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**Excess Water Use**  
**&**  
**The Biology 1 AquaLab:**  
**Is There a Practical Solution?**

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**ERS 316 Integrated Urban Water Systems Planning and Management**  
**Term Project**



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## **Executive Summary**

The University of Waterloo Plant Operations Department, has expressed much concern over the continuing level of water consumption from the Biology 1 AquaLab. The AquaLab, located in the basement of the Biology 1 Building is used for rearing and holding fish. The fish are used in research and testing conducted by the Department of Biology. Unfortunately the holding tanks system is connected to a flow through system that consumes about 25.3% of the total campus water consumption (University of Waterloo, 2003). This makes the lab by far, the highest single user of water on campus. The percentage of campus water use can peak in certain months to upwards of 40%. The research team has quantified the amount of water consumed by the fish lab, and how the system currently operates, where the water supply is provided from, and where the wastewater leaves the system.

The project also explores the possibility of a new aquatic facility that would institute a state of the art recirculation system that would recycle 95% of the water. Such a recirculation system can drastically reduce the consumption of water for fish holding activities on campus. The development of a recirculation system is the ideal option to address the consumption problem and possibly is the only feasible option. However, the research team will also explore other possible options to curb consumption or at least reduce the water that is wasted in the AquaLab. If the new facility is not implemented it will be necessary to development a more creative solution to the over consumption in B-1. Although Alternatives are offered it is recommended that further research into other alternatives be completed before any new management plan is developed.

## **1.0 Introduction**

In Canada, water consumption is one of the highest per capita levels of water use amongst industrialized countries. One of the highest water consumers within the municipal system are institutions which account for 17% of total water use (Polis Institute, 2003). Institutions such as the University of Waterloo are faced with the growing challenges to provide clean, safe, and high water quality supply to meet the demands of drinking, watering, cleaning, and research purposes. Using the campus as a laboratory, four students take on the challenge of finding ways to reduce water consumption from Biology 1 (B-1) aquatic research facility (*AquaLab*). This paper will examine some of the solutions and alternatives to improve the current systems and practices which are being utilized in this technical institution.

## **1.1 Background**

At the University of Waterloo, some of the largest water consumers on campus are the first year residence complexes (Villages 1 and 2), the facilities managed by the department of athletics (Columbia Icefield and the P.A.C), and the buildings contained within the engineering block (University of Waterloo, 2003). Ironically, the Biology 1 building with an aim to learn about nature and its ecosystem components is the largest and most expensive user of water resources at the University of Waterloo (Zalagenas, 2003).

Built in the 1964, the B-1 AquaLab contains a large aquatic testing facility which houses 53 different fish tanks of varying sizes, shapes which are used in a variety of experimental purposes, including aquatic toxicity, reproductive and physiological stress testing (Ryan, 2003). Currently, water supplied for the AquaLab is piped from the Region of Waterloo's Well 4 (R.O.W. W4). Located adjacent to Ring Road and Laurel Creek, R.O.W.W4 draws water from an underground contained aquifer. This well does not provide water for generalized consumption on-campus, but is a water source for only the AquaLab and B-1 Greenhouses (refer to Figures 1 & 2). The latter consumes a negligible

amount of roughly 0.14% of the total water use per month (Hoyles, 2003), leaving the AquaLab as the predominant user of water resources from R.O.W. W4.



