Environmental Problem Solving II

Rainwater Collection System: A Feasibility Study for Dalhousie University

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ABSTRACT

The *Rainwater Collection and Cistern System: A Feasibility Study for Dalhousie University* is based on the core requirements of the Environmental Problem Solving II (ENVS: 3502). The report includes a variety of methods to determine the feasibility of a Rainwater Collection system (RWCS) at Dalhousie University. Such methods include extensive research, the utilization of expert advice from an interview/survey, and completion of a cost benefit analysis to determine economic feasibility.

The main purpose for conducting this feasibility study is to obtain a better understanding of environmental solutions to everyday problems. For instance, determining the feasibility of implementing a rainwater collection system at Dalhousie is an environmental alternative solution for reducing Dalhousie's municipal water consumption.

The location for the theoretical study area was determined by the interview/survey of several experts and through various calculations. After determining the location and size of the study area, the cost benefit analysis was completed and the overall cost of the study was compared to the current municipal water costs. The cost benefit analysis determined that a RWCS is feasible for the study area. If the RWCS was incorporated into a new building design, there is a possibility of the system being more economically feasible then if it was incorporated into a preexisting building. The development of this project provided our group with a greater interest in environmental problem solving and information for future students and staff to use for further research.

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1.0 INTRODUCTION

Water resources are important to life on earth; however, they are being polluted and consumed by humans at extremely high rates. Sustainability of water resources is just one of the many objectives of the Greening the Campuses movement. In the following research it will be determined if it is feasible for Dalhousie University to implement a rainwater collection and cistern system (RWCS).

1.1 Background and Setting

Water resources are an issue of increasing concern on every level from the international to the individual. There have been many international disputes regarding river systems, oceans, and rainwater because the hydrological cycle is a global system that transcends all political boundaries (http://www.ijc.org/rel/agree/water.html, October 2005). On an individual level, every person has basic water consumption needs; yet, fresh water is a limited resource. According to Kirby (2003), "97.47% of the world's water supply is saltwater (oceans, groundwater, inland seas), 2.53% is freshwater that we do not have access to (glaciers, groundwater, permafrost), and only 0.01% is actually accessible for human consumption (lakes, rivers, marshes, groundwater, soil moisture, and water in plants and animals)." Although Canada is fortunate to have an abundant freshwater supply, Canadians must follow sustainable practices to ensure future water quality is high.

Even though Canada has a large proportion of fresh water, there is a history of water contamination and mismanagement. Examples include the Walkerton tragedy and the recently revealed problems in northern native communities (Death on tap, 2005; Contamination prompts boil order, 2006). Canada has a responsibility to its citizens and to the rest of the world to maintain a high level of freshwater quality because of the large proportion of fresh water that flows within our borders. One of the primary ways to ensure a high level of water quality is to develop a broad range of knowledge and experience in all facets of water resource management. The fundamental place for the development of these needs is through education and research institutions.

While the collection and reuse of rainwater is an effective way to provide water for multiple uses, it also simultaneously reduces the strain on the existing water infrastructure, and reduces the impact of storm water runoff. Water harvesting methods have been around for millennia to collect rainwater for irrigation and drinking purposes. Ancient Iraq is believed to have been the origin of such techniques, 4000 to 6000 years ago (Goins, 2002). In Mexico, the indigenous people collected rainwater for irrigation in semi-arid regions. The Mayans in the Yucatán peninsula used underground cisterns lined with cement to store this water. During the Roman Empire, cisterns were also used to collect rainwater from large atriums. In Istanbul, enormous cisterns known collectively as the Yerebatan Sarayi (Sunken Palace) were built beneath the city to store rainwater. The vault-like cisterns were built with tall columns and boats could navigate its interior (*History of Rainwater Collection*, 2006).

Over the years, as human populations moved into cities and developed water distribution systems, the practice of rainwater collection became less frequent. Soluble atmospheric pollutants associated with larger cities were responsible for contaminating the collected rainwater once used for drinking. As a result, purification methods and filtration systems were needed to improve the water quality.

Given the improvements in treatment systems, rainwater collection and reuse is still common practice in many regions of the world. Varying methods of rainwater collection, from advanced technology to simple solutions, provide supplies for potable water, irrigation, and industrial needs (Konig, 2001; Silva Ariyabandu, 1995). Water collection and reuse has a long history and a broad range of present day functions.

Another benefit of rainwater collection is the reduction of storm water runoff. There is a direct correlation between urban sprawl, storm water runoff and water pollution. Wide paved streets, highways, large industrial buildings, parking lots and other impermeable surfaces all of which contribute to storm water runoff, characterize urban areas. Storm water runoff or urban runoff refers to rainwater that hits the asphalt, concrete and rooftops instead of soaking into the ground. It collects road residues and other pollutants that are funnelled into storm sewer pipes where it empties into rivers and streams. These runoffs pollute the water system, killing fish and other wildlife, as well as making the rivers and lakes unusable for drinking water and recreation (Understanding Sprawl: A Citizens Guide, 2003: pg 17). Rainwater harvesting is one measure to decrease the amount of rainwater entering storm water systems.

Rainwater collection and reuse is used frequently and extensively in the past and continues to be used in a variety of ways today. There are three main benefits to rainwater collection and reuse: it provides a source of fresh water; it reduces the strain on or need for existing water supply infrastructure; and it reduces the amount of storm water runoff. These benefits contribute to a sustainable way of living that reduces the amount of resources used to provide water and reduces the impact of the urban environment on aquatic ecosystems.

1.2 <u>Present Water Use at Dalhousie University</u>

While the main benefit of rainwater collection and reuse is to provide water to areas that may have limited resources, it also reduces reliance on the existing water infrastructure systems. Halifax Regional Municipality uses two water reserves to provide for the city: Pockwock Lake and Lake Major. Pockwock Lake and Lake Major currently supply 320,000 people in the Halifax Regional Municipality with clean, fresh, potable water by using 1300km of piping. The estimated life of the piping based on these flow levels is 50 years (Water treatment facilities, 2005). Rainwater collection and reuse would reduce reliance on the existing infrastructure and extend the time between replacement and breakdown.

The current system in the Halifax Regional Municipality has a capacity of supplying, at maximum, 310 million litres of water per day. Stats retrieved from the 2004 ENVS 3502 Dalplex Project estimates that Dalhousie University consumes over 1 billion litres a year with an approximate cost of $2,300,000. Toilets are one of the largest consumers of water on campus. In private households, the Canadian Department of the Environment estimates that the average Canadian uses 100 litres a day flushing the toilet, which accounts for 30% of the total indoor water use (www.ec.gc.ca/water).

1.3 Creswell's Research Methods

In the beginning of the project, the research team had little background on rainwater collection. A sequential, mixed method approach towards research was used to diversify the team's knowledge on rainwater collection systems. This approach has allowed for reflection on both open and closed ended questions, both predetermined and emerging methods, multiple forms of drawing on all possibilities, and statistical and text analysis. The sequential aspect was accomplished by conducting interviews with experts to help establish the direction of the research, followed by a quantitative method to decide the best possible rainwater collection system to meet the needs of the faculty and student bodies of the Dalhousie Campus.

In order to increase the reliability of the obtained results, the team has included a step-by-step description of the research methods employed and the complete breakdown of the final cost analysis in the appendix. The study was delimited to the Life Sciences Centre second floor washroom and specifications were made on the set of washroom toilets studied to ensure the reproducibility of results in the event a similar study is to be carried out.

Validity of the research was established by allowing the triangulation of data drawn from three resources, which are interviews with experts, electronic text resources, and a cost analysis of the proposed rainwater collection system. Catalytic validity was another important concept to stress and has been achieved in the study by economically typifying the research and increasing its appeal through short-term economic payback upon implementation of the findings.

1.4 Objectives

Defining what objectives are in the RWCS feasibility study is important in determining that the study is coherent and meets all of its goals. Objectives of the study include:

- Analysis of present water use at Dalhousie University
- Problems with current system
- Goals, constraints and regulations
- Advantages and disadvantages
- Feasibility of rainwater collection system with recommendations

1.5 Limitations of the Report

When completing a research paper, it is important to understand the limitations that may arise. Our group recognizes the following limitations we incorporated throughout the duration of this report:

1. Time Constraints: the amount of time available to complete the report, limits the content and the research extent of the report.
2. Hypothetical Study: the report can only be based on theoretical findings. We have limited access to the tools required to implement a bench scale test
3. Funding: the amount of funding available is none. Therefore, all costs that result from the report and other course objectives are paid by the group; with the exception of $25.00 cheque to go towards poster printing costs.
4. Data Collection: all of the data collected is based on averages and estimations; therefore, we cannot hold account for the accuracy of the findings. In addition, our group did not obtain CSAF results, which could have helped with our term report.
5. Generalization: this report is generalized due to limitations; therefore, the limitations combined are a limitation of generalization.

1.6 <u>Delimitations</u>

Along with the limitations of the report, there is also delimitations. Delimitations we decided to be implemented when completing the report is the following:

1. Non-Potable Water: when completing the report we decided we would only incorporate non-potable water due to the necessary requirements to consider when dealing with potable water such as regulations, health, safety.
2. Cistern Location: we limited the cistern location to the Studley Campus because the majority of our group attends this campus and were able to obtain information easier.
3. Location: the location for the cistern to supply was also limited to the LSC bathrooms in the Earth Science/Biology department. We decided this for a couple of reasons, one was because of our cistern location and cost issues, the other was to simplify our theoretical study as much as possible so it would be realistic and straight to the point.

1.7 <u>Definitions</u>

The following is a list of definitions that correspond to this report.

