Trent Vegetable Gardens' Ecological Irrigation Project

Includes:

Research Report

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Trent Vegetable Gardens Ecological Irrigation Project: Research Report

Abstract: Aimee Blyth, the coordinator of Trent vegetable gardens and student volunteers, are currently collecting rainwater in barrels to irrigate a small 1 acre garden at Trent University. Using this method, they do not collect enough water to irrigate the garden during periods without rain. The lack of water for irrigation is reducing both the quantity and quality of fresh organic produce grown for the Seasoned Spoon Café and more recently the Peterborough community, primarily for Food Not Bombs. The purpose of this project is to investigate ecologically friendly irrigation techniques that could be adopted by Trent vegetable gardens. Irrigating the garden in a more efficient and ecological manner will allow Trent vegetable gardens to further contribute toward their mandate of encouraging local, organic food production and reconnecting students with their food source.

Keywords: Irrigation, Ecological, Rainwater Harvesting, Solar, Drip Irrigation, Windmill.

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<u>Section 1</u>: Introduction

<u>Purpose</u>

Aimee Blyth, the coordinator of Trent vegetable gardens and student volunteers, are currently collecting rainwater in barrels to irrigate a small 1 acre garden northeast of the Environmental Science Building at Trent University. Using this method, they do not collect enough water to irrigate the garden during periods without rain. The lack of water for irrigation is reducing both the quantity and quality of fresh organic produce grown for the Seasoned Spoon Café and more recently the Peterborough community, primarily for Food Not Bombs. The purpose of this project is to investigate ecologically friendly irrigation techniques that could be adopted by Trent vegetable gardens. Irrigating the garden in a more efficient and ecological manner will allow Trent vegetable gardens to further contribute toward their mandate of encouraging local, organic food production and reconnecting students with their food source.

<u>Importance of Ecological Irrigation</u>

Moving Towards a Sustainable Food System at Trent

One hundred and fifty years ago, the primary production of food in the Peterborough area was for farmers themselves and local communities. This system was based on a scheme of mixed farming and trade of agricultural goods within communities (Andree, 1997). Over a relatively short period of time, the traditional system based on the consumption of food where it was produced changed to a system based on the shipment of food from far-off places (Andree, 1997). Specifically, our food system has become largely dominated by multinational, conglomerate retail chains (Winson, 1993). Trent vegetable gardens, together with the Seasoned Spoon, are providing students with an alternative to convenience food franchises like Tim Horton's and on-campus food outlets like ARAMARK that source their ingredients from food conglomerates like SYSCO (Blyth et. al., 2006). As a result, the food system at Trent is becoming more sustainable. By increasing both the quantity and quality of vegetables produced through more efficient, ecological irrigation, the mandate of Trent vegetable gardens will be strengthened and the food system at Trent will be further improved.

Education

Part of Trent vegetable garden's mandate is to provide space for students to learn more about the food system, ecological agriculture and to acquire gardening skills. These learning opportunities take the form of reading courses, workshops, independent research, and through volunteering. Specifically, the one acre on campus vegetable garden will be used as a model/demonstration site for sustainable and ecological agriculture. Therefore, the development and implementation of on-site ecological irrigation methods will have considerable educational value. Importantly, the Environmental Science Department will be able to provide students with a unique, hands-on learning opportunity with emphasis on food and agriculture. While having a firm understanding of theoretical principles is important, students will acquire practical skills and knowledge that are simply not available on PowerPoint slides. For example, students will learn how to design, install and operate various components of an ecologically friendly irrigation system.

The Current Irrigation Situation

As we've already mentioned, the staff and student volunteers from Trent vegetable gardens are currently collecting rainwater in barrels. Specifically, a 250 gallon water tank stores rainwater harvested from one slope of the farmhouse roof. It takes approximately one or two good rains to fill the 250 gallon storage tank. Water is then gravity fed through a garden hose to a barrel near the 1-acre garden. Once this barrel is filled, the garden is 'irrigated' using buckets. Without question, the current method is labour intensive and time consuming. Importantly, the gardeners do not collect enough water to irrigate the garden during periods without rain (A. Blythe, personal communication, October 9th 2008). Currently, there is not enough water storage capacity to harvest rainwater from the entire roof.

About Ecological Irrigation

Agricultural irrigation consumes vast quantities of water. In fact, agriculture accounts for 70% of worldwide water withdrawal (FAO, 2007). On average, an individual uses 600 m³ of water per year. Alarmingly, this represents approximately 63% of renewable freshwater resources in areas like North Africa (FAO, 2007). To keep up with the growing demand for food during the next 30 years, it has been estimated that the amount of irrigated agricultural land in developing countries will need to be increased by 34% (FA0, 2007). In North America, particularly in the American Midwest, demand for irrigation water will likely increase substantially because of climate change (USEPA, 2007). We have to develop irrigation strategies that distribute water efficiently and rely less on the consumption of fossil fuels. Showcasing ecological irrigation strategies like rainwater harvesting or solar pumping at Trent will only further enforce this directive.

Key Research Goals

- How much water will be required to irrigate the 1 acre garden?
- What is already being done regarding irrigation on the 1 acre garden?
- What options are available for ecologically friendly irrigation at the 1 acre garden?
- What are the costs involved with the various options?
- What is the status of the on-site well?

Major Research Findings

- Approximate garden water requirement: 81, 562 gallons
- 50,000 litres is the maximum amount of water that can be taken from any water source on any given day in Ontario.

- Approximately 12,082 gallons of rainwater could be harvested from the farm house roof (June-September).
- Un-capping the farmhouse well is not an option. Drilling a new well would be far cheaper.
- The approximate cost of drilling a new well is $3050
- Trent vegetable garden's current budget of $1000-$2000 is insufficient for developing an ecological irrigation system.
- If the long-term goal is to showcase ecological irrigation at Trent, we believe Trent Vegetable gardens should invest in a pond and a diesel pump powered by vegetable oil.
- Further research is urgently needed. Specifically, a group of students should be given the task of researching various funding options.

<u>Section 2</u>: Water Requirements

According to Rebecca Shortt (personal communication, November 4th, 2008) a water quantity engineer with the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), during a summer with 'normal' rainfall, the 1 acre vegetable garden will require approximately 3 weeks of irrigation. Over this 3 week span, the garden will have to be 'covered' with approximately 75 mm (3") of water. There are 27,154 gallons of water in an acre inch of water (Zawacki, 2008). Therefore, approximately 81, 462 gallons of water will be required to irrigate the 1 acre garden during a 3 week dry period. Please note that this is only an approximation. The actual volume of water to be used for irrigation will depend on what will be grown and what kinds of yields/losses Trent vegetable gardens is willing to accept (R. Shortt, personal communication, November 4th 2008). These variables have not been included in our water requirement calculations (see Appendix). It is important to note that water use could be significantly reduced by mulching (Gouranga et. al., 2007), and other water wise gardening practices like irrigating at night. In addition, the water requirement of the 1 acre garden could be drastically reduced by irrigating only half the garden, and leaving the other half in a cover crop rotation that does not need to be irrigated.