*Aerial view of the north end of the AquaLab, showing shelving units holding many of the smaller fish holding tanks.*



*One of the large square fish holding tanks containing rainbow trout. This species is used often in testing and research.*



*Water piping system shown going along the wall. This is the intake pipe supplying the holding/rearing tanks that is connected to the well.*

**Figure 1:** *The B-1 AquaLab- Tanks, Testing and Facilities #1*

*Northeast corner of the lab showing some of the larger holding tanks.*



*Mid-sized rearing tanks containing fathead minnow.*



*One of four large circular holding tanks of approximately 9.36 m<sup>3</sup> of total water volume.*



**Figure 1:** *The B-1 AquaLab- Tanks, Testing and Facilities #2*

**Figure 2:** *The B-1 Greenhouse*



## **1.2 Research Team**

Handed with the task to find a solution to the high water resource consumption and costs, our research team is composed of four Environment & Resource Studies students in the ERS 316 Integrated Urban Water Systems Planning and Management course: Alice Ng, Will Gibbons, Sandy Kiang and Craig Sabine. Guided by Professor Jim Robinson, the research team had approximately three months to gather information, meet with relevant stakeholders, and compose this report. Such a strict timeline significantly limited the scope, boundary, and breadth of this report. Nonetheless, it is hoped that our recommendations can be used to solve the water consumption problems pertaining to the AquaLab that is managed by the Department of Biology.

## **1.3 Research Question**

Within the given scope of this project, the research team set out to attempt to answer the following question:

*How can water resource utilization be minimized in the Biology 1 AquaLab?*

## **1.4 Research Methods**

Research was conducted via both primary and secondary research methods. This was done so to encompass both practical and theoretical concepts, technologies and principals which will hopefully give a more holistic and comprehensive approach to solving the problems at hand.

### **1.4.1 Primary Research**

Primary research was conducted by interviewing various University of Waterloo and Region of Waterloo staff, and asking them a wide variety of questions pertaining to the research topic. The following is a list of interviewees and the rationale for including them in our interview sampling frame:

#### **A.) Department of Biology- Key Actors**

A1.) *Martin Ryan, Biology AquaLab Technician, Department of Biology*

Staff at the Department of Biology Undergraduate Office referred the research group to Martin Ryan, whom provided details on the AquaLab (i.e. water parameters required in the fish tanks, type of fish, and basic functioning of the AquaLab). Martin Ryan also gave the research group a tour of the AquaLab and recommended that the research group speak to Dr. Brian Dixon, Lynnette Hoyles, Dr. Matt Vijayan, and Dr. D.G. Dixon (Dr. D.G. Dixon could not be contacted).

A2.) *Dr. Brian Dixon, Professor, Department of Biology*

Martin Ryan referred the research group to Dr. Brian Dixon, one of the primary faculty researchers whom utilizes the facility located at B-1-177. Dr. Dixon is also part of the committee that has proposed a new Aquatic Facility be built. Dr. Dixon was able

to supply the group with details of plans for this new Facility, which is still pending funding and final approval.

A3.) *Lynnette Hoyles, Greenhouse Laboratory Technician, Department of Biology*

Martin Ryan referred the research group to Lynnette Hoyles because of her expertise on the consumption of R.O.W. W4 resources that the B-1 Greenhouses consume. She also provided a tour of said facilities and a demonstration of the watering systems.

A4.) *Dr. Matt Vijayan, Professor, Department of Biology*

Martin Ryan referred the research group to Dr. Matt Vijayan whom uses the AquaLab for research purposes. He is also part of the same committee that is undertaking the new AquaLab facility proposal. Dr. Vijayan also provided useful information pertaining to the possibilities of recirculating systems in the existing facility.

**B.) Others Key Actors**

B-1.) *Rick Zalagenas, Plant Operations Director*

Jim Robinson referred the research group to Rick Zalagenas because he originally requested that research be undertaken with respect to water conservation in the B-1 AquaLab due to its extensive drain on University fiscal resources. After meeting with Mr. Zalagenas, he outlined the problems at hand, and gave us the initial direction as to what further research was required to be conducted.

B2.) *Monica Emelko, Professor, Department of Civil Engineering*

Rick Zalagenas referred the research group to Professor Emelko because of her involvement in the design of the initial Aquatic Facility upgrade proposal. Her expertise

also helped the group focus on appropriate recirculating system technologies that could be incorporated into the lab design, as well as providing some guidance on other water conservation methods, such as reuse and recycling.