Irrigation*:* The controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall

<u>http://ga.water.usgs.gov/edu/dictionary.html#I</u>

Potable water*:* Water that is safe for human consumption

<u>www.halligan-seaman.com/page.asp</u>

Storm water*:* Water produced by the interaction of precipitation event and the physical environment (buildings, pavement, and ground surface)

<u>www.stoller-eser.com/Annuals/2003/AppendixE.htm</u>

Sustainability*:* Meeting the needs of the present without compromising the ability of future generations to meet their own needs

<u>www.afsc.org/trade-matters/learn-about/glossary.htm</u>

Urban runoff*:* Stormwater from urban areas, which tends to contain heavy concentrations of pollutants from urban activities

http://www.stormh2o.com/sw_glossary.html#u

2.0 RESEARCH METHODS

The following is a replication of the methods we will use and feel necessary to complete our rainwater collection research project:

- Experienced Advice
  - By setting meetings with the following professionals and asking for their advice we should be able to obtain first hand knowledge about what is involved with the harvest of rainwater
    - Advice from Professor John Zuck, landscape architect, who has agreed to lend his expertise on how to integrate the rainwater harvesting system into the Dalhousie landscape.
    - Advice from professional civil and environmental engineers who have experience/knowledge with rainwater collection
    - Advice from water quality specialists/inspectors who have experience with rainwater collection
- Research
  - Review previous reports, research, calculations, and educational books on rainwater collection and water quality
  - Review and implement a mixed-method, pragmatic research project format using our textbook as a guide
  - Review electronic journal sources, which is valuable for our research due to their accessibility and their presentation of up-to-date information that describes the evolving water conversation industry.
  - Cost analysis books like RS Means, which provides an accurate estimate of various materials required and their different prices. We should be able

to compare different methods of implementation based on their cost and performance

- Pilot test
    - Analyze and complete a bench scale pilot project to observe how well a rainwater collection system works, if time permits and if it will benefit the projects results
    - Research previous rainwater collection systems and analyze their results
- Data Collection
    - Questionnaires/surveys may be given to randomly selected students and facilities management
    - Interviews with professionals and/or facilities management team will give us documentation, and written opinions, concerns and advice about the research topic
- First-hand knowledge
    - Utilize our educational experience and knowledge to develop some of the discussion and analysis of our report
- Data Calculations
    - Calculations will be based on an estimate roof area based on the maps obtained from the Geospatial Information Collection at Dalhousie
    - The calculations include the area for the buildings that would collect the rainwater, the cistern volume, the amount of water collected after 1mm of rain, municipal water costs for particular site, and amount of water required for the study area for five day storage
- Mapping
    - Contact with the Map and Geospatial Information Collection at Dalhousie University
    - The use of MAGIC services and a request to create a map for our group with the following information:
        - Include all three Dalhousie Campuses
        - Building footprints and infrastructure including underground systems, such as heating, sewage, water, and electrical

2.1 Case Studies

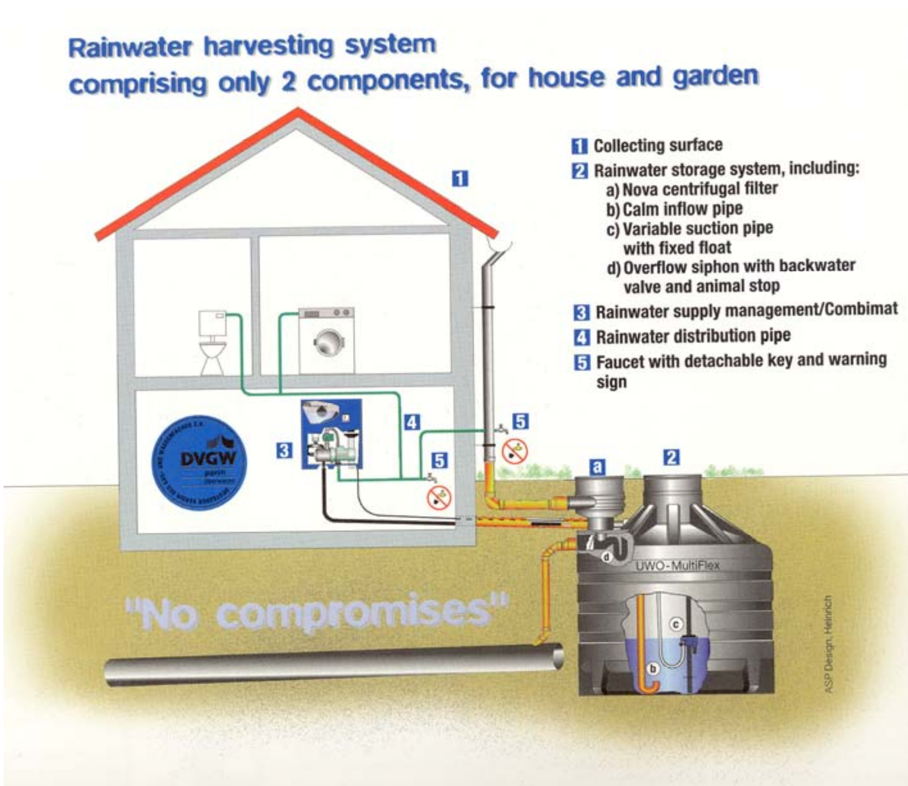
There are a few buildings, other than residential buildings, in Canada using rainwater collection and cistern systems. Mountain Equipment Co-op (MEC), in Ottawa, is an example of how rainwater can be collected and used. The MEC retail store is the first retail building to comply with Canada's C2000 Green Building Standard. This is a program that has been put together "to provide specifications for environmentally appropriate buildings" (www.mec.ca). As well as using many other environmental friendly technologies, "A cistern is filled by storm water and gravity fed to landscaped areas" (www.mec.ca).

Another example of a rainwater collection and cistern system in use in Canada is CMHC's Healthy House in Toronto. In this system "rain and snow collected from the roof provides all of the water supply. Water is stored in an underground cistern and purified without the use of chemicals" (www.cmhc-schl.gc.ca). Once the rainwater has been used and becomes waste water it is treated in a system and reused for toilets, showers, and the washing machine. "Water is typically recycled up to five times, with a small amount being safely released into the soil each day" (www.cmhc-schl.gc.ca). The house also uses appliances that consume less water.

A few of the countries taking the lead on rainwater collection systems are Bermuda and the US Virgin Islands, which by law require rainwater collection systems in all new construction (www.advancebuildings.org). "California offers a tax credit for rainwater harvesting systems and financial incentives are offered in Germany and Japan" (www.advancebuildings.org). In Nova Scotia the school board has made a decision to incorporate rainwater collection systems in all new schools in the province where water quality and quantity are issues. The new Citadel High School, in Halifax, is one of the new schools which will incorporate such a system.

3.0 HOW A CISTERN WORKS

In order to determine the costs of a RWCS it is important to identify the type of RWCS to implement and the components of the system. Rainwater hits the roof of a building (catchment area) it then runs into a gutter system that funnels the rainwater into a cistern. Our group has determined that the cistern will be a large underground storage tank made out of concert. Since the water will be used for non-potable purposes a filter will not be required. When needed the water in the cistern will be pumped out, flow along plumbing pipes and will be used as toilet water. The following diagram depicts a simple private home RWCS.



<u>Figure 1: Rainwater Harvesting System</u> (ASP Ad form The Rainwater Technology Handbook: Rain harvesting in Building)

3.1 Possible Limitations to a Rainwater Collection System

Our group recognizes that there will be limitations to the extent we may be able to research our project on rainwater collection systems at Dalhousie. The following is a list of possible limitations to the implementation of a RWCS.

1. Existing by-laws and regulations of the City of Halifax, as well as Dalhousie University regulations that may not allow the construction of such a system without a change in policy.
2. Locating of a rainwater collection system may be difficult due to infrastructure presently on the site including underground systems, such as, heating, plumbing, electric and other systems our group may not be aware of.
3. Geology of the site may be a limitation if an underground cistern is found to be the most practical system. The City of Halifax sits on a layer of bedrock that has the potential to cause acid rock drainage; strict environmental regulations need to be followed when construction in such a site occurs.
4. The type of roofing material on buildings in which we are researching their feasibility as a rainwater collection roof may be difficult to determine. As well, roofs that may hold the greatest possibility as a collection roof may be determined to be unfit due to their construction materials.
5. Nova Scotia's climate is difficult to predict. For this reason weather would be a determining factor in the creation of a rainwater harvesting system. Extreme cold and dry periods of time could either freeze the water in the system or, during dry periods, rain may not occur over several weeks, drying the system out.
6. The possible scale of the research project will be a limitation. If the scale is too large the amount of time the project takes will be too long but the project has to be large enough to make a difference on Dalhousie water consumption and storm water runoff.