If Trent vegetable gardens takes more than 50,000 L of water on any given day from any water source (well, pond, wet area, drainage ditch etc) they will have to apply to the Ontario Ministry of the Environment for a 'Permit to Take Water' (see Appendix). This law is governed by the Ontario Water Resources Act and the Water Taking and Transfer Regulation (OMOE, 2008). Since there is only 1 acre of garden area to be irrigated, the gardeners may be able to stay under the 50,000 L/day (12.4mm over the entire 1 acre area) threshold (R. Shortt, personal communication, November 4th 2008). This would be even less if only half the garden was intensively irrigated. The biggest challenge for Trent vegetable gardens is securing an adequate supply of water (R. Shortt, personal communication, November 4th 2008).

<u>Section 3</u>: Options- Securing an Adequate Supply of Water

<u>Rainwater Harvesting</u>

Rainwater harvesting involves collecting or 'harvesting' rainwater and storing it for future use (see Appendix). According to Kincaid-Levario (2007), "Rainwater collection has been used for several thousand years as a way to take advantage of seasonal precipitation that would otherwise be lost to runoff or evaporation". Currently, gardeners from Trent vegetable gardens are harvesting rainwater from the nearby farmhouse roof and storing it in a small tank for use as irrigation water. However, less than a ¼ of the roof's total surface area is being utilized. The harvested rainwater is then gravity-fed to a series of 45 gallon barrels. From here, the rainwater is bucketed to plants (A. Blythe, personal communication, October 9th 2008). Alternatively, rainwater could be harvested from the entire roof. This would require a large tank because of the increased need for storage capacity. The stored rainwater could either be dispersed to the distribution system via gravity or pumped.

The surface area of the farmhouse roof, including the addition and drive shed is equal to approximately 1902 square feet. The mean depth of summer rainfall (Table 1) measured at the Trent University Climate Station from 1971 to 2000 is 323mm (Environment Canada, 2006). For our calculations (see Appendix), we used a collection efficiency of 80%. From June through September, approximately 12,082 gallons of rainwater could be harvested from the farmhouse roof. Considering that periods of drought often occur all at once, harvested rainwater would have to be stored ahead of time. Please note that the figure noted above does not consider the timing of a drought period. Regardless, 12,082 gallons represents only a small proportion of the estimated water requirement (81,462 gallons). Irrigating the garden for just one week would require a 19'x19'x10' (27,000 gallon) storage tank. Over a three week span, this tank would have to be filled three times (R. Shortt, personal communication, November 4th 2008). Although large tanks are available, they are very expensive (D. Davidson, personal communication, November 25th 2008).

Because of limitations involving water volume and storage, it appears the value of rainwater harvesting is limited if Trent vegetable gardens intends to irrigate the garden intensively (27,000 gallons/week). If rainwater was harvested from a larger surface area, perhaps from the barn roof, more water could be acquired. Unfortunately, the steel sheeting on the barn roof is slowly falling off piece by piece. Securing an adequate supply of water via a rainwater harvesting system definitely falls within the realm of ecological irrigation. If 12,082 gallons were applied evenly over a 3 week span, roughly 575 gallons could be applied per day. Depending on the yields/losses Trent vegetable gardens is willing to accept, this may be a viable option. The majority of the farmhouse's eaves troughs would need to be replaced, a solid platform, perhaps a concrete footing, would have to be installed for a storage tank and finally, a large storage tank would be required with enough storage capacity to handle the harvested rainwater. We are unsure exactly how much this would cost.

Table 1: Average Summer Rainfall

Month	June	July	August	September
Average Rainfall (mm)	78.9	68.4	91.6	84.3
Total	323.2			

Well Water

There is an abandoned well near the front entrance of the farmhouse. In accordance with Ontario's Water Resources Act, Regulation 903 (1990), abandoned wells shall be sealed at the ground surface by means of:

i. Placing between 50 and 150 centimetres in vertical thickness of bentonite chips, pellets, granules or powder in the well opening in accordance with the manufacturer's specifications, and;

ii. Fill the remaining well opening to the ground surface with soil cover, or other material that is more in keeping with the surface material immediately adjacent to the well opening, to prevent inadvertent or unauthorized access.

We spoke with Dan MacIntyre (personal communication, November 19th 2008) a hydro geological technician with Oak Ridge Environmental Inc. regarding the practicality of un-capping the abandoned well. We contacted Oak Ridge Environmental Inc. because the company is designated by the Ontario Ministry of the Environment as a licensed well contractor. According to Mr. McIntyre, if the well was abandoned in accordance with Ontario Regulation 903, a portion of the well would have been filled with Bentonite, an absorbent clay-like material. The remainder would have been filled with soil and the opening capped with cement. In addition, the well fracture would have likely been filled with cement. Therefore, it would be necessary and far more cost-effective, to simply drill a new well.

We spoke with Herb Lang (personal communication, November 19th 2008), a local well driller about having a new well drilled. Mr. Lang has been drilling wells in the vicinity of Trent University for the past 40 years. In this area, he has generally had to drill anywhere between 40 and 70 feet before hitting water. He charges $40.00 per foot, including labour. In addition, there is a $1450.00 environmental fee. This fee includes the installation of a well shoe, a well casing, a vermin proof cap and the filing of a well tag and record with the Ontario Ministry of Environment. Therefore, if a well was drilled to a depth of 40 ft, it would cost Trent vegetable gardens approximately $3050.00.

Otonabee River

The third option is to pump water from the Otonabee River. This could be done in two ways:

a) pump water into a tank and deliver it to the garden site or;
b) pump water from the Otonabee River directly to the garden site

The first scenario would require two tanks. One tank would be used to deliver water from the river to the garden site. Trent vegetable gardens already own a small tank that could be utilized for this purpose. The second tank would have to be much larger in order to handle the volume of water needed for irrigation. In addition to the cost of purchasing a large storage tank, some kind of platform would likely be required for the tank to sit on. Perhaps the university's physical resources staff could pump water from the river and transport it to the garden site.

Like the first scenario, the second scenario would require a large storage tank. Specifically, water could be pumped from the Otonabee River (see 'Options-Pumping Water' below) into a large storage tank at the garden site. There are several problems associated with this scenario. First, the water would have to be pumped across Nassau Mills Road. This could possibly disrupt traffic and minimize pumping efficiency. Secondly, a large amount of pipe would be needed to pump water from the river to the garden site. Considering the distance between the river and the garden site, this would be quite costly. Finally, the garden site is located up-hill of the river. This would reduce pumping efficiency. Unfortunately, moving the garden closer to the river is not an option considering riverside acreage is not included in the 25 acres designated for agricultural use by the university's administration (T. Hutchinson, personal communication, October 28th 2008).

<u>Pond</u>

Ponds are often used as a source of water for irrigation. As we have noted above, Chris Lincoln and Brenda Tonn pump water from a relatively large pond in order to meet their irrigation needs. We also spoke with Pat Learmonth, a local gardener who recently had a pond dug on her property (personal communication, December 4th 2008). Although she uses the pond as a source of irrigation water, the pond also provides habitat value (P. Learmonth, personal communication, December 4th 2008). According to Pat, the pond has a capacity of approximately 900,000 gallons of water and it has a depth of about 25 feet in the deepest spot. Her pond has never gone dry, not even during periods of extreme drought (P. Learmonth, personal communication, December 4th 2008). If Trent vegetable gardens were to dig a pond for irrigation purposes only, Pat estimates that it would cost approximately $12,000 (P. Learmonth, personal communication, December 4th 2008). We spoke with Chad Mathews who is the owner of a very reputable local excavating company. Chad's hourly rate is $100.00 per hour. He also charges an additional float fee (C. Mathews, personal communication, October 2008). If Chad spent 5 days (8 hours/day) digging a pond for Trent vegetable gardens, it would cost approximately $4000.00. This is comparable in price to having a well drilled.