B3.) *Tim Walton, Water Quality Technician, Region of Waterloo*

Tim Walton was located from the Region of Waterloo website. Mr. Walton handles any inquiries into groundwater quality reports in the R.O.W. He provided us with comprehensive chemical testing results on well 4 (Refer to Appendix F).

#### **1.4.2 Secondary Research**

Secondary research included literature review of the Ministry of Environment (MOE) guidelines on water quality and standards, specifically the 2001 Ontario Drinking Water Standards guidelines. These guidelines provided a guide to what physical, microbiological, organic/inorganic chemical and aesthetic parameters are recommended for potable water sources such as those from the well (MOE, 2001).

Secondary review also included examination of literature on recirculating systems, which in turn provided guidance on other water conservation methods, such as reuse and recycling. Since the technology of recirculating systems is very specialized, only a few journals and articles were located. More information concerning recirculating systems was located on the Internet and with the resources provided by Professor Emelko. Material on reuse and recycling was located primarily in journal articles and Internet resources.

## 2.0 Biology 1: Fish Tanks

The following is an inventory of the various vessel types that are currently located in the B-1 AquaLab.

**Table 1:** *B-1 AquaLab Fish Tank Inventory, November 2003*

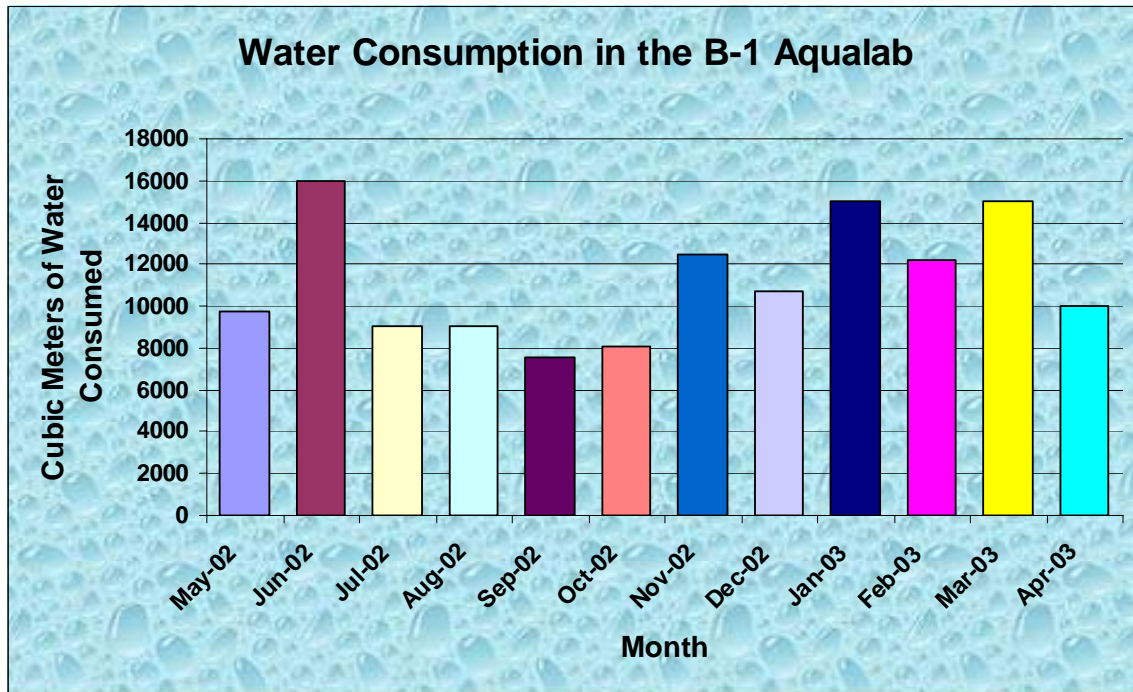
Tank Type	Quantity*	Dimensions (cm)	Volume Per Unit (m <sup>3</sup> )	Volume Per Tank Type(m <sup>3</sup> )
Plastic Type A	4	38 x 178 x 190	1.29	5.14
Plastic Type B	1	38 x 178 x 178	1.20	1.20
Plastic Type C	2	158 x 158 x 53	1.32	2.65
Plastic Type D	2	104 x 104 x 41	0.44	0.89
Plastic Type E	2	78 x 66 x 43	0.22	0.44
Plastic Type F	11	40 x 28 x 20	0.02	0.25
Plastic Type G	15	51 x 51 x 24	6.24	93.64
Glass Type H	6	20 x 40 x 23	0.02	0.11
Glass Type I	3	27 x 50 x 28	0.04	0.11
Plastic Type J	1	97 x 97 x 28	0.26	0.26
Plastic Type K	1	101 x 97 x 43	0.42	0.42
Circular Type L	4	r = 178, h = 94	9.36	37.43
Circular Type M	1	r = 20.5, h = 56	0.07	0.07
<b>Total Volume</b>	<b>53</b>		<b>20.91</b>	<b>142.61</b>

