, as well as pH monitors, to log the data and send to a computer program for analysis. An LED design is involved, strategically placed and with a modifiable timer system. The computer program will take all logged information and compare it with the schedules for watering and lighting. This will provide easy monitoring and improved maintenance of the living wall.

Overall, this living wall will no doubt improve the aesthetic appeal of the Bioresource Engineering alcove. It will also provide an educational experience for those who pass by the wall, and demonstrate the many benefits of having plants indoors. The self-sustaining aspect of this wall is also a major component, which can be upgraded to be a self-regulating aspect.

5.0 Acknowledgements

Dr. Grant Clark

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Dr. Mark Lefsrud

Mr. Scott Manktelow

Anthony Rossi

6.0 Background References

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APPENDIX A

Table 3. Detailed Bill of Materials

Use	**Component**	**Estimated Price**
Structure	14 wire shelves, 18” by 48” each	$50 * 14 = $700
	8 mobile posts, with stem caster addition possibility, 96” long each	$30 * 8 = $240
	12 x 39” by 5.5” wood panels	Already available
	5 x 19” by 3.5” wood panels	Already available
	8 T-shaped straight flat brackets	$30
	4 partial wrap-around cabinet hinges	$20
	2 generic chain locks	$40
	2 x 48” by 18” water proof sheets	$15
	12 I-shaped straight flat brackets	$60
	14 x 4 plastic split sleeves	$3 * 56 = $168
	8 polyurethane casters with brakes	$30 * 8 = $240
Securing reservoirs and pots	10 wire tension clamps	$100
	840” (70 feet) length wire rope	$35
	28” rods x 4 (metal or plastic), with tie-wraps to hold in place	$20
Planting System	Plant pots	Available on campus
	Soil	Available on campus
	Plant boxes	$10 * 20 = $200
	2 x 18” by 96” rope mesh	$35
Irrigation System	2 x 68L+ Reservoir	2 * $125 = $250
	1” Inlet tube	$20
	2” Outlet tube and Siphon bell (PVC)	$20
	2” Overflow tube	$40
	60 Dripper heads	60 * $5 = $300
	Drip line	$10
	48 Drip T junctions	$25
	12 Drip L junctions	$10
	2 Inlet valves	$100
	1 x PVC Y junction 2” – 1” step-down	$12
Lighting System	4 LED	Donated
	Heat sink system	$50
	AC/DC 12V adapter	$50
	Timer	$50
Monitoring System	2 Soil moisture sensor & 2 pH sensor	$900
	Computer	$300
Maintenance Inventory	Fertilizer	Homemade - $25
	Spray bottle	Donation
	Shears	Donation
	Total	**$3615**