There are two types of ponds, dug ponds and damned ponds. The implementation of either is decided by site qualities. To find a suitable site for a pond, the following criteria should be followed. The soil should be impermeable to water (such as clay) and not sandy or gravelly. To test this, soil samples should be taken as deep as the pond depth. Once the soil test is complete, the topography of the site should be examined. If the drop across 100 yards is between 0-2 feet (0-0.6 m) then a dug or excavated pond would be best suited. If the drop across 100 yards is between 2-4 feet (0.6-1.2 m) then an impoundment or "berm" pond is suitable. An excavated pond is dug by heavy machinery, and is essentially a hole in the ground. This method is more expensive and the removed dirt from the site has to be relocated. An impoundment pond uses a gentle slope and berms to hold water, much like a damn, and is significantly cheaper because it requires the removal of less dirt. If the site satisfies these requirements and is not located in a floodplain or stream (for erosion issues and sediment accumulation in the pond) then a pond could be implemented. However, the pond needs to be placed in lowland that will accumulate water. (Ducks Unlimited, 2008)

From our own personal experience, placement of the pond will be essential. Recently, Bryce's parents purchased 60 acres adjacent to their home farm. The previous owners dug three ponds, all of which are spring fed on a year round basis. Unfortunately, all three ponds go dry each summer. This is because the previous owners did not seriously consider soil parameters. The ponds should have been located in an adjacent spillway where there is a deep layer of clay beneath the upper soil layers. In last year's soil management and conservation class, Bryce did a soil survey of the area directly west of the current 1 acre garden site. There is a large spillway that runs north and south, east of the Rotary trail. Approximately 2 feet beneath the upper soil layer, there was a viscous layer of clay with very pronounced mottling which is indicative of an area that undergoes periodic flooding. The soil pit quickly filled up with water. We think this would be a great spot to dig a pond. We believe a diesel pump powered by vegetable oil would be capable of pumping water from this location to the garden site. However, we're unsure if the spillway is part of the 25 acres designated for agricultural use by the university's administration (T. Hutchinson, personal communication, October 28th 2008).

Although we did not have a chance due to time restraints, certain calculations and data should be researched. The design of the pond will be based on the water requirements of the garden. To calculate the amount of water available for irrigation in a pond, the following values must be found: the seepage rate of the soils, the amount of water evaporated in a summer, and the permanent pool of water that is unavailable for irrigation. Once these values are found, they are subtracted from the total volume of water. The final value is the amount of water available for irrigation. Another important value is the ability of the watershed to recharge the pond. Once the pond site has been located, the amount of water that could be collected from the local watershed needs to be calculated in order to determine the proper size of the pond. (McCarty, 2008)

If Trent vegetable gardens decide to dig a pond, we believe it should provide habitat value in addition to being a source of water for irrigation. We spoke with Jennifer Lavigne, a conservation specialist with Ducks Unlimited Canada concerning getting funding for a small pond. Ducks Unlimited provides funding for shallow wildlife ponds (3-4 feet deep) in low disturbance areas. In order to receive funding, Trent University would have to sign a conservation agreement with Ducks Unlimited Canada. Trent vegetable gardens should be in contact with Jennifer as soon as possible for this option to be considered. There are conservation authority approvals, Ministry of Natural Resource (MNR) approvals, match funding dollars, agreements etc. that take months to process (J. Lavigne, personal communication, December 3rd 2008). Due to time constraints, we were unable to look into this further. However, future students should be charged with the task of researching various construction scenarios and funding options in further detail.

After talking Dan Bughas at the Otonabee Conservation Center (personal communication, December 8th, 2008), the construction of a pond might or might not require a permit. If the proposed site is in a regulated area then a permit is required, if the proposed site is not then no permit from the conservation authority is needed. He advised that after a suitable site is found, whoever is involved in the project should be in contact with him to discuss these details.

<u>Section 4</u>: Options-Pumping Water

<u>Windmill Pumping Systems</u>

Designs

Historically, windmills have been used to pump water for many years (see Appendix). There are three basic windmill pumping designs that can be used to pump water- mechanical pumping, air pumping and electric pumping. Each design has its own advantages and disadvantages (Stone & Clarke, 2004).

The mechanical pumping design involves a large bladed prop, a gear box and a piston pump. As the bladed prop rotates, it creates energy. This energy is transferred to the gear box. In turn, the gear box drives the piston pump. The major disadvantage of this design is that the windmill has to be placed directly over a well (Stone & Clarke, 2004).

The air pumping design involves forcing compressed air through a pipe via the rotational energy of the windmill. Through the process of aeration, a certain proportion of water rises up the pipe because it is lighter than the surrounding water. A major advantage of this design is that the windmill can be placed away from the well, perhaps on a hill. In addition, the design is quite economical. However, this system has a couple of distinct disadvantages. First, the piping system needs to be placed far below the well's water line. Most wells do not have enough depth to meet this requirement. Secondly, the design is limited in terms of how much water can be pumped (Stone & Clarke, 2004).

The electric pumping design utilizes the rotational energy of the windmill to produce electricity. This electricity is then used to run a pump. Although some pumps are capable of pumping water as the windmill rotates, a large storage tank is required to hold the water. Alternatively, a battery system can be purchased to store the electricity generated by the windmill. If this were the case, the pump could be activated at will. Of the three pumping designs, this design will pump the most water. In addition, the windmill can be conveniently placed away from the well.

On-Site Considerations

For obvious reasons, if a windmill pumping system is to function as designed there has to be wind. Therefore, it would be necessary to take on-site wind measurements with an anemometer prior to installing a windmill pumping system. Wind data from the University's climate station is available from Peter Lafleur, a geography professor here at Trent (P. Lafleur, personal communication, November 11th 2008). Stone and Clarke (2004) recommend that windmills be placed at least 9 metres (30') above and 90 metres (300') away from any wind reducing object, including trees, buildings etc.

Cost

According to Stone and Clarke (2004), “The price of windmill systems can vary greatly depending on the size and quality of components used. A very rough approximation is $3,000-$6,000”.

<u>Case Study</u>*: The Lincoln/Tonn Experience*

Chris Lincoln and Brenda Tonn own a ¾ acre market garden east of Havelock, Ontario. They use a windmill to pump pond water into a 500 gallon storage tank that has been raised off the ground 8 ft. The water flows from the tank to their drip irrigation system by gravity. For ‘deep’ watering (1 ½ gallons/plant), 500 gallons of water will irrigate approximately 330 plants. The windmill runs a submersible horizontal pump that sits 28 ft. below the surface of their pond. From the pond to the storage tank, the pump delivers water through a pipe a distance of 70 meters (B. Tonn, personal communication, November 24^{th} 2008). According to Brenda, the major advantage of this system is its ecological friendliness. However, there are some major drawbacks. Even though Chris and Brenda placed the windmill on top of a large hill, there is simply not enough wind to rotate the windmill when water is desperately needed during periods of drought. Unfortunately, placing the windmill on top of the hill cost the couple a considerable amount of extra money. Another major drawback is the fact that it takes approximately 3 hours to fill the 500 gallon tank with water. Once they have emptied the tank, they simply don’t have 3 hours to wait for it to fill back up. For this reason, the couple compensates for the poor pumping efficiency of their windmill system by using a gas powered pump. This pump fills the tank in about 5 minutes. If there is a lot of time to spare, this may not be an issue. The third drawback is cost. For the windmill and pump, the couple spent roughly $4000.00. In retrospect, Brenda admits they are receiving a poor monetary return on their investment (B. Tonn, personal communication, November 24^{th} 2008).