\* Volumetric assessment was done under the assumption that the maximum numbers of utilizable tanks are being used under experimental conditions and under full capacity

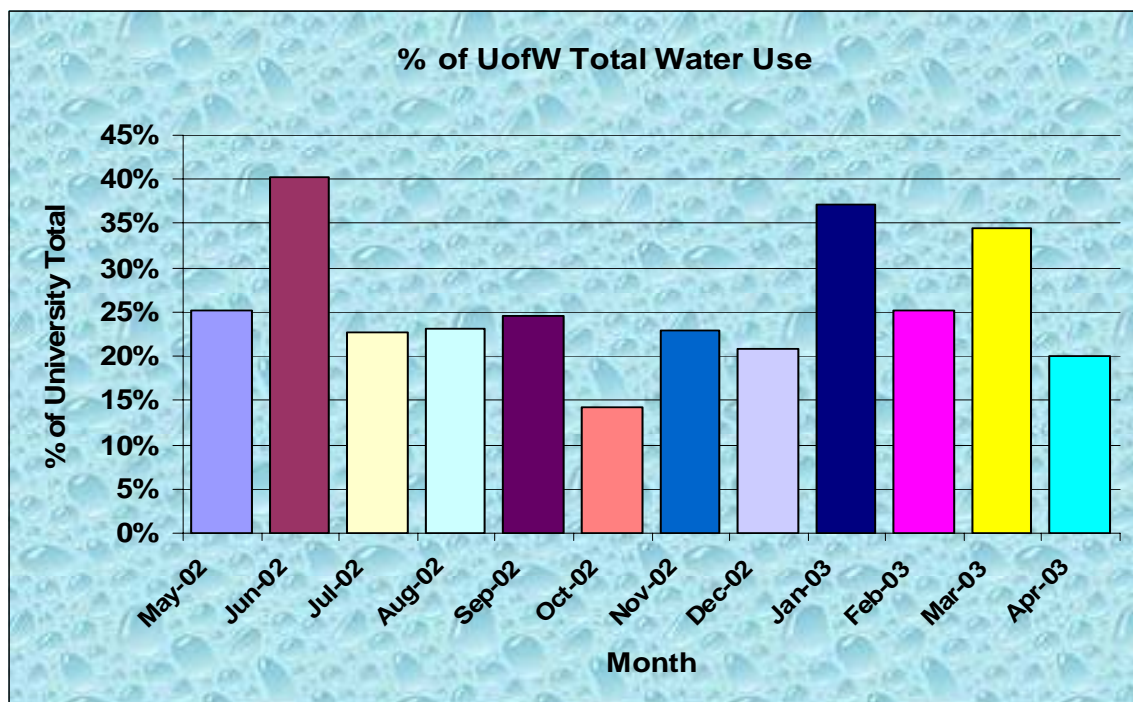
## 2.1 Current Consumption

The B-1 AquaLab is the largest individual water resource user at the University of Waterloo. In the 02/03 fiscal year, 25.3% (University of Waterloo, 2003) of all water resource use at the University of Waterloo was due to the facilities located in B-1 177. Monthly use in the laboratory is consistently above 20% of the university total, and depending upon testing requirement, it may account for in upwards of 40% of the university total on a monthly basis (University of Waterloo, 2003).