4.0 CRITERA FOR RAINWATER COLLECTION SYSTEM

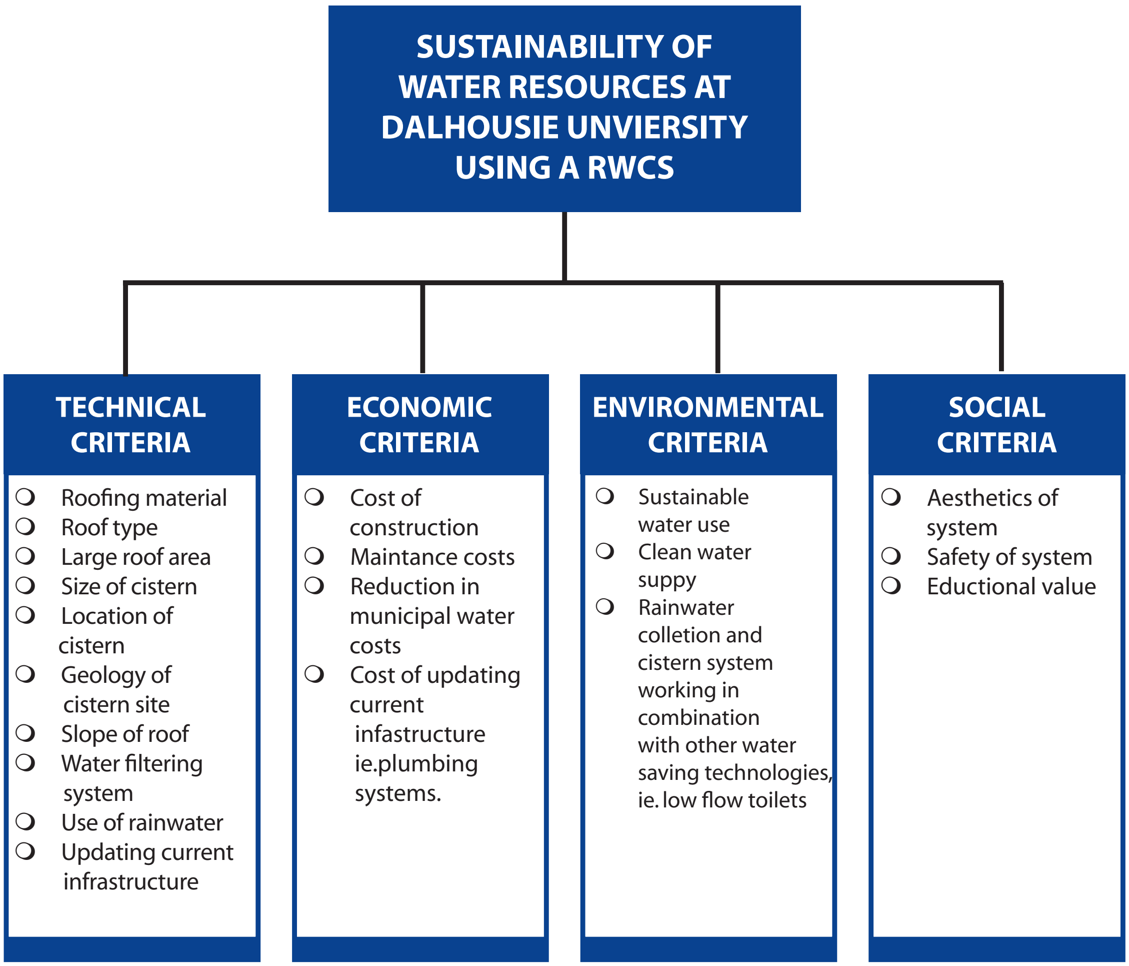


Figure 2: Sustainability Criteria

4.1 Criteria to Consider in Site Selection

1. *Maintenance:*

The technologies of different systems will require variable levels of maintenance and expertise. For example, a system that relies on a number of small barrels to collect water will require a different sort of maintenance than a large cistern system. The use of the water will play a part in determining the level of expertise needed. If the water were used for flushing toilets, regular plumbing skills would be needed, and not much more. If the water were to be used as a drinking source, swimming or for the Aquatron systems, a high level of monitoring would be necessary. This would include monitoring of residual particulate, bacteria and pH. The monitoring of these would have to follow guidelines. The guidelines for the Aquatron systems are stringent and can be found at www.ccac.ca

2. *Possible uses for collected rainwater:*

i. Irrigation: water that is collected could be used to irrigate/ water plants and flowers on campus. This would require little water and minimal treatment. Water for this use would only be needed for a few months of the year.

ii. Swimming pool: Water collected could be used to fill the swimming pool at Dalplex. This would require storage of a large amount of water. The treatment for this use would be as intensive as for that of potable water.

iii. Flushing toilets on Studley campus: the scale of usage would determine the size of the tank and the collection area. Treatment of water would be minimal, filtering would be needed, but chemical treatment wouldn't be necessary. To implement this would require changing and adding to the existing plumbing system to keep the rainwater separate from the potable water. A back up system connected to the municipal source would still be needed.

iv. Aquatron: Water used in the Aquatron requires careful monitoring of the chemistry of the water. The guidelines are outlined at www.ccac.ca

3. *Geology:*

The geology in the Halifax Region is underlain by the Meguma Groups, which includes the Goldenville Formation, consisting of sandstone and slate and the overlying is the Halifax Formation, consisting of slate and siltstone. These rocks were folded and the South Mountain Batholith intruded. Glaciations are the cause of such formations as Citadel Hill and Halifax Harbor (Jamieson, R.A, (2005)).

The Studley Campus of Dalhousie University lies on the south dipping limb of an upright anticline (geological term to describe the folding of the earth in "A" shape direction). The upright folds are associated with steeply dipping slatey cleavage that has been altered due to contact metamorphism (forming of metamorphic rock by an intrusion of magma baking the outer edges) (Jamieson, R.A, (2005)).

Biotite and chlorite-muscovite are present on the campus as well as andalusite and cordierite porphyroblasts. The limitation with the geology in Halifax and Dalhousie Studley Campus is the minerals in the rocks. Weathering and erosion of the rocks creates oxidation and dissolution of iron sulphides, which may lead to acid rock drainage, and contamination of runoff in an exposed area. Therefore, when considering breaking ground we must determine the rock type in the location and find a solution if the rock contains iron minerals such as pyrite (fool's gold) (Jamieson, R.A, (2005)).

4. *Roofing Materials and Drainage Patterns:*

Roofing materials and drainage patterns are both important criteria to consider in rainwater collection. Roofs are the most popular surfaces for rainwater collection due to their widespread availability. The suitability of the roof for rainwater collection is dependent on factors such as the construction style and the material of the roof, also, the consideration of the use of the collected rainwater for potable or non-potable purposes. These materials include asbestos sheet, corrugated iron sheet, tiles, slate, and thatch. All these materials are appropriate for rainwater collection as long as they are used for non-potable purposes.

Drainage patterns can be controlled by guttering systems. Guttering is usually fixed to the building just below the roof and catches the water as it falls from the roof. There are many aspects to consider when installing a gutter system such as cost and durability. It is necessary to design and install a gutter system in a specific manner so that when overflowing occurs water is directed away to insure it does not pond, or enter into, the building. Gutters that pond water pave the way to the formation of mosquito breeding habitats. The installation of a slotting gutter, an oversized gutter below the top edge of the fascia or the installation of rainwater heads with overflow slots helps prevent mosquito nests formation. As well, downpipe spacings are to be considered. They are designed to ensure the adequate performance of the flow of water from concentrated areas on the roof. Overflow chances increase as the downpipe spacings increase, which is an aspect to be considered.

5. *Aesthetics and Public Perception:*

Aesthetics and public perception was added to the list of criteria associated with choosing a viable location for a rainwater collection and cistern system. It is important that the system blends into the landscape of Dalhousie University to ensure the system does not negatively affect the campus's aesthetic integrity. Another option would be to create a system that is visually appealing, integrates into the Dalhousie landscape, and allows the public to see the system and how it works. This may be a benefit to the public perception of the program. It would demonstrate Dalhousie University is moving towards sustainability and is an active participant in the Greening the Campus movement.

6. *Cost:*

The cost of the proposed system is an integral element of the feasibility of the project. Computing the total cost will involve the consideration of all of the materials involved in the production of the system, the required labour for its construction and both the labour and materials needed for the maintenance of the final system. The system proposed, if feasible, would be in use for many years (as opposed to just one); hence future costs (and benefits) will have to be discounted before computing total cost.

7. Proposed Locations:

i. Soccer Field

The soccer field was an option put on the Rainwater Collection Feasibility Survey. The reason it was chosen for a potential cistern location was because a large cistern could be constructed under the field with the field placed on top. This area is downhill so that rainwater would be fed into it. It was concluded after the survey was completed and returned that this location would be inappropriate. There are underground tunnels around this area of the Dalhousie campus and the soccer field was recently refinished costing the school a large sum of money.

ii. Old Management Building

A potential location for the implementation of a rainwater collection system on the Dalhousie University campus is the old Management building site. This building is located at 6152 Coburg Rd. where this road meets LeMarchant. This location, until the creation of the Kenneth C. Rowe building in 2005, housed the university's faculty of Management. Future plans for the old Management building have yet to be made public but there has been mention of the possibility of housing research labs and offices for the Computer Science department.

iii. Biology Ocean Pond

The ocean pond is located on the north side of the life sciences centre directly across from the Chase Building. The ocean pond's construction was in 1997, to remove the problems associated with field trips and to provide the campus with an ecological garden. The first year biology laboratories and other biology classes use the ocean pond for observation studies as well the pond provides an esthetic appeal. The ocean pond consists of only Nova Scotia native plant species and is the habitat of diverse microbiology of both flora and fauna (Baccardax, A).

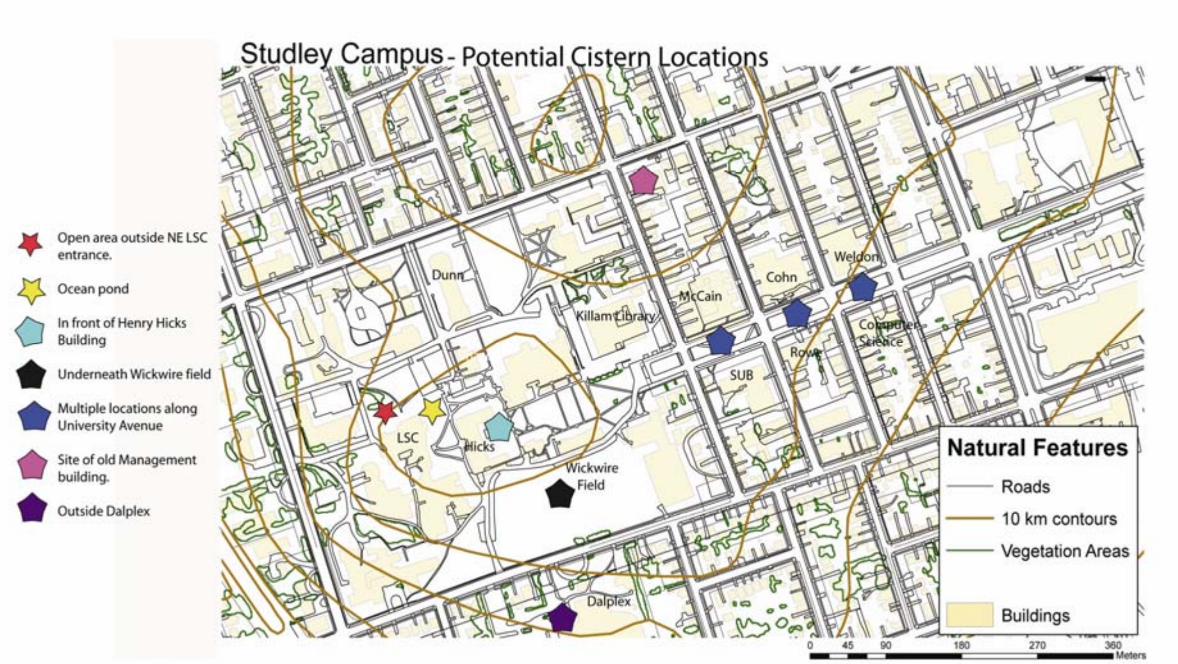
The installation of the rainwater collection system would disrupt the biological habitat. The purposed placement of the rainwater collection system is underneath the biology pond, which would lead to the temporary draining of the pond. This could cause problems and a disruption to the habitat and use of the pond. Overall, this is a good location but because of the pond, it brings strong limitations.