<u>Solar Pumping Systems</u>

Designs

According to Agriculture and Agri-Food Canada (2007), “A solar-powered pump is a normal pump with an electric motor. Electricity for the motor is generated on-site through a solar panel which converts solar energy to direct-current (DC) electricity” (see Appendix). There are two types of solar pumping systems, the ‘direct-drive’ and ‘battery’ systems. As the name implies, the direct-drive system is capable of pumping water while the solar panel/s capture the sun’s energy. This system requires a large tank to store the water. Alternatively, the battery system is capable of storing the electricity generated by the solar panel/s (Agriculture and Agri-Food Canada, 2007; Stone & Clarke, 2004). Therefore, this specific system can pump water ‘on-demand’ and does not generally require a tank for water storage. The volume of water that a solar pump can deliver is directly related to the amount of energy it receives from the sun. Therefore, if clouds block out the sun, pumping efficiency is dramatically reduced (Helikson et. al., 1991). However, a major advantage of the battery system is that it can store electricity for use on cloudy days.

Several solar pump designs are available for specific applications. A submersible centrifugal pump is well suited to situations where water must be pumped from a well. Floating pumps are a common choice for tank or pond applications. The amount of water that can be delivered by a solar pump is dependent on several factors besides the sun's irradiance. According to Agriculture and Agri-Food Canada (2007) "The amount of water a solar powered pump can deliver is a function of how far the water has to be lifted, the distance it has to travel through a delivery pipe (and the size of pipe), the efficiency of the pump being used, and how much power is available to the system". It is important to remember that power (Watts) delivered to the pump can be increased by adding more solar panels (Agriculture and Agri-Food Canada, 2007).

On-Site Considerations

The angle of the photovoltaic solar panels should be adjusted on a seasonal basis so as to maximize absorbency of the sun's energy (Stone & Clarke, 2004). To increase the efficiency of the system, specialized tracking devices are available. These devices track the sun's movement throughout the day and adjust the solar panels accordingly. For certain applications, the increased cost of adding such devices might not be worth the bother (Agriculture and Agri-Food Canada, 2007). Ideally, the solar panel/s should face directly south, perhaps on the farmhouse roof. For maximum efficiency during the summer, it is recommended that the panels be tilted in accordance with the latitude of the site, minus 10-15 degrees (Agriculture and Agri-Food Canada, 2007).

We spoke with Jason Wright (personal communication, November 27th 2008) a solar pumping specialist with Cap Solar in Olds, Alberta. According to Jason, before he can properly design a solar pumping system for any given application, he needs to know the approximate daily operating hours of the solar pump, the vertical 'lift' from the water source (i.e. well), the seasonal parameters of the application (i.e. summer or winter) and whether or not the specific application requires an 'on-demand' battery system.

Cost

According to Agriculture and Agri-Food Canada (2007), "The cost of a solar-powered pumping system will naturally vary according to its capabilities, but the cost of most systems for stockwatering applications ranges between $2,000 and $6,000". We spoke with Simon Boone (personal communication, November 27th 2008) from Generation Solar here in Peterborough regarding the cost of a solar powered pumping system for a 1-acre garden irrigation application. Depending on details like pumping distance and lift, Trent vegetable gardens could be looking at approximately $5000 - $9000 for a submersible pump system to provide only 1000 gallons per day.

Sling Pump System

Design

The sling pump is powered by the flow of moving water like that of the Otonabee River (see Appendix). An attached propeller slowly rotates the entire pump, and while it's rotating, water and air enter the pump from behind. Once it enters the pump, the water is forced through a coil of plastic tubes and is then pushed out the exhaust hose and into a stock tank (Stone & Clarke, 2004). For a sling pump to operate effetively, they require a minimum of 2.5 feet of water to operate in. Sling pumps also require a minimum stream velocity of approximately 1.5 feet per second to operate. These pumps can provide the power to pump the water to elevations greater than 50 feet with flow rates of one to two gallons. Sling pumps have high maintenance requirements. Floating debris can stop the pump from rotating; the pump must be properly secured so it does not get lost during high-water events; and frequent monitoring and cleaning are required for dependable operation. (Stone & Clarke, 2004)

On-Site Considerations

The sling pump can be used to assist in the collection of water for distribution. It is an economical and environmentally sound way of pumping the water to the garden site. However, there are some significant problems that must be confronted. First is the issue of the road and Trent Parking lot directly in between the two areas. Not only would we have to find a way of covering and protecting it but also a way ensuring that it is not damaged in vehicle accidents. In addition, the elevation and distance of the gardens from the Otonabee might be too much for the pump to handle, accurate measurements of the elevation and distance must be measured before to ensure that this is a viable option.

Cost

According to Stone & Clarke (2004), "The cost for a sling pump ranges from $900-$1,600". This is by far the cheapest ecological water pumping option we have encountered. Sling pumps can be purchased from a number of manufacturers, Rife Water pumps and Real Goods, U.S.A. are two examples.

Treadle Pump System

Design

Treadle pumps are a human powered design. They consist of a cylinder, a piston, and levers to move the piston up and down in the cylinder (see Appendix). A pipe connected to a water source is fitted to the cylinder with a non-return valve, preventing the escape of water back in the source. The raising of the cylinder creates a vacuum in the cylinder, and water is sucked into the pump. When the piston is then pushed down, water via a valve is then released above the piston. When the piston is raised again, the water that was collected above the piston is released out of the top of the pipe into a collection area to be used for irrigation. Advances in the design include the addition of two cylinders side by side. With the placement of levers, the design can be used to utilize leg power by the motion of walking. The levers are placed below the area where someone's feet would be in a walking stance, much like the stair climbing exercise machines; the downwards pressure of the individuals body weight operates the pump (Brabben, 2000).

On-Site Considerations

The length of the water intake pipe is extremely important. Because of pressure limitations, the pipe should be no more than 7m (23 feet) long. In other words, the longer the pipe, the less water pressure the pump is able to produce. Ideally, the shorter the pipe the better, but this is limited by the depth of the water source (Brabben, 2000). For example, if water was pumped from a well with a depth of 40 feet, a treadle pump would not be a viable option because the water intake pipe would be longer than 23 feet.

Cost

The cost of the treadle pump is dependant on a number of features, such as the quality of the materials and the production costs. For a well made system in the United States it could cost around $2700, however, for much less one can be built by the Garden committee. (New Dawn Engineering, No Date).