**Figure 3:** Monthly Total Water Use in the AquaLab



**Figure 4:** AquaLab Water Use as a % of the Total Water Use at the University of Waterloo

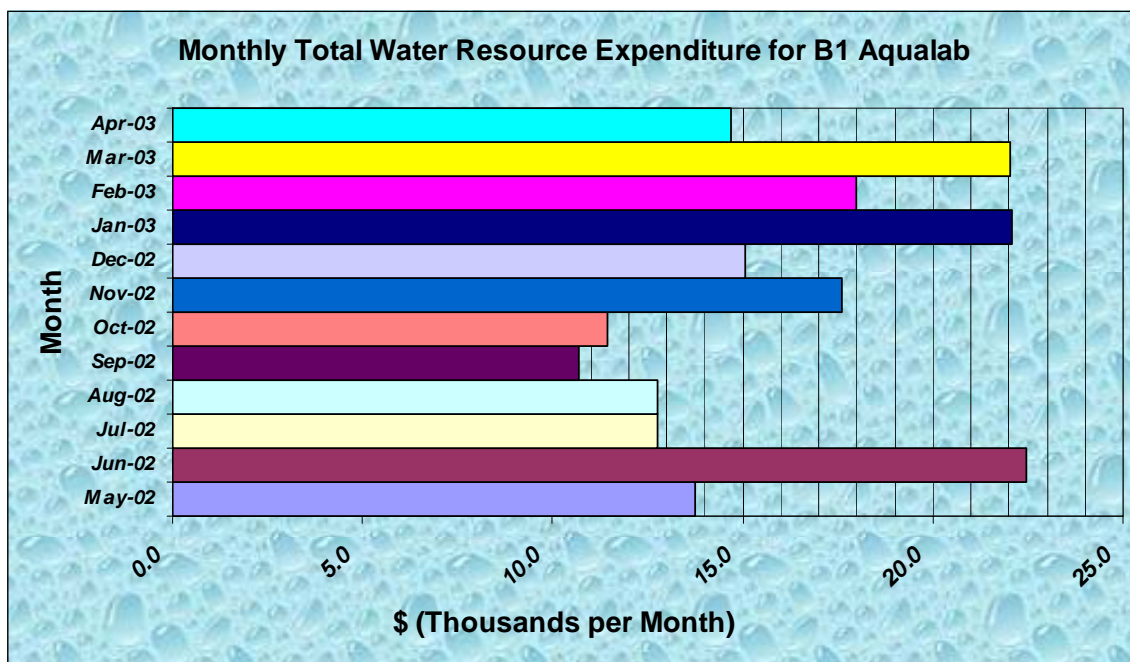


## 2.2 Cost

In accordance with the statements made in the consumption section, the B-1 AquaLab was the single largest water user located at the University of Waterloo during the latest fiscal year. The total yearly expenditure for combined wastewater and raw water charges was a total of \$193,259.01 for the facility, or an average of \$16,104.00 per month (refer to Figure 5 and Appendix C) (University of Waterloo, 2003).

Given the considerable monetary implications of such an expensive resource user, this makes the viability of finding alternatives a worthwhile endeavour. Improvements in practices and principles in combination with an examination of alternative water conservation technologies in amalgam have the potential to mitigate the total cost effects of this facility. Given proper resource capital, the existence of short periods of payback returns exist as a potential for any larger scale initiatives that may be undertaken after further examinations of all problem specifications have been assessed.