iv. University Avenue

University Avenues spans the area between South Park St. and a "dead end" located right after LeMarchant Street, in front of the Killam Library. The section of the Avenue between Robie Street and the "dead end" is occupied by Dalhousie's Studley campus. The largest concentration of the University's building, including the Killam Library, the Student Union Building, the Weldon Law Building, etc., is located along this part of University Avenue. Between LeMarchant and Seymore is the notorious "University Boulevard" which is only accessible to pedestrians, and splits the road into two lanes of one-way traffic (as opposed to its' one lane of two-way traffic along the area between South Park and Robie Street). This area is highly congested with pedestrians and vehicles, especially during the peak hours of weak days. Also dividing the flow of traffic and pedestrians on University Avenue is a boulevard located between Henry Street and Robie Street, however, pedestrians do not as consistently occupy it as the former boulevard. University Avenue intersects with the following residential streets: LeMarchant, Henry, Seymore and Edward. As a result, the area experiences a lot of through traffic from residents and other vehicles from these streets, adding to the density of traffic to the area.

v. Area between Life Sciences Centre and Kings College

The area between the Life Sciences Center (LSC) and King's College is located on the North side of the LSC where the Earth Sciences department exits. Several obstacles including, five to six trees, a walkway, and new night-lights that would have to be solved before implementing the cistern. There is approximately 1-2m of soil before reaching the bedrock. This is a possible and probable location.



<u>Figure 3: Map of Studley Campus</u>

4.2 Expert Survey and Interview

As part of the feasibility study for a rainwater collection and cistern system at Dalhousie University, experts in the areas of water resource management, geology, engineering, plumbing, urban planning and economics were asked to complete a survey created by our group. The survey was administered through an interview process and additional information provided by the experts was recorded. Questions on the survey consisted of:

- How much did the expert know about rainwater collection systems?
- What did they believe was the best location on campus to locate such a system?
- What was the most practical use for the water collected?
- What was the most important aspect of such a system?

4.3 Survey Methods

We designed surveys to be administered to select experts in the field of rainwater collection systems or criteria associated with such systems. These individuals specialized in geology, hydrology, plumbing, environmental economics, rainwater collection systems, and their installation. The surveys included ranking and open-ended questions *(Appendix1: Survey/Interview).* The purpose of these first questions was to rank predetermined criteria associated with rainwater collection systems, locations, and potential uses for the collected rainwater. The purpose of the open-ended questions was to further our knowledge and understanding of rainwater collection systems and factors involved in their installation.

4.4 Survey Results and Analysis

We compiled the results from the surveys and determined average rankings for each criterion, location, and potential use. The drainage pattern, cost, and maintenance criteria were ranked the highest in terms of importance when considering the implementation of a rainwater collection system (Table 1). The highest ranked potential uses for the collected rainwater were summer irrigation, toilet flushing, and the Dalplex pool. The highest ranked locations were the Ocean Pond, the area between the Life Sciences Centre (LSC) and King's College, and the old Management building site. We further analyzed potential locations for a rainwater collection system because our results indicated the Henry Hicks, soccer field, and University Av. areas could not feasibly house such a system. These areas already have underground infrastructures such a piping and tunnels that would interfere with the installation of a rainwater collection system. The remaining three locations, Ocean Pond, the area between the LSC and King's College, and the old Management building site, were qualitatively analyzed by scoring each location based on the weighed criteria (Table 2). The criteria determined unattainable were the associated costs for the old Management building site and the public perception associated with the Ocean Pond site. Following this analysis, the area remaining to be considered was between the LSC and King's College. Conclusively, our analysis indicates the area between the Life Sciences Centre and King's College as the most feasible location for a rainwater collection system.

Table 1: Ranking of criteria, potential locations, and potential uses for rainwater collection system

Rank	**Criteria**	**Location**	**Use**
1	Drainage patterns	Ocean Pond	Summer irrigation
2	Cost	LSC/King's	Toilet flushing
3	Maintenance	Management building	Dalplex pool
4	Roof materials	Henry Hicks	Potable water
5	Proximity to purpose	University Av.	LSC Aquatron
6	Geology	Soccer field	
7	Public perception		
8	Aesthetics		

Table 2: Qualitative evaluation of possible locations for rainwater collection system

Criteria	**Management building**	**Ocean Pond**	**LSC/King's**
Drainage patterns	10000000	10000000	10000000
Cost	0000000	1000000	1000000
Maintenance	100000	100000	100000
Roof materials	10000	10000	10000
Proximity to purpose	1000	1000	1000
Geology	100	100	100
Public perception	10	00	10
Aesthetics	1	1	1
Total	**10111111**	**11111101**	**11111111**

1 attainable, acceptable, or appropriate

0 unattainable, unacceptable, or inappropriate

5.0 CALCULATIONS

5.1 Average Flow of Toilets

Based on the criteria study, the best use for the cistern collection water is for toilet purposes and the best location of the storage tank is between the Earth Science department of the Life Science Centre (LSC) and King’s University. The feasibility study will include five toilets and three urinals, which are located on the second floor of the Earth Science and Biology wing in the Life Science Centre. The following are the calculations required to determine the average flow per day.

We assumed that the toilets are using 22L/flush due to the extensive time it takes for the toilet to stop flushing (it does not have the flush specifications on the toilet) and 4L/flush for the urinals based on the Waterloo University study. The average amount of flushes per toilet is also based on the Waterloo University study. The observation showed approximately four flushes per hour over a twelve-hour period from 8am to 8pm (Chan, F., Finan, H., Leung, M., Skublak, C. (2005), pp. 9-10).

1 toilet x 22L/flush x 4 times/hour x 12hours/day = 1056L/day per toilet

1056L/ day per toilet x 5 toilets = 5280L/day

1 urinal x 4L/flush x 4 times/hour x 12 hours/day = 192L/ day per urinal

192L/day per urinal x 3 urinals = 576L/day

5280L/day + 576L/day = 5856L/day required for bathrooms

Assuming required storage for five days

5856L/day x 5days = 29280L storage required, 30,000L (30m^3) storage tank required

Because of the limited space available, we recommend the storage tank to have a 5x3x2m (length, width, height) dimension.

5.2 Possible Collection Areas

The location of the storage tank system, the roof materials, and the criteria study indicates that the best collection areas are the roofs the nearest to the proposed placement of the underground storage tank. These roofs are Sheriff Hall, King's University, King's Gymnasium, and the greenhouse on top of the LSC. The use of maps to scale and the following calculations determined the area of the roof and the potential rain it can collect after 1mm of rain.

Sample calculation:

<u>Measured Amount of Area in Question (13.5mm)</u> = 0.5 x 100m = 50m

Known Amount of Area in Question (27mm = 100m)

<u>Measured Amount of Second Area in Question (6.75mm)</u> = 0.25 x 100m = 25m
Known Amount of Area in Question (27mm = 100m)

50m x 25m = 1250m^2

For example, 1mm of rainfall

$$1250m^2 \times 0.001m \text{ (rain)} = 1.25m^3 \text{ of rain} \times \frac{1000L}{1m^3} = 1250L \text{ of rain at 100\% collection}$$

At 95% collection rate = 1250L x 0.95 = 1188L of rainwater collected

For actual measurements of possible buildings (note: all measurements are approximate value):

Sheriff Hall: 4600m^2

King's College Main Building: 520m^2

King's Gymnasium: 2176m^2

Life Sciences Center including Oceanography Wing: 7202m^2

Life Sciences Center's Greenhouse Section: 864m^2

5.3 Cost for Dalhousie University's Municipal Water Supply

A telephone inquiry with the Halifax Water Commission on March 23, 2006 determined that there are several prices for water supply based on the inlet pipe size; hence, the more water required the increase in quarterly (every three months) or monthly fees. The following are the monthly reoccurring charges for municipal water supply in Halifax, Nova Scotia.

The municipal water supply system has set charges for the following:

Wastewater Fee: 0.3286¢/m^3

Environmental Fee: 0.7004¢/m^3

Note: These fees are for the new sewage treatment system in Halifax Harbour

Basic Water Charge: 0.2910¢/m^3

The following charge are set fees either in quarterly or monthly based on the size of the inlet pipe system:

A residential inlet pipe at 5/8-inch: $35.26/quarterly

¾-inch: $67.86/quarterly

1-inch: $111.32/quarterly

1-½ inch: $219.97/quarterly

2-inch: $350.35/quarterly

3-inch: $232.68/month

4-inch: $363.06/month

6-inch: $725.22/month (approximately the size of Dalhousie's inlet pipe for the LSC)

8-inch: $1304.69/month

10-inch: $1449.66/month

An average monthly cost for the toilet system (using the inlet pipe monthly charge) is the following:

30m^3 is the flow required for five days of the toilets and urinals in Earth Science bathrooms.