<u>Traditional Diesel Pump Powered by Vegetable Oil</u>

Design

We spoke with Darnell Kahn and Dave Wilkins, two renewable fuels specialists with Alternatech Canada about the possibilty of retrofitting a diesel powered pump to run on vegetable oil or bio-diesel. Diesel engines were first designed to run on vegetable oil. In fact, vegetable oil combusts more easily than traditional diesel fuel because of the vegetable oils inherently high amount of cetane, which is equivalent to octane found in traditional fuels (D. Kahn & D. Wilkins, personal communication, December 3rd, 2008). Amazingly, the fuel efficiency of vegetable oil does not differ from that of traditional diesel fuel (D. Kahn & D. Wilkins, personal communication, December 3rd 2008). Any diesel engine can run on vegetable oil as long the oil is heated prior to combustion. If vegetable oil is put into the engine unheated, carbon deposits will build up on the valves and pistons resulting in damage to the engine. In fact, the engine may even sieze. This makes sense considering that cold vegetable is viscous and hard to move, creating friction between the engines moving parts (D. Kahn & D. Wilkins, personal communication, December 3rd 2008). Fortunately, oil can be pre-heated by an 'air to liquid' heat exchanger that uses the heat created by the running engine to heat the oil. This process is known as 'heat reclamation' (D. Kahn & D. Wilkins, personal communication, December 3rd 2008).

The second major design aspect is ensuring that the oil is properly filtered prior to being used in an engine. Specifically, used vegetable oil normally contains by-products of the frying process, particularly food particles and water. Water is particularly problematic because it ruins fuel injectors. Fortunately, both food particles and water can be removed from used vegetable oil by allowing the oil to settle in a closed container for at least a week. (D. Kahn & D. Wilkins, personal communication, December 3rd 2008).

Both Darnell and Dave agree that biodiesel is not as well suited in comparison to vegetable oil for this specific application. Making bio-diesel is relatively dangerous with an assortment of chemicals involved. For example, pottasium hydroxide is used as the base, or catalyst. Spills are hard to deal with and the production of bio-diesel requires a chemistry lab setting with high inputs of water and electricity (D. Kahn & D. Wilkins, December 3rd 2008). They doubt that the university's administration would be open to the idea of producing bio-diesel because of these safety constraints (D. Kahn & D. Wilkins, personal communication, December 3rd 2008). Furthermore, producing biodiesel costs roughly 25 cents per litre in comparison to vegetable oil which is generally free (D. Kahn & D. Wilkins, personal communication, December 3rd 2008).

On-Site Considerations

Both Darnell and Dave believe the opportunities for irrigation using a vegetable powered pump are endless. They suggest that a small passive solar building (similar to a greenhouse) would be required to house the diesel engine, pump and filtration system. If the dimensions of the building were less than 100 square feet, no building permit would be required (D. Kahn & D. Wilkins, personal communication, December 3rd 2008). They believe that the passive solar design would generate enough natural heat inside the building to pre-heat the vegetable oil (D. Kahn & D. Wilkins, personal communication, 2008). Of course, exhaust fumes would have to be vented outside the building.

Used vegetable oil could be collected from the Aramark facilities on campus. It would be delivered to the passive solar building (see Appendix) and poured into a 45 gallon barrel through a large funnel and screen filter that would catch most of the large food particles. Over time, the debris (food particles and water) would settle to the bottom of the barrel and the oil would settle to the top. A drain would be installed on the bottom of the barrel so that the debris could be periodically drained. This would need to be done at least once a year. A handpump would be installed on the barrel in order to pump the oil out of the barrel. Importantly, the handpump's intake hose would have to be elevated above to bottom of the barrel so that it would not pump out any debris. A 10 micron'water block' filter and a 5 micron traditional water filter would be spliced into the pump's outlet hose in order to remove any remaing food particles, water or other debris. In this manner, vegetable oil could be delivered to the diesel engine's fuel tank as needed (D. Kahn and D. Wilkins, personal communication, December 3rd 2008).

Importantly, this pumping option provides room for expansion. Specifically, Trent vegatable gardens could plant canola, harvest it, and render their own canola oil using a cold press. This canola oil could be used to run the pump. The 'meal' created as a by-product of this rendering process could be composted or fed to local cattle. A large cold press generally sells for approximatly $2000.00. Amazingly, 1 acre of canola can yield approximatly 3000 litres of canola oil a year (D. Kahn & D. Wilkins, personal communication, December 3rd 2008).

Cost

PumpBiz® Inc (2008), a reputable pump supplier in Illinois advertises an engine driven portable pump kit for $260 on their website (see Appendix). This pump is capable of pumping 200 gallons per minute at a pressure of 46.32 pounds per square inch (p.s.i). In addition, this specific pump has a lift of 107 ft. and requires a 5 horsepower engine (PumpBiz® Inc., 2008). In terms of buying the engine, Darnell and Dave assured us that deals are available. Many construction companies are retrofitting their portable roadside signs. Specifically, they are having the small diesel engines that produce electricity in order to run the signs removed and replaced with photovoltaic solar cells. Darnell and Dave recently purchased one of these engines for $250.00 (D. Kahn & D. Wilkins, personal communication, December 3rd 2008). Princess Auto has a 10 horsepower diesel engine on sale in their most recent flyer for $488.00 (see Appendix). In terms of the filtration system, Trent vegetable gardens should be able to find a used 45 gallon barrel for free. A hand pump for the barrel generally sells for about $ 60.00 and the necessary filters sell for about $20.00 each (D. Kahn and D. Wilkins, personal communication, December 3rd 2008). We are unsure how much the passive solar building would cost. However, many of the materials, particularly windows, could be purchased at local flea markets etc.

Section 5: Options- Distribution

Drip Irrigation

Why Drip Irrigation?

For this specific application, drip irrigation is the most practical irrigation strategy (R. Shortt, personal communication, November 4th 2008). Drip irrigation systems are far more efficient and inexpensive than other systems, particularly sprinklers. Specifically, sprinkler systems do not distribute water as efficiently and require larger pumps (Kovacs, personal communication, November 20th and 21st 2008). For example, the sprinklers commonly recommended for this kind of application require approximately 7 gallons of water per minute. A single sprinkler would irrigate a radius of 46 feet. Therefore, three of these sprinklers in a row would only irrigate a ¼ of the garden and would consume approximately 24 gallons of water per minute (D. Kovacs, personal communication, November 20th and 21st 2008). Because of their inefficiency, government agencies have recommended that sprinkler irrigation systems be eventually disallowed (NHDES, 2007; OMAFRA, 2004). There are other specific advantages besides water efficiency. For example, some plants respond negatively to direct, topical water application. With drip irrigation, only the plant roots are watered. In addition, gardeners have more control over weeds with drip irrigation, particularly between rows. This is because water application is controlled rather than broadcast (B. Tonn, personal communication, November 24th 2008).

Pressurized Drip Irrigation

Design

David Kovacs, an irrigation specialist from Vanden Bussche Irrigation in Delhi, Ontario was kind enough to provide us with a quote for a drip irrigation system (see Appendix). We made a couple of assumptions to put this quote together. The garden is 125’ x 200’. Over a 200’ span we assumed there would be between 65 and 75 rows. If the rows were 125’ long, each row would require 0.24 gallons of water per minute. Multiplied by 70 rows, the entire drip system would require approximately 17 gallons of water per minute (D. Kovacs, personal communication, November 20th and 21st 2008).