**Figure 5:** *Monthly Water Resource Expenditure on B-1-177 AquaLab*



## **2.3 Required Parameters**

Water Quality Parameters required for the raw water resource utilized in this facility are proxied by those represented for potable human drinking water standards. Individual physical, microbiological, organic/inorganic chemical and aesthetic standards have been specified by the MOE in the 2001 Ontario Drinking Water Standards guidelines, which may be found in Appendix G.

## **3.0 Solutions**

### **3.1 Recirculating Systems in B-1**

The AquaLab currently operating in B-1 does not contain a recirculating system and therefore no water entering the system from the well is recycled or reused. The system as it exists currently is comprised of 53 tanks, utilizing a freshwater “flow through” system where water is constantly pumped from the source. The H<sub>2</sub>O then flows through the tanks and is piped out of the system into a water drainage ditch. The piped out water eventually ends up draining into the municipal storm sewer system.

The water is constantly running through the system and no water is recycled or reused. Furthermore, little conservation is attempted to reduce the consumption as it proceeds through the open-ended system. Requirements of the fish housed in the wet lab are quite stringent, which require fresh and clean water (absent of harmful substances or micro-organisms), with zero chlorination, a high oxygen content that varies little and a small range in temperature.

The fitness of the fish and the accuracy of any testing results relies’ on these parameters being met. The current system supplies high quality water that meets these stringent demands and is ideal for growing the relevant fish species. This is why there has been little motivation or interest in finding other sources of water or reducing current usage.

However, in lieu of recent findings, it may not be feasible to accept the large water consumption costs and water waste simply for the health of the fish. It is necessary both in an economical and environmental sense to investigate other options to supply the fish with an adequate supply of water, without all of it being wasted. The ideal situation would call for the installation of a recirculating system of water supply and removal of the existing flow through system.

This option may be realised through the grant proposal currently being reviewed which would fund the construction and operation of an entirely new facility housing a state of the art recirculation system. If this grant were to be approved there would no

longer be any need for the flow through system in B-1 to be operating and water consumption would be substantially reduced. With the proposed Aquatic Facility in place, the existing B-1 Facility will be used as holding tanks for fish prior to research. Thus, a recirculating system is justified since the facility will still be in use.

### **3.1.1 Recirculating Aquaculture Systems**

Recirculating Aquaculture Systems (RAS) are closed or partially closed units, composed of fish tanks and a complex system where effluent water is treated and recirculated (Primary Industries, 2000). Primary functions of RAS are:

- to hold and culture fish, shellfish, crustaceans or plants under controlled conditions,
- to reduce water replacement when water supply is at a premium and/or when energy costs for reheating or cooling are high, and
- to reduce and manage effluents to minimize negative environmental effects.

Efficient recirculation systems recycle 95% of the water, thus, a continuous supply of fresh “new” water is greatly minimized (Virginia Tech, 2003). The combination of good water quality, appropriate temperature and oxygenation allows stocking densities of more than 50 kg/m<sup>3</sup> without limiting the health or well being of the fish (AWI, 2003).

Effluent water is treated using biological and mechanical filtration processes that remove by-products from the water, and oxygen generation or aeration that add oxygen to the water. The process of biological filtration involves that conversion of toxic ammonia and nitrite in by-products, excess food and detritus into nitrate. This process is facilitated by cultivating nitrifying bacteria (bacteria that consume the toxic ammonia and nitrites) on biofilter mediums such as gravel, rotating biological contactor, and bead filters (AWI, 2003).

As the recirculating water passes through the biofilter, nitrifying bacteria are provided with oxygen and thus can perform the required conversion. This process is known as nitrification. Any other by-products that are not removed through biological filtration are removed via mechanical filtration. Mediums such as screens, sand, gravel, or settling

devices are used in mechanical filtration (AWI, 2003). For diagrams illustrating RAS and filters, refer to Appendix E.