30m^3 x 6 (for a 30 day period) = 180m^3

180m^3 x 0.3286¢/m^3 (Wastewater fee) = $59.15/month

180m^3 x 0.7004¢/m^3 (Environmental Fee) = $126.70/month

180m^3 x 0.2910¢/m^3 (Basic Water Charge) = $52.38/month

6-inch pipe inlet system = $725.22/month

The total monthly estimated cost for the Earth Science Bathrooms including reoccurring charge for pipe inlet system is *$963.45*

The total monthly estimated cost for the Earth Science Bathrooms without reoccurring charge for pipe inlet system is *$238.23*

Therefore, the annual estimated cost for the use of the Earth Science Bathrooms is *$2858.76*

Because the inlet pipe size will not change with the implementation of a rainwater collection system, the monthly charge for the Earth Sciences Bathrooms that will be used for the cost benefit analysis is $238.23.

6.0 COST-BENEFIT ANALYSIS

6.1 Cost-Benefit Analysis Identification

The economic analysis of this study takes into account the associated monetary cost and benefits associated with the proposed rainwater recycling system. It is important, however, to consider all costs and benefits, not solely those with a dollar sign attached to them. These types of costs and benefits are social and environmental ones. A rainwater recycling system would lessen Dalhousie's reliance on the HRM's water supply by localizing a proportion of the source of its water. Not only is this environmentally efficient it will save the University in costs normally paid to the HRM for providing it with the service. A localized water system may reduce potential piping hence future community construction which may be abrasive to the university's surrounding residential neighbours; a social benefit. Other important non-monetary costs aside from a reduced environmental impact include public perception of Dalhousie as an environmentally conscious university as well providing research opportunities for students involved in the system's implementation, maintenance and progress.

6.2 Financial Cost-Benefit Analysis Methods

Material costs were obtained from various Maritime plumbing and piping suppliers. Labour costs were based on Nova Scotian provincial averages of fair labourer wages. These were obtained in 2002 dollars, but were adjusted for inflation using the CPI measurement given by Statistics Canada. All wages given in the report have been adjusted to 2006 dollars. Labour hours were calculated based on the assumption the installation of the system would take three regular workdays of 8 hours each. The maintenance costs for the systems' upkeep would be incurred in the future and were unable to be assigned an exact monetary value, but were accounted for in the final calculation as a constant "A". The constant A also included rental costs for installation. The financial benefits were based on a study done at Waterloo University (Chan, F., Finan, H., Leung, M., Skublak, C. (2005)). The cost to Dalhousie of the municipal water needed to supply the 5 toilets and 3 urinals this study was based off of were considered. It was based on the estimates given by the Waterloo study, the Halifax Regional Water Commission and personal observations. This cost was considered as a "forgone cost" to Dalhousie in the monetary benefit section of the analysis.

Calculations:

Materials:

1 ½" PVC Piping= = $199.50

Drainage Screens: $69.50

6" inlet pipe: $7.81

Cement tank: 30,000L = 6,810.62 USG = $6,810.62 (i.e. 1$/USG)

Total Material Costs:

Labour costs: $2633.28 (4 Steamfitters, 3 8 hour days) + $408.8 (1 plumber, 2 8 hour days)

Steamfitter's wage (NS): $27.43/hr

Plumber’s wage (NS): $25.55/hr

Maintenance and Equipment Rental = A

Forgone Cost: **$**238.23 * 12 = $2,858.76

6.3 Cost Benefit Analysis Results

Net Benefit = $2,858.76 – ($10,129.51 + A) =

-$7270.75 – A

If a discount rate of 5%, the following payback period is obtained:

Year	Cost	2006 Value ($)	Cumulative Cost ($)	Benefit	2006 Value ($)	Cumulative Benefit ($)
2006	$10,129.51	$10,129.51	$10,129.51	$2,858.76	$2,858.76	$2,858.76
2007	$1	.95	$10,130.46	$2,858.76	2722.63	$5581.39
2008	$1	.91	$10,131.37	$2,858.76	2592.93	$8174.40
2009	$1	.86	$10,132	$2,858.76	$2469.50	$10,643.90

Table 3: Cost Analysis Results

Although the net benefit is negative, the payback period of the proposed system is 3 years, thus it is feasible!

7.0 RESULTS

Based on the monthly water costs ($238.23) of operating the toilets in our study area over a 12-month period ($238.23 * 12) it was determined that total water costs for the year would be $2,858.76. The net benefit for the cost of running the rainwater collection and cistern system over a one year period would be ($2,858.76 - ($10,129.51 +

A)) -$7270.75 – A. But the system would be in use for longer than one year, making the payback period of the system approximately 3.75 years. A payback period of 3.75 years meets the objectives of many five-year short-term budget plans.

8.0 SUMMARY

As stated previously the purpose of our research was to determine if it is feasible for Dalhousie University to implement a rainwater collection and cistern system. Our group delimitated the research to a location on the campus and use of the water that was determined through the results of the expert survey/interview. Cost of the current municipal water system was compared to the costs of a RWCS and a payback period of 3.75 years was determined. This payback brought our group to the conclusion that it was indeed feasible for Dalhousie University to implement of RWCS at the study site.

Decision makers at Dalhousie will require a more detailed study of the RWCS before the implement of such a tool. However, this initial research should lead them to decide that further investigation is warranted into this green technology.

Possible flaws in the research may stem from the fact that we were unable to obtain the help of an engineering expert who would have been able to give us more precise requirements of such a RWCS. An engineer may have also provided us with additional potential problems of such a system. Our research could have also benefited from the expertise of Materials Management, who was unobtainable. They may have been able to provide us with information about the site that our group was not aware of and would have been able to give us their incite on use of a RWCS.

9.0 CONCLUSION

The preliminary cost benefit analysis suggests that implementing a rainwater collection system is feasible on the location outlined. Not only is the cost of the system feasible, extra benefits would be added to the system, such as reduced impact on the environment, research opportunity, and better public perception of Dalhousie University's goals towards sustainability. The cost of implementing an RWCS would be further reduced by including it in the construction of a new building or during a major renovation of an existing building. Therefore, it is our group's conclusion, after analysis of the current system and a feasibility study of our proposed RWCS, that Dalhousie considers implementing such a system.

Opportunities for future research in the implementation of a RWCS on the Dalhousie Campus could include the determination of other surfaces to collect rainwater, such as paved surfaces, like parking lots. Also included could be a comprehensive list of possible sites for a RWCS on all three of Dalhousie's campuses, as well as, finding alternative uses for the rainwater other than flushing toilets and determining the costs of implementing a RWCS in a new building being proposed for the school.

10.0 REFERENCES

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APPENDICES

APPENDIX 1: SURVEY/INTERVIEW

Feasibility of a Rainwater Collection System at Dalhousie University
Survey - Pilot Test

Please sign approval to release your name in the final report: _______________

1. The following survey is based on that the limitations listed below are conquered:
    - Halifax, Nova Scotia consistently has a high enough annual rainfall in order to sustain a rainwater collection system
    - All regulations and municipal by-laws are accounted for and nothing withstands the construction or implementation of a rainwater collection system at Dalhousie University
    - The implementation of a rainwater collection system is proven as sustainable
    - The necessary technology for the implementation of the rainwater collection system is local and readily available

2. What are your previous experiences/ knowledge of criteria to consider when planning to implement a rainwater collection system? (see criteria list below)

____

____

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____

3. What do you think are the integral components of a rainwater collection system?

____

____

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4. What is your opinion on the importance and feasibility of implementing a rainwater collection system at Dalhousie University?

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Below is a list of criteria associated with choosing an appropriate location for the implementation of a possible rainwater collection system. Please rank the following criteria in order of importance (1 being the most important and 8 being the least important).

1. Roof materials ________
2. Drainage patterns ________
3. Geology ________
4. Cost ________
5. Esthetics ________
6. Public perceptions ________
7. Proximity to purpose ________
8. Maintenance ________

Below is a list of possible locations for the implementation of a rainwater collection system at Dalhousie University. Please rank the following locations in order of suitability (1 being the most suitable and 6 being the least suitable).

1. Soccer field
2. Old management building ________
3. University Avenue ________
4. Ocean Pond (biology habitat) ________
5. Front of Henry Hicks building ________
6. Between the LSC-Biology and ________
   Earth Science building and the ________
   University of King's College

Below is a list of possible uses for the collected rainwater. Please rank the uses in the order you judge best (1 being the best use and 5 being the worse).

1. Dalplex pool
2. LSC Aquatron
3. Toilet flushing on Studley campus
4. Summer irrigation
5. Potable water on Studley campus

Geology Interview:

1. What are your major geological concerns when implementing a rainwater collection system at Dalhousie University?

2. Where do you believe the best location is to implement a rainwater collection system at Dalhousie University?

3. Do you believe implementing a rainwater collection system at Dalhousie University is feasible?

4. What do you believe to be the best use for the rainwater collected?

5. Do you have any other major concerns when implementing a rainwater collection system at Dalhousie University?

____

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APPENDIX 2: LITERATURE REVIEW

A DUAL-MODE SYSTEM FOR HARNESSING ROOFWATER FOR NON-POTABLE USES

Appan (2000) tested a simple input-output model incorporating a dual-mode system (DMS) that is for non-potable purposes only. They collected roofwater from the north spine of the Nanyang Technological University Campus in Singapore, which is a high-rise building and has an area of 38,700 meters squared. The water storage tank is connected to the existing water tanks in the building with pump cut-in and cut-out electrodes placed at depths of 1 m and 1.5m above the base of the tank. The results show that by retaining the breadth and depth of the distribution tank but progressively increasing, the length to an optimum value of 41 meters has caused full-utilization of the collected roofwater and the rainwater is stored in a separate tank but also links to the potable water distribution tank, a mechanism controlled by the DMS. Appan recommends that utilization of roofwater will create savings of about $ US 18,400/month (12.4% of the current monthly expenditure for water use on campus).

The methodology described in this article could prove useful to the project due to its relatively simple premise in separating potable water from rainwater in the distribution tanks. Toilet flushing is a possible use for the collected rainwater because it will save money and water due to the large amount of water a toilet consumes per flush.

Appan, A. (2000). *A Dual-Mode System for Harnessing Roofwater for Non-potable Uses*. Urban Water, 1(4), 317-321

URBANIZATION OF AQUATIC SYSTEMS: DEGRADATION THRESHOLDS, STORMWATER DETENTION, AND THE LIMITS OF MITIGATION

Booth and Jackson argue that "urbanization of a watershed degrades both the form and the function of the downstream aquatic system" (1997). They provide examples from Washington of lowland streams and the impact stormwater has on them. This journal article provides technical information on a detention pond's deficiencies and the actual ability to mitigate impacts of urban development.