On-site Considerations

To be safe, David recommends getting a pump that will deliver 20 gallons of water per minute at a pressure of 15 pounds per square inch. A regulator will adjust the water pressure delivered through the system (D. Kovacs, personal communication, November 20th and 21st 2008). We asked David if this particular system could operate from gravity. According to David, a storage tank would have to be elevated 36ft from ground level in order to generate enough static pressure to create 15 pounds per square inch of water pressure. If this were to be done, the ‘tower’ would have to be properly engineered to withstand an incredible amount of weight. For example, 1000 gallons of water weighs approximately 8, 340 pounds! Another problem is finding an energy efficient pump with enough lift to do the job (D. Kovacs, personal communication, November 20th and 21st 2008). For example, if water was pumped from a drilled well with a depth of 40ft, the pump would have to have at least 76ft of lift.

Cost

The approximate cost of this drip irrigation system would be $788.63. This does not include the main water line from the water supply to the field layout or the water pump itself. In terms of design, the supply line could be buried permanently or set-up and removed on a seasonal basis. If the supply line were buried permanently, 1 ½’ PVC pipe would be required. This pipe is worth 0.70 cents per foot. Alternatively, a 250’ roll of black polyethylene pipe can be purchased for $261.00. This pipe is well suited to seasonal applications because it can be set-up, removed and stored quite easily. A more expensive option is 2” aluminium irrigation pipe. It comes in 30’ lengths and costs $3.00 per foot (D. Kovacs, personal communication, November 20th and 21st 2008).

Gravity Drip Irrigation

Design

The specific design of gravity operated drip irrigation systems varies greatly. During our research, we found systems as simple as a 5 gallon bucket with an attached hose to more elaborate systems with large elevated storage tanks. We know these designs work, although we are unsure how efficient they are in comparison to pressurized drip irrigation system noted above. As we've mentioned in Section 4, Chris Lincoln and Brenda Tonn have attached an elevated 500 gallon storage tank to their drip irrigation system. This system irrigates about ¾ of an acre of mixed vegetables. Specifically, the tank has been elevated 8ft off the ground on a sturdy wooden stand (B. Tonn, personal communication, November 24th 2008). If our calculations are correct, their drip system is operating on approximately 3.44 p.s.i of pressure. Chris and Brenda are relatively happy with the drip system itself. It is highly manoeuvrable and therefore, they can pick and choose specific zones in their garden that need to be irrigated the most. Most importantly, the system is gravity operated. However, Brenda highlighted the importance of the filter. Without it, the drip emitters become clogged with debris quite quickly (B. Tonn, personal communication, November 20th and 21st 2008).

On-Site Considerations

When we spoke with Chris and Brenda (personal communication, November 24th 2008) they had already moved the components of their drip system inside for winter storage. Therefore, we were unable to see exactly how the system operates. However, we know that this type of system requires an elevated storage tank for water. As we see it, the storage tank would be need to be placed on site, and filled with water. Further research is needed to see **exactly** how these systems work for different applications and under different operating conditions.

Cost

According to Brenda (personal communication, November 24th 2008) the approximate cost of their gravity operated drip irrigation system, including the tank, stand and filter is $2000.00. Considering the extra cost of a pump and supply line, the cost of this system is far less than the cost of the pressurized drip irrigation system quoted by David Kovacs.

<u>Section 6</u>: Summary of Research Findings and Recommendations

<u>Water Requirements</u>

During a summer with 'normal' rainfall, the 1 acre vegetable garden will require approximately 3 weeks of irrigation. Over this three week span, approximately 81, 462 gallons of water will be required for irrigation. The actual volume of water to be used for irrigation will depend on what will be grown and what kinds of yields/losses Trent vegetable gardens is willing to accept. For example, shallow rooted crops like corn and lettuce generally require more water than vegetable crops that have inherently deep root systems like tomatoes, squash and melons (Richards, 2008). To lower the garden's water requirement, Trent vegetable gardens should focus on warm season, shallow rooting vegetable crops. If more than 50,000 litres of water are taken from any water source on any given day, Trent vegetable gardens will have to apply to the Ontario Ministry of the Environment for a 'Permit to Take Water'. The biggest challenge for Trent vegetable gardens will be securing an adequate supply of water.

Securing an Adequate Supply of Water

From June-September, we've calculated that approximately 12,082 gallons of rainwater could be harvested from the farmhouse roof. Because of limitations involving volume and storage, it appears the value of rainwater harvesting is limited if Trent vegetable gardens intends to irrigate the garden intensively. However, securing an adequate supply of water via a rainwater harvesting system definitely falls within the realm of ecological irrigation. This is particularly true if Trent vegetable gardens opt to grow on a half acre with the remaining half acre in a cover crop rotation. If Trent vegetable gardens are willing to accept the fact that less water means lower yields and greater losses, rainwater harvesting might be a viable option for securing water.

Un-capping the well near the farmhouse is not possible. If Trent vegetable gardens decide that a well is a necessary component of their ecological irrigation strategy, it would be necessary and far more cost-effective, to simply drill a new well. The estimated cost of drilling a new well is $3050.00.

Water could be pumped from the Otonabee River. This could be done in two ways:

a) Pump water into a tank and deliver it to the garden site or;
b) Pump water from the Otonabee River directly to the garden site.

Both scenarios would require a large storage tank and some type of platform for it to sit on. For the first scenario, the university's physical resources staff could pump water from the river and transport it to the garden site. Although this would be quite labour intensive, Trent vegetable gardens already own a small, enclosed plastic tank that could be used for this purpose. The second scenario is less practical. Specifically, a lot of pipe would be needed to cover the span between the garden site and the river. A powerful (expensive) pump would also be required because of the local topography (uphill). However, a diesel pump powered by vegetable oil would likely do the job. Moving the garden site closer to the river is currently not an option because riverside acreage is not included in the 25 acres designated for agricultural use by the university's administration.

Trent vegetable gardens could possibly have a pond dug on site. We believe that this is a very viable option. If the pond is not constructed properly, there is a real risk of it going dry. There is a large spillway west of the garden site that we believe would be an excellent location for a pond. We recommend that future students be charged with the task of researching various construction scenarios and funding options.

Pumping Water

If a windmill pumping system is to function as designed there has to be wind. Therefore, it would be necessary to take on-site wind measurements with an anemometer prior to installing a windmill pumping system. We spoke with two local gardeners regarding their windmill pumping system. Although they agreed that their system is ecologically friendly, they highlighted several important drawbacks. First, there is simply not enough wind to rotate the windmill when water is desperately needed during periods of drought. Secondly, it takes approximately 3 hours to fill their 500 gallon storage tank with water. Once they have emptied the tank, they simply don't have 3 hours to wait for it to fill back up. Finally, the windmill and pump cost the gardeners roughly $4000.00. They did not feel like they were getting a monetary return on their investment.

Several solar pump designs are available for specific applications. A submersible centrifugal pump is well suited to situations where water must be pumped from a well. Floating pumps are a common choice for tank or pond applications. The amount of water that can be delivered by a solar pump is dependent on several factors besides the sun's irradiance. In terms of cost, these systems are very expensive and would require considerable expertise for both installation and maintenance. However, battery-based solar pumping systems are reliable and do not require large water storage tanks.