### **3.1.2 Assessment Feasibility of RAS in B-1**

Given the technological advances of a RAS, such a system has the ability to minimize both water consumption and impacts on the external environment by containing and treating wastewater. RAS allow the control the essential production parameters such as water temperature, oxygen concentration and the spread of diseases (AWI, 2003). Thus, aspects of tank environment may be controlled to achieve optimum conditions.

A major disadvantage of a RAS, however is the initial capital and operation costs for establishing and maintaining the system. Initial capital costs range from \$250,000 - \$500,000 for a 20 tonne system, and operation costs range from \$7-10 for each kilogram of fish. Although recirculation systems are more expensive to install than flow-through systems, due to reduced pumping costs the running costs are lower (Primary Industries, 2000).

Additional costs include the need for a high level of human capital investment in order to properly understand the maintenance and operation procedures involved in RAS. Workers who are knowledgeable in RAS plumbing and various filtrations used are required. Moreover, recirculating systems require intensive, constant monitoring of the various parameters of water quality, as malfunction of the facility can prove quite costly if not noticed in time (Virginia Tech, 2003).

## **3.2 Other Technologies, Practices and Principles for Conservation**

Developing other technologies and practices in the existing B-1 AquaLab would be beneficial on several levels. First, if the grant for the new AquaLab is not approved, it will be necessary to continue to use the existing system. In this case, reduction in water consumption will be highly desired to cut costs and to reduce the highly wasted water. Secondly, if the grant is approved, it will be 5 to 6 years before the new system is ready for operation. Water conservation during this intra-period may also be desirable. Finally,

the existing system will continue to be used, albeit on a lesser scale, even after the establishment of the new Aquatic Facility for some specific purposes. In this case it will still be beneficial to attempt reductions in waste water at the site.

### **3.2.1 Reuse**

One possible option may be to reuse the water once it has flowed through the system. The tanks currently empty used water into drainage and ultimately the municipal storm sewer system. The water could be diverted from this current path and directed towards a holding tank where it would be stored for grey water uses. Possible options might include campus garden and lawn watering or uses in the existing B-1 Greenhouses. Also water may be reused for cleaning activities inside B-1 and other connected buildings (Emelko, 2003).

If the reuse option was instituted, researchers would be forced to be cautious in their practices of disposing of wastewater. During research activities it would be important for the researchers to ensure the absence of toxics or any other possible harmful substances by keeping separate water used during research and experiments from that of water simply used for fish holding which could be reused (Emelko, 2003).

### **3.2.2 Recycling**

Through further research, it may also be possible to direct some of the water back into the groundwater well where it originated. Therefore all of the water used in the AquaLab would not be completely removed from the system. This would greatly depend on its quality after leaving the lab and if it meets standards for return to its original aquifer. This may involve the installation of some form of additional treatment system (Emelko, 2003).

### 3.2.3 Other Practices

If the development of the proposed Aquatic Facility is not approved, the implementation of other options to curb water consumption and reuse waste water will be necessary. Further research will be required to determine what possible uses for water exiting the current system may be. Several options have been noted above; however other uses may be determined through further research. At this point the quality to the water needed can be determined and a suitable treatment option can be developed, if treatment is necessary at all. The following describes treatment system options to improve the outgoing water quality.

#### A.) *Carbon Filtration*

The use of activated carbon is the most popular means of chemical filtration. Activated carbon binds organic compounds efficiently and may act as a substitute for a biological filter. When treating a tank with antibiotics or other therapeutic agents it is important to discontinue the carbon filter during treatment since the charcoal will remove the medication from the water (do not discontinue aeration however) (EPA, 1998).