Booth, D., & Jackson, R. (1997). *Urbanization of Aquatic Systems: Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation*. Retrieved on January 23, 2006, from the Journal of the American Water Resources Association Web site: http://www.cwp.org/WRI_Seattle/Tuesday/ProgramH_Booth_and_Jackson_1997.pdf

THE USE OF NON-CONVENTIONAL WATER RESOURCE ALTERNATIVES IN WATER SHORT AREAS

Consideration in the development of a long-term water resource strategy that is feasible from a financial, social and political point of view in water-short areas. Each locality must carefully examine its own situation to determine whether any of the available non-conventional water resource techniques are appropriate. Among the non-conventional techniques that should be examined are wastewater reuse, desalination of brackish and seawater, use of rainwater catchments, transport of water by tankers, and weather modification. In 1985, as part of the International Drinking Water Supply and Sanitation Decade (1981-1990) the United Nations sponsored a number of activities including a new publication, "The Use of Non-Conventional Water Resources in Developing Countries" and an interregional seminar in Curacao that focused on the use of non-conventional techniques.

Brewster, MR., & Buros, OK (1985). *The use of non-conventional water resource alternatives in water short areas.* Desalination.

OCCURRENCE AND BEHAVIOR OF PESTICIDES IN RAINWATER, ROOF RUNOFF, AND ARTIFICIAL STORMWATER INFILTRATION

To prevent overloading of sewer systems and to ensure sufficient recharging of the groundwater underneath sealed urban areas, collection and artificial infiltration of roof runoff water has become very popular in many countries including Switzerland. However, there is still a considerable lack of knowledge concerning the quality of roof runoff, particularly with respect to the presence of pesticides. In this work, the occurrence and the temporal variations in concentration in rainwater and in roof runoff from different types of roofs (i.e., clay tile roofs, polyester roofs, flat gravel roofs) were determined for the most important members of three widely used classes of pesticides (i.e., triazines, acetamides, phenoxy acids). It is shown that in rain and roof runoff, maximum pesticide concentrations originating primarily from agricultural use occurred during and right after the application periods. Maximum average concentrations for single rain events and total loads per year were, for example, for atrazine, 903 ng/L and 13 900 ng/ (m super (2) year); for alachlor, 191 ng/L and 5900 ng/ (m super (2) year); and for R-dichlorprop, 106 ng/L and 5100 ng/ (m super (2) year). Further, the study reveals that a major portion of the compounds washed out from the atmosphere may actually reach the groundwater, particularly if the roof runoff is infiltrated directly into highly permeable zones of the subsurface. Nevertheless, although in some cases European Union and Swiss drinking water standards (100 ng/L) were not always met in rain and roof runoff waters, for the three compound classes investigated, the groundwater contamination potential of the pesticides originating from the atmosphere can be considered of equal or even smaller importance as compared to their direct use in agriculture. The investigations also show that leaching of pesticides used as construction chemicals on roofs, that is, as roof protection agents in sealing used on flat gravel roofs, may be a much more significant source of organic pollutants present in roof runoff.

Bucheli, TD., Mueller, SR., Heberle, S., & Schwarzenbach, RP. (1998). *Occurrence and behavior of pesticides in rainwater, roof runoff, and artificial stormwater infiltration*. Environmental Science & Technology [Environ. Sci. Technol.]. Vol. 32, no. 22, pp. 3457-3464.

CASE STUDY OF A RAINWATER RECOVERY SYSTEM IN A COMMERCIAL BUILDING WITH A LARGE ROOF

Chilton, Francis, Maidment, Marriott, and Tobias tested a prototype rainwater recovery system that recovers rainwater from the roof and then uses it for toilet flushing in a supermarket. A record of the test results over approximately eight months to estimate the rainwater recovered. The system installed had an approximate cost of 7700 pounds, with a payback time of about 12 years. The surface area of the roof of which the rainwater is collected is 2200 m^2. The full-text article describes the technique used in the water collection. Assessment of system efficiency was determined in two trials, and the authors concluded an overall annual efficiency of 51% and given the 612.5mm total rainfall recorded for Greenwich in 1998, this would deliver 687.2 m^3 of rainwater to the system annually. The cost of the tank is approximately 65% of the total cost, so there is a potential to reduce the costs by reducing the size of the tank. The full area of the roof was not used for rainwater collection, so if more the roof were utilized then there would be larger yields of collected rainwater. The authors recommend that the tank be maintained empty in order to maximize rainwater collection, and they believe that the payback period is acceptable but with some modification in the size of the tank (to $5m^3$), there would be little loss of efficiency (from 7.5 % water loss to 17.4% water loss) and faster payback. In addition, they believe that further research should concentrate on reducing costs and requires more trials to determine the most economical tank size for the rainwater recovery system.

This article is useful for the project because it can help us realize how tank size fluctuations can easily raise or lower the costs involved in building an efficient water collection system.

Chilton, J.C., Francis, A., Maidment, G.G., Marriott, D., & Tobias, G. (2000). *Case Study of a Rainwater Recovery System in a Commercial Building with a Large Roof.* Urban Water, 1(4), 345-354

THE COMPLETE ENVIRONMENTAL AUDITING HANDBOOK

This book is a reference for environmental audit practitioners and audit program managers. It provides a basic grounding in audit procedures and techniques plus a variety of useful and practical audit tools to assist in audit execution. This book provides examples of checklists, questionnaires, and an environmental management system (type of sustainability guideline).

This book is a useful guide for our research guidelines, checklists, and questionnaires. It also provides basic structure and format to follow a sound environmental research project. Although, this book is directed towards auditing it will be useful in the preparatory activities required for our group project.

Dunn, K. (n.d). *The Complete Environmental Auditing Handbook.* Toronto: ON, Canada: Templegate Information Services Inc.

MODELING THE PERFORMANCE OF RAINWATER COLLECTION SYSTEMS: TOWARDS A GENERALIZED APPROACH

Fewkes wanted to test the water conservation aspects of a system installed in a residential house and monitored for a period of twelve months. The objectives of the field tests are threefold. Firstly, monitor and document the rainwater inflows and outflows from the rainwater collector to determine the actual amount of water conserved. Secondly, use the collected data to verify and refine a rainwater collection-sizing model. Thirdly, use the refined model to develop a series of design curves relating rainfall level, demand, collection area, storage volume, and system efficiency. The system tested consisted of a rainwater collector and a storage tank supplied by Wilo Salmson Pumps Limited. Installation of the system in a two and half storey house that had a combined roof area of 85 m^2, results for the twelve-month monitoring period showed water savings efficiency ranges from 4% for June to 100 % for September and February. The results of this study show that the incorporation of rainfall losses into a run-off coefficient sensitivity model is essential to maintain accurate assessment of the collector's performance. The rainfall loss parameters for the roof of the house were modeled using initial depression storage with a constant proportional loss model, which produced acceptable results. There is no known effect from the wind speed and direction on the amount of water collected. The author does not provide any recommendations.

Although the author does not provide any recommendations his research takes into account factors such as run-off coefficient sensitivity and constant proportional loss, which are extremely important is assessing the rainwater collection efficiency in potential systems.

Fewkes, A. (2000). *Modeling the Performance of rainwater collection systems: towards a generalized approach*. Urban Water, 1(4), 323-333

ATLANTIC CLIMATE CHANGE CENTRE: THE CLIMATE OF NOVA SCOTIA

The *Atlantic Climate Change Center* Web site is apart of Environment Canada. This web site provides the average climate and the average rainfall of Nova Scotia. The average rainfall for the southern coast (Halifax and surrounding area) is 1500mm. This web site covers the basic essentials for describing Nova Scotia's climate accurately and thoroughly.

This web site is important for our research project for describing Nova Scotia's climate and more importantly its average rainfall in the parameters of our study. We can use this information for calculations regarding the project and as background information.

Government of Canada, Atlantic Climate Centre. (n.d). *Atlantic Climate Change Centre: The Climate of Nova Scoti*a. Retrieved January 22, 2005, from the Climate Centre Web site: http://atlantic-web1.ns.ec.gc.ca/climatecentre/default.asp?lang=En&n=61405176-1

LOW-IMPACT DEVELOPMENT: LOT-LEVEL APPROACHES TO STORMWATER MANAGEMENT ARE GAINNING GROUND

Hager discusses low-impact development approaches and their role in utilizing storm water for non-potable usages. He explains that LID takes a lot-level approach to stormwater management, treating rainwater where it falls by creating conditions that allow water to infiltrate back into the ground. In addition, he talked about rain gardens as means to manage stormwater by detaining rainwater in small depressions that are near where the rain falls. They use native species that are dry and wet tolerant. Implementation of these rain gardens in some residential homes in Maplewood, MN, with success in infiltrating stormwater run-off without additional concrete infrastructure. Rain barrels with minimum storage capacity of 1000 liters to attenuate first flush off the roof is a possible implication. Hager explains that each rain barrel installation with a soak-away pit or drywell that is composed of granular material covered with a grate that infiltrates rain barrel overflow into the groundwater table. This process prevents stormwater flow, provides water efficiency, and recharges soil with rainwater. The city of Ottawa's Water links has distributed 500 rain barrels to interested parties as part of a program to study the water efficiency rates garnered by this technology. He claims that it is early to compare LID maintenance practices with those of conventional stormwater management practices, since those LTD mechanisms have very low initial costs but might fluctuate over time with opening new drainage systems. Hager recommends serious thought to the LID practices in order for implementation due to its ecologically sound premise as the costs minimize over time.

This article is very useful to the water collection project since it provides a good explanation of rain gardens and rain barrels; however, it does not give mention of exact testing methods to examine efficiency rates. It has good material for the introduction.