Depending on the vertical distance between the Otonabee River and the garden site, a sling pump could possibly pump water from the river to the garden site. Also, a sling pump could possibly pump water from the river into a transport tank for delivery to the garden site. Besides using a gasoline powered water pump, we are unsure how the water could be pumped from the transport tank into the on-site storage tank.

A treadle pump may be a viable option. A major advantage of the treadle pump is that Trent Vegetable gardens could demonstrate the system as a method for irrigation in underdeveloped countries. However, the treadle pump design is limited in terms of design. For example, The length of the water intake pipe is extremely important. Because of pressure limitations, the pipe should be no more than 7m long. A major downfall is that the treadle design depends on human power.

A traditional diesel pump powered by vegetable oil is a very viable pumping option. We feel that this is likely the best pumping option for this specific application. The benefits are many. Specifically, used vegetable oil is generally free, pre-heating and filtering the oil is relatively simple and perhaps best of all, pumps and low horsepower diesel engines can be purchased for relatively cheap. In addition, this pumping option lends itself to expansion and would be an amazing educational tool!

Distribution

For this specific application, drip irrigation is the most practical irrigation strategy. Drip irrigation systems are far more efficient and inexpensive than other systems, particularly sprinklers. Specifically, sprinkler systems do not distribute water as efficiently and require larger pumps. Government agencies have recommended that sprinkler systems be disallowed entirely. For this reason, we did not even consider them.

Based on a 70 row field layout, David Kovacs of Vanden Bussche Irrigation gave us a quote for what we call a 'pressurized' drip irrigation system. This system requires a pump that will deliver 20 gallons of water per minute at a pressure of 15 pounds per square inch. A special regulator will ensure proper function by adjusting the pressure delivered through the entire system. The estimated cost of this system is $788.63. This does not include the main water supply line or the water pump itself.

The specific design of gravity operated drip irrigation systems varies greatly. We know these designs work, although we are unsure how efficient they are in comparison to pressurized drip irrigation systems. Further research is needed to see **exactly** how these systems work for different applications and under different operating conditions. Only then will Trent vegetable gardens be able to make an informed decision concerning the utility of gravity drip irrigation systems for their specific application.

Table 2: Estimated Costs, Major Advantages and Major Disadvantages of Water Options

Option- Securing Water	**Estimated Cost**	**Major Advantages**	**Major Disadvantages**
Rainwater Harvesting	- Varies depending on installation and construction costs.	- Rainwater is readily available for use. - Rainwater harvesting is definitely an ecologically sound method for acquiring irrigation water. -Could be used as an auxiliary water source.	-Limited in terms of volume. -A lot of variability. -Requires water budgeting. -Requires a large tank for storage capacity. - Farmhouse's eaves troughs in need of repair. -Rainwater could possibly be contaminated with pollutants.
Well Water	$3050.00	-On-site water Source -Reliable water source -Does not require a large water storage tank.	-Expensive -Does not necessarily conserve groundwater.
Otonabee River	Depends on Scenario a) or b)	-A considerable source of water. - Physical resources could possibly deliver water from the river to the garden site.	- If water was pumped to the site, a lot of pipe would be required. - Requires a pump with enough 'lift' to pump water to the garden site. - Difficult to design because of Nassau Mills Road. - A large storage tank would be required at the garden site. -Dependent on physical resource staff. -River water could possibly be contaminated with pollutants.

<u>Table 2 Continued</u>: Estimated Costs, Major Advantages and Major Disadvantages of Water Options

Options- Securing Water	**Estimated Cost**	**Major Advantages**	**Major Disadvantages**
Pond	Approx: $4000-$12,000	-Funding is available -Provides habitat value -Diesel pump powered by vegetable oil could be used to pump water from the pond. -Dimensions of the pond could be customized to suit the needs of Trent vegetable gardens. -A great demonstration tool. It's really something that farmers could do! - Adds a great educational element. - If located properly, a ponds is a reliable source of water! -Could be designed in such a way so as to capture overland flow. -Low maintenance	-A pond has to be situated properly in accordance with soil conditions etc. - Very little room for error. -Expensive! - Pond may have to be dug off site depending on local site conditions. - The pond may need to be aerated in order to reduce algal growth. - Cannot be placed in a high erosion area or in an existing wetland or water course.

Table 3: Estimated Costs, Major Advantages and Major Disadvantages of Pumping Options

Options- Pumping Water	**Estimated Cost**	**Major Advantages**	**Major Disadvantages**
Windmill Pumping	$3,000-6,000	- Ecologically sound -Relatively low maintenance. -Design and installation generally requires expertise.	-Expensive -Slow (poor pumping efficiency) -There may not be enough wind when water is needed. -Windmills can't be near buildings, trees or other wind reducing objects. - Difficult to install
Solar Pumping	$2000- 9000	- Ecologically sound -'On-demand' pumping -Versatility in design. -Would be an excellent demonstration component.	- Expensive -Design and maintenance generally require high levels of expertise.
Sling Pump	$900-1600	- Ecologically sound - Cheap -Could be used to pump water from the river	- Has to be removed from moving water in order for it to be removed. - Has to be frequently cleaned. - Relatively poor pumping efficiency
Treadle Pump	$2700	- Ecologically sound - Relatively cheap - Would be an excellent demonstration component.	- Limited in terms of design. -Depends on human power - Operation is labour intensive

Table 3 Continued: Estimated Costs, Major Advantages and Major Disadvantages of Pumping Options

Options- Pumping Water	Estimated Cost	Major Advantages	Major Disadvantages
Diesel Pump Powered by Vegetable Oil	Approx. $1000-2000 for engine, pump and filtration system. Small Building: Unknown.	-Used vegetable oil is free and available on campus. - Ecologically sound -Passive solar design could be used to pre-heat vegetable oil. - Diesel pumps have a MUCH higher pumping efficiency than any of the other pumps featured in this report. -Relatively low cost -Versatility in Design -Would be an excellent education/demonstration component. -Well suited to all student skill sets - Could be used to pump water from the river or a pond. - Does not require a whole lot of expertise. -Local specialists have offered to help out with design/troubleshooting.	-Requires careful attention (oil temperature and filtering). -Solar passive design would be required in order to heat the oil. This means a small building would have to be constructed in order to house the engine, pump and filtering equipment.

Table 4: Estimated Costs, Major Advantages and Major Disadvantages of Distribution Options.

Options- Distribution	Cost	Major Advantages	Major Disadvantages
Intensive Drip Irrigation System	$788.63 not including main supply line.	-Far more inexpensive and efficient than sprinkler systems. -Relatively low labour input	- Requires a pump and a lot of pressure. - Difficult to operate from static pressure due to design constraints.
Non-Intensive Drip Irrigation System	$2000	- No pump required - Ecologically sound - Highly manoeuvrable - Relatively cheap	- There are some ‘unknowns’ in terms of efficiency - Requires an elevated storage tank/s.

Recommendations

If the long-term goal is to showcase ecological irrigation at Trent, we believe Trent Vegetable gardens should invest in a small, relatively portable diesel engine and pump, a vegetable oil filtration system, a small passive solar building and finally, a pond. In combination, these systems are well suited to this specific application.

After researching the prospect of harvesting rainwater from the farmhouse roof, we have come to the conclusion that not enough rainwater would be available to satisfy the water requirements of the 1 acre garden. It should be used as an auxiliary source only. As a primary water source, we believe the water must come from a dug pond or the river. If Trent vegetable gardens decide to dig a pond, a traditional diesel pump powered by vegetable oil should be used to pump the water from the pond. This we believe is the most efficient option; there are too many issues with sourcing water from the Otonabee River

Because of the many advantages of drip irrigation, we feel that it is essential considering the issue of water supply. The type of drip irrigation matters on the plans of the garden itself. Because the garden is being rotated, the rigidity of a fixed sub-surface irrigation system would not be an efficient use of resources. This is why we recommend that a surface drip system be installed, allowing the gardeners to manipulate the layout of the garden, allowing for different crops and different rotations. An added bonus of a surface drip system is that it is visible, creating a demonstration model for sustainable agriculture and community based projects for people to study. We have discussed the idea of using gravity and pressurized delivery systems, but we feel that the efficiency of the gravity system needs further research. The efficiency in operating a gravity system might be lower than that of a traditional pressurized drip system, so it is our recommendation to use a pressurized drip irrigation system. Unlike the other ecological pumping options we have researched, a traditional diesel pump powered by vegetable oil will create more than enough pressure (> 20 g.p.m) to operate a pressurized drip irrigation system efficiently.

After examining the various ecological irrigation systems and methods, we have concluded that the budget outlined by Trent vegetable gardens at the beginning of the project is insufficient to accomplish the goal of developing an ecological irrigation system for the 1 acre garden. We truly believe the 1 acre garden at Trent should be a real showpiece, something so outstanding that Trent will become a leader in the area of sustainable agriculture. If this truly is the goal, we do not recommend simply making a short-term investment in a cheap irrigation system. Specifically, our recommendation provides an open door for future expansion. The cost of digging a pond alone exceeds the Trent vegetable gardens budget of $1000-$2000. It is our recommendation that the budget be increased to at least $8000-$10,000. This figure should be sufficient to develop an ecological irrigation system based on our recommendations. Importantly, our recommendation is something that farmers would be interested in doing on their own farms. According to Paula Anderson (personal communication, December 2nd 2008), a well respected gardener and academic in the area, a farmer should be able to make $10,000 a year selling vegetables. In light of this, Trent vegetable gardens should be able to make a reasonable return on their investment within a few years.

This report has provided a foundation for future research. Further research is urgently needed. Specifically, a group of students in next fall's Canadian Food Systems course should be given the task of researching various pond construction scenarios and funding options. Our report and any subsequent work should be combined into a single document and presented to the university's administration.

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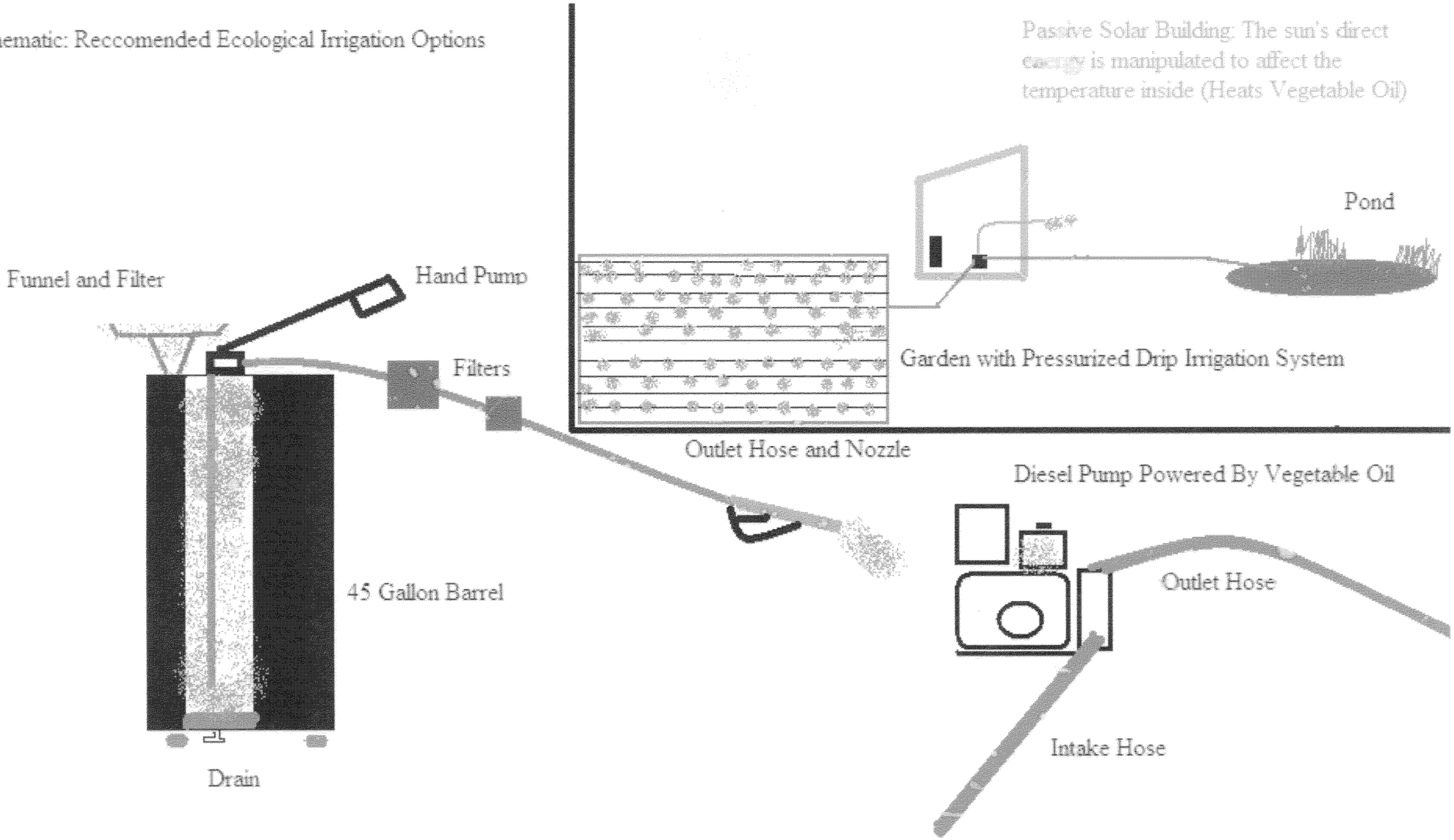
Schematic: Reccomended Ecological Irrigation Options



Sustainable Irrigation at the Trent Vegetable Garden

Bruce Sharpe and Ryan Ogilvie

Project Details

- To find a sustainable and economical way of irrigating a rotating field 1 acre vegetable garden.

Project Findings

- To satisfy the water requirements of the garden, we would have to be able to hold and distribute large amounts of water (over 80 000 gallons).
- Rainwater harvesting is a viable option for an auxiliary water source but not a primary water source , other options must be pursued
- Drip irrigation is the most efficient delivery system for irrigating the crops
- Most economical and sustainable method that we found was to use a pressurized drip irrigation system that was sourced from a dug pond and pumped using a converted diesel engine pump.