Hager, M. (2003). *Low-Impact Development: Lot-level Approaches to Stormwater Management are Gaining Ground*. Retrieved on January 23, 2006 from The Journal for Surface Water Quality Professionals Web site: http://utilities.ci.columbus.oh.us/project/docs/LID%20lot%20level%20approaches%20stormwater_feb2003.pdf

INTEGRATED DESIGN AND OPERATION OF WATER TREATMENT FACILITIES, 2ND EDITION

This is a comprehensive book on the design and operation of water treatment facilities. This book is hard reading but it provides some essential points about dealing with the design of basic treatment process unit, management of the design project, preliminary studies, detailed designs, operation and maintenance and specific water treatment processes. *Integrated Design and Operation of Water Treatment Facilities* also includes practical ideas and important detail.

Although this book focuses more toward the industrial and municipal aspect of water treatment, it provides some major points and possible problems we should consider when completing our research project for rainwater collection at Dalhousie University.

Kawamura, S. (2000). *Integrated Design and Operation of Water Treatment Facilities, 2nd Edition.* Toronto: ON, Canada: John Wiley and Sons Inc.

THE RAINWATER TECHNOLOGY HANDBOOK- RAINWATER HARVESTING IN BUILDING

This book offers many examples of rainwater collection systems from basic and local to highly technical and grand. A section that shows many of the devices needed for a proper system. There is a detail checklist of things to consider when constructing a RW collection system. Published in Germany this book offers some legal issues to consider in that country.

Konig, K. (2001). *The Rainwater Technology Handbook- Rainwater harvesting in Building*. Wilo-Brain.

SUSTAINABLE BUILDING ENVELOPE: GARDEN ROOF SYSTEM PERFORMANCE

This document discusses green roofs. My interest in the article is the discussion that relates to stormwater runoff. The main information pertains to the stormwater quality and quantity.

Liu, k. (2004). *Sustainable Building Envelope: Garden Roof System Performance*. Retrieved on January 23, 2006, from the NRC-CNRC Web site: http://irc.nrc-cnrc.gc.ca/fulltext/nrcc47354/nrcc47354.pdf

THE USE OF RAINWATER FOR DOMESTIC PURPOSES IN NOVA SCOTIA

This publication provides guidelines for design and implementation of cisterns in Nova Scotia. It offers some basic design principles, charts on storage capabilities and treatment systems. It is basic is scope and depth but offers insight on some issues that might be found for this locality.

Nova Scotia Department of Health. (1992). *The Use of Rainwater for Domestic Purposes in Nova Scotia*.

RAINWATER HARVESTING: THE COLLECTION OF RAINFALL

This article discusses the importance of rainwater in developing nations and rainwater harvesting techniques. It provides information on rainwater storage tanks and cisterns, collection surfaces, guttering, first flush systems, filtration systems and settling tanks. It also talks about how to install these systems and provides diagrams to accompany the information.

Pacey, & Colluis. (n.d). *Rainwater Harvesting: The Collection of Rainfall.* Retrieved on January 23, 2006, from the Practical Answers to Poverty Web site: www.itdg.org/docs/technical_information_service/rainwater_harvesting.pdf

SWALES & BERMS VS CONCRETE: LOW TECH SOLUTIONS FOR STORMWATER RUNOFF

This is a small informative web site on swales and berms as an alternative to conventional rainwater collection. Swales and berms are esthetically appealing, cheap, and collect stormwater runoff naturally. Berms are raised beds that can be used to direct water to swales and swales are simply shallow, low depressions in the ground designed to encourage the accumulation of rain during storms and hold it for a few hours or days to let it infiltrate into the soil.

This is a brief but informative web site about the benefits of swales and berms. Although our research project is mainly focusing on the collection of rainwater, it is important to review other alternatives from the focal objectives.

Pushard, D. (2004). *Swales & Berms vs Concrete: Low Tech Solutions for Stormwater Runoff.* Retrieved on January 21, 2005, from the Harvest H2O Web site: http://www.harvesth2o.com/swales.shtml

RAIN BARREL GUIDE: HOW TO USE RAIN BARRELS FOR WATER COLLECTION

Similar to previous research this web site provides the basic information on rainwater collection. However, this web site provides an estimate for the rainfall to the area of the roof, which I thought would be useful. This web site states that for every inch (25mm) that falls on a catchment area (roof) of 1000 square feet (92.90m), you can expect to generate 6000 US gallons (22713 L).

This will provide an estimate of how much water we can collect based on the amount of rainfall vs. the area of the roof on the building(s) in question for the rainwater collection analysis and research project.

Rain Barrel Guide. (2004). *Rain Barrel Guide: How to Use Rain Barrels for Water Collection.* Retrieved on January 23, 2005, from the Rain Barrel Guide Web site: http://www.rainbarrelguide.com/

WATER SUPPLY AND WASTEWATER ENGINEERING

This book is a basic civil and environmental engineering guide on water supply and wastewater engineering. This book includes a full section on the rainfall, runoff, surface and groundwater sources and collection. In addition, this book includes thorough discussion and examples of various water related topics such as the quantity and quality of water, transportation of water, treatment of water, water distribution, and examination of water.

This book provides essential knowledge for the collection of rainwater and other related water topics necessary for this research project. I believe this book will be helpful when designing the rainwater collection system for our research project at Dalhousie University.

Raju, B. (1995). *Water Supply and Wastewater Engineering.* Toronto: ON, Canada: Tata McGraw-Hill Publishing Company Limited.

DESIGN OF STORM WATER WETLAND SYSTEMS

Thomas Schueler presents a manual on the criteria for the design and construction of stormwater wetland systems in the mid-Atlantic region. The manual discusses design criteria such as "creating deep-water cells, developing pondscaping plans, reducing future maintenance burdens, and avoiding secondary environmental impacts" (1992). As well, Schueler talks about the stormwater ponds potential to reduce pollution and about native species planting guide.

Schueler, T. (1992). *Design of Storm water Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region*. Washington: Metropolitan Washington Council of Governments.

DEVELOPMENT OF GUIDELINES FOR RAINWATER CISTERN SYSTEMS IN NOVA SCOTIA

This article provides a background on cistern use in Nova Scotia and examines local issues of groundwater quality. This paper discusses the various components of a rainwater cistern system and presents recommendations for system design and system operation and maintenance in Nova Scotia.

Scott, R., & Waller, D. (n.d). *Development of Guidelines for Rainwater Cistern Systems in Nova Scotia*. Conference on RWCS (5^{th} intl.).

RAINWATER CISTERNS- A NEW APPROACH TO SUPPLEMENT THE RURAL WATER SUPPLY SYSTEM IN SRI LANKA

This paper proposes a way of catching water off rooftops to collect water for drinking water and cleaning uses. It compares the cost of jars and tanks. It also brings to light the social implications of women not having to spend a large portion of their day fetching water.

Silva Ariyabandu, R. *Rainwater Cisterns- A New Approach to Supplement the Rural Water Supply System in Sri Lanka*. Conference on RWCS (5^{th} intl.).

SUSTAINABLE EARTH TECHNOLGIES: GREYWATER TREATMENT

This is a basic information web site about the collection and treatment of grey water. Grey water is used water excluding sewage and possibly kitchen water (black water or high organic content). This web site provides a natural treatment system that is both economic and esthetically pleasing since it uses microbiology and their natural habitat to treat the water. This is similar to the existing biology marsh pond at Dalhousie.

This web site is useful because it provides some basic knowledge and perhaps a contribution to a case study, an alternative or an addition to our research project. It also aids as an introduction to the definition, re-use, and treatment of grey water.

Sustainable Earth Technologies. (2003). *Sustainable Earth Technologies: Greywater Treatment.* Retrieved on January 22, 2005 from the Sustainable Earth Technologies Web site: http://www.sustainable.com.au/greywater.html

RAINWATER HARVESTING

The Intermediate Technology Development Group provides technical data to install many different types of water collection systems by examining examples in different developed countries and developing countries. In addition, the article examines different types of filtration systems one of which devised by a German company (WISY). The filter has a 90% efficiency rate and it takes in water through a fine mesh (~0.20mm), which blocks large debris and silt. The article provides directions on how to calculate the proper size of the collection tank. It talks about the different factors to consider in building a rainwater collection system such as rainfall quantity (mm/year), rainfall pattern, collection surface area, available storage capacity, daily consumption rate, number of users, cost, alternative water sources and water management strategy.

This article is very detailed in its presentation of methods to build a water collection system. In addition, the study cases it examines are very helpful to help our group find a water collection system that is efficient considering the Dalhousie campus needs and capabilities of adopting such a system.

The Intermediate Technology Development Group (2000). *Rainwater Harvesting*. KDG 1, 1-24

RAINWATER HARVESTING AND UTILIZATION- AN ENVIRONMENTALLY SOUND APPROACH FOR SUSTAINABLE URBAN WATER MANAGEMENT

This pamphlet outlines needs for efficient water use on a global scale. It is promoting the idea of rainwater reuse for underdeveloped areas or urban centers without running water. It offers case studies that show the needs and benefits of rainwater collection and reuse.

UNEP. (2001). *Rainwater Harvesting and Utilization- An Environmentally Sound Approach for Sustainable Urban Water Management- An Introductory Guide for Decision Makers*. United Nations Environment Programmes.

FINAL REPORT

The final report is a study completed on the feasibility of harvesting rainwater at the University of Waterloo by the WATGreen Team. This report evaluates rain water system sustainability, purpose and goals of rain water supply, parameters of the rain water system, how the rainwater system works, benefits of a rain water system (both environmental and economic), costs of implementing a rain water system (specified for Waterloo University), maintenance, limitations, and recommendations of a rain water system.

This report not only provides background information for the university, but it provides problems encountered when researching for the rainwater collection at a university. The only downside of this report is its research information is not thorough. Although, it does provide basic direct knowledge for our research project and it will when researching for our group project.

University of Waterloo. (n.d). *Final Report*. Retrieved January 21, 2005, from the University of Waterloo Web site: http://www.adm.uwaterloo.ca/infowast/watgreen/projects/library/760/final.html#introduction

BUILDING CONSTRUCTION COST DATA, 63RD ANNUAL EDITION

This annual cost analysis book discusses various cost estimates of thousands of common engineering construction. RS Means is a product from Reed Construction Data Inc. and it provides the most current and comprehensive cost data possible. However, the costs of the construction are in US dollars and will have to be converted. This book also gives thorough instructions on how to use this book efficiently.

This book is essential for our research project since it specifies accurate information for various construction costs for the implementation of a rainwater collection system. I am researching the engineering aspect for the development of our group research project on the collection and usage of rainwater at Dalhousie University.

Waier, P. (Eds.). (2003). *RSMeans Building Construction Data, 63rd Annual Edition.* Kingston: MA, United States of America: Reed Construction Data, Inc.

INNOVATIVE RESIDENTIAL WATER AND WASTEWATER MANAGEMENT

This book is a complete guide for implementing a collection system for a residential scale. There is a detailed history, technical advise, municipal regulations and offers a list of obstacles to consider. There are a number of case studies from all over the world. It has a section on treatment processes needed.

Waller, DH., Mooers, JD., Samostie, A., & Sahely, B.(1998). *Innovative Residential Water and Wastewater Management.* Canada Mortgage and Housing Corporation

WATERMAGAZINE: RAINWATER HARVESTING & COLLECTION-ARTICLE LINKS

The Water Magazine web site provides useful links related to rainwater harvesting and collection. The articles I reviewed so far seem to be very useful and informative solutions to common questions and problems associated with the collection of rainwater. For instance, one of the article links is a paper from India discussing results that show; this paper uses similar annual rainfall numbers as Halifax's annual rainfall and it provides an estimate on what to expect through the research project.

The Water magazine provides easy readable papers, articles and reports directly related to our research project. This web site is very useful and practical for the theoretical and application part of our research project on the collection of rainwater at Dalhousie University.

Water Magazine. (1999). *WaterMagazine: Rainwater Harvesting & Collection - Article Links.* Retrieved on January 21, 2005, from the WaterMagazine Web site: http://www.watermagazine.com/secure/raincoll.htm

RAINWATER HARVESTING

This article is a concise overview of rainwater harvesting systems. It delves into some of the associated costs and benefits, economic, environmental and otherwise, with the implementation of a rainwater collection system. Areas in which it touches on include a basic look into the mechanics behind collection and treatment systems as well as the different materials, and their monetary costs, used to create the systems. In addition, this article outlines "six different components to a state of the art rainwater collection system" as well as providing a basic labeled diagram of this system. The six components include catchment area, roof-wash system, rainwater conveyance system, cistern, delivery system, and water treatment system. The article briefly overviews the types of roofs that are generally less preferable for rainwater collection and a brief summation of conditions that are optimal for such collection.

This article gives a nice preliminary starting point for cost benefit analysis because it states some associated pros and cons for financial issues, environmental issues, and practicality issues of installing rainwater-harvesting systems. The article concludes that rainwater harvesting is not economically beneficial for buildings with municipal water sources; however, this is with only finances and not any other type of cost in mind. This article is almost ten years old, thus a lot might have changed in terms of associated financial cost as well as the efficiency of the technology behind rainwater collection. Although the article is brief, it is a good article for a basic insight into the materials, mechanics of the system and the financial cost associated with rainwater harvesting.

Wilson, A. (1997). *Rainwater Harvesting.* Retrieved on February 5, 2006, from the Environmental Building News. Vol.6, no.5, Web site: http://www.buildinggreen.com/auth/article.cfm?fileName=060501a.xml

RAINWATER HARVESTING: AN ANCIENT TECHNOLOGY-CISTERNS-IS-RECONSIDERED

Winterbottom discusses the ancient technology of cisterns and their role in addressing water resource issues. Landscape architects are now incorporating cisterns in many of their designs or redesigns. Winterbottom talks about cistern designs, building material, costs, and advantages.

This book provides us with an architect's perspective on rainwater harvesting. This will give us an insight to how we can incorporate rainwater collection into the landscape. It also provides us with some cost estimates and advantages.

Winterbottom, D. (2000).*Rainwater Harvesting: An ancient technology–cisterns–is reconsidered*. Landscape Architecture, 4, 40-46.

APPENDIX 3: TIMELINE

Item No.	Task	Time	Start Date	Finish Date
1	**First ENVS 3502 Class**	**0.38 days**	**1/3/2006 17:30**	**1/3/2006 20:30**
2	Introduction to course	3 hrs	1/3/2006 17:30	1/3/2006 20:30
3	**Second ENVS 3502 Class**	**0.25 days**	**1/10/2006 17:30**	**1/10/2006 19:30**
4	Course Information	2 hrs	1/10/2006 17:30	1/10/2006 19:30
5	Introduction to Sustainability (CSAF)	0.25 hrs	1/10/2006 17:30	1/10/2006 17:45
6	Discuss Possible Projects	0.5 hrs	1/10/2006 17:30	1/10/2006 18:00
7	Discussion of Groups for Project	0.25 days	1/10/2006 17:30	1/10/2006 19:30
8	**Pre-Checklist Meeting**	**15 mins**	**1/10/2006 17:30**	**1/10/2006 17:45**
9	**Third ENVS 3502 Class**	**0.13 days**	**1/17/2006 17:30**	**1/17/2006 18:30**
10	First Group Meeting	0.13 days	1/22/2006 8:00	1/22/2006 9:00
11	Discussion of Literature Review	1 hr	1/22/2006 8:00	1/22/2006 9:00
12	Discussion of Proposal Ideas	0.5 hrs	1/22/2006 8:00	1/22/2006 8:30
13	**Fourth ENVS 3502 Class**	**0.25 days**	**1/24/2006 17:30**	**1/24/2006 19:30**
14	Course Information	2 hrs	1/24/2006 17:30	1/24/2006 19:30
15	Discussion of Literature Review and Project Proposal	1 hr	1/24/2006 17:30	1/24/2006 18:30
16	**Fifth ENVS 3502 Class**	**0.25 days**	**1/31/2006 17:30**	**1/31/2006 19:30**
17	Test	1 hr	1/31/2006 17:30	1/31/2006 18:30
18	Course Information	2 hrs	1/31/2006 17:30	1/31/2006 19:30
19	**Second Group Meeting**	**0.03 days**	**2/2/2006 8:00**	**2/2/2006 8:15**
20	Assign Tasks for Proposal Completion	0.25 hrs	2/2/2006 8:00	2/2/2006 8:15
21	Discuss the Statement of Problem	0.25 hrs	2/2/2006 8:00	2/2/2006 8:15
22	Discuss the Goals and Objectives	0.25 hrs	2/2/2006 8:00	2/2/2006 8:15
23	Discuss the Purpose and Scope	0.25 hrs	2/2/2006 8:00	2/2/2006 8:15
24	Discuss the Introduction	0.25 hrs	2/2/2006 8:00	2/2/2006 8:15
25	**Third Group Meeting**	**2 hrs**	**2/6/2006 8:00**	**2/6/2006 10:00**
26	**Completion of Presentation and Proposal**	**3 hrs**	**2/6/2006 8:00**	**2/6/2006 11:00**
27	**Sixth ENVS 3502 Class**	**0.13 days**	**2/7/2006 17:30**	**2/7/2006 18:30**
28	Proposal Due	0.5 hrs	2/7/2006 17:30	2/7/2006 18:00
29	Presentation	1 hr	2/7/2006 17:30	2/7/2006 18:30

30	Ethics Form Due	0.5 hrs	2/7/2006 17:30	2/7/2006 18:00
31	Course Information	1 hr	2/7/2006 17:30	2/7/2006 18:30
32	**Seventh ENVS 3502 Class**	**0.25 days**	**2/14/2006 17:30**	**2/14/2006 19:30**
33	Discussion on Pilot Testing	1 hr	2/14/2006 17:30	2/14/2006 18:30
34	Group work on projects	2 hrs	2/14/2006 17:30	2/14/2006 19:30
35	**Eighth ENVS 3502 Class**	0.13 days	2/28/2006 17:30	2/28/2006 18:30
36	Feedback from presentations	1 hr	2/28/2006 17:30	2/28/2006 18:30
37	Individual project analysis assignment	1 hr	2/28/2006 17:30	2/28/2006 18:30
38	Groups present favorite case	1 hr	2/28/2006 17:30	2/28/2006 18:30
39	**Ninth ENVS 3502 Class**	**0.13 days**	**3/7/2006 17:30**	**3/7/2006 18:30**
40	Writing Good Reports	1 hr	3/7/2006 17:30	3/7/2006 18:30
41	Readings Discussions	1 hr	3/7/2006 17:30	3/7/2006 18:30
42	Group work on projects	1 hr	3/7/2006 17:30	3/7/2006 18:30
43	**Tenth ENVS 3502 Class**	**0.19 days**	**3/14/2006 17:30**	**3/14/2006 19:00**
44	Making Good Presentations and Posters	1.5 hrs	3/14/2006 17:30	3/14/2006 19:00
45	Group work on project	1.5 hrs	3/14/2006 17:30	3/14/2006 19:00
46	**Eleventh ENVS 3502 Class**	**0.19 days**	**3/21/2006 17:30**	**3/21/2006 19:00**
47	Test 2	1.5 hrs	3/21/2006 17:30	3/21/2006 19:00
48	Group work on project	1.5 hrs	3/21/2006 17:30	3/21/2006 19:00
49	**Twelfth ENVS 3502 Class**	**0.38 days**	**3/28/2006 17:30**	**3/28/2006 20:30**
50	Poster Display and Presentations	3 hrs	3/28/2006 17:30	3/28/2006 20:30
51	**Thirteenth ENVS 3502 Class**	**0.38 days**	**4/4/2006 17:30**	**4/4/2006 20:30**
52	Poster Display and Presentations	3 hrs	4/4/2006 17:30	4/4/2006 20:30
53	**Fourteenth ENVS 3502 Class**	**0.38 days**	**1/3/2006 17:30**	**1/3/2006 20:30**
54	**Projects Due**	**3 hrs**	**1/3/2006 17:30**	**1/3/2006 20:30**