#### B.) *Ultraviolet and Ozone Filtration*

Ultraviolet and Ozone Filters are commonly used together since ultraviolet light will inactivate ozone which can be harmful to aquatic life in the tank. These filters are not usually directly exposed to the aquarium water but rather some of the water from the aquarium is shunted to the filters so that over a period of time all of the water has passed through the filters. When water flows are properly controlled and the filters are adequately maintained these filters can remove organics from the water and kill bacteria, algae, fungi, and suspended parasites (EPA, 1998).

### **3.3 Proposed Aquatic Facility**

Since the existing B-1 Facility is an open concept facility, professors at the University of Waterloo are finding it difficult to create a controlled environment – where access to the room is limited, stress to the fish is reduced, and variations to light exposure. These limitations are preventing certain research projects from proceeding, and even from beginning.

A solution to this problem is to build an improved aquatic facility, which has individual rooms, controlled personnel access, and a recirculating system. A proposal for a facility of this kind was first submitted by the University of Waterloo (Biology Department and Plant Operations) in May 2002 (Dixon, 2003), but was not approved by the funding organization, due to the success of a similar bid submitted by the University of Guelph.

In May 2003, the University of Waterloo resubmitted their proposal, and are very optimistic at of its approval because no other university has applied for similar funding. The University of Waterloo has applied for an approximately \$2 million grant which will be partitioned as follows (Dixon, 2003):

- \$1.5 million for the construction of the Aquatic Facility building
- \$400 thousand for the construction and installation of the recirculating system
- \$100 thousand for maintenance and operation.

The proposed Aquatic Facility will be an addition to the Biology 2 (B-2) Building and will extend to the basement of Needles Hall. To increase security measures of this laboratory, the extension to Needles Hall will be underground and hidden from sight. To allow research equipments to be conducted simultaneously and in controlled environment, it will contain 11 individual rooms (refer to Appendix B). To control access to the Aquatic Facility, double locked doors with access codes given to only cleared researchers (Vijayan, 2003). As well, to ensure water efficiency and cost effectiveness, a recirculating system will provide water for upwards of 25, 3 x 3 x 2 meter tanks.

The adopted recirculating system is anticipated to provide a minimum 200L/minute; a maximum of 500L/minute; and an average of 400L/minute of recycled water (Dixon,

2003). The planning and design of the recirculating system and building has yet to be contracted out as of our project completion date. Given the confidentiality of the proposal no further specifics were provided.

If approved in February 2004, the Aquatic Facility will not be ready for operation for at least another 5-6 years (Dixon, 2003). Thus, even though the University has plans to greatly increase water efficiency and cost effectiveness with the recirculating system, plans for the interim are required. Therefore, it is recommended that a recirculating system be built for the existing B-1 Facility.

## **4.0 Conclusions**

With approval of the new Aquatic Facility grant pending, many of the water use issues would be solved with its' institution. The recirculation system that the facility would operate recycles 95% of the water it uses, therefore the same stock densities of fish would be reared at a fraction of the water consumption each month. This is the ideal outcome for the future of biology fish lab operations. The research team highly recommends the approval of this option, and supports further work to make the realisation of this project possible.

Alternately, if the grant is not approved, exploring the feasibility for the installation of a recirculation system in the current AquaLab would also be a desired option. However, this may not be possible or economically feasible in the short term. More research and development of this option, both from an engineering standpoint and an economical one would be necessary to address its possibility.

At the current AquaLab, the problem lies in the fish needing high quality water with very stringent standards that vary little from day to day and month to month. The current flow through system meets these requirements, however by a very inefficient means. It is necessary to develop a method of supplying the same standard of water without continually drawing it out of well and disposing of it at current rates. Research into engineered methods of solving this problem should be implemented.

In light of water consumption and waste from the AquaLab, and the high costs of supplying water to the facility. It is recommended that research be conducted into uses for grey water around campus, and the feasibility of implementing a system of water reuse. If the water exiting the facility is of high enough quality for any specific water uses around campus, it would be satisfactory to at least reuse the exiting water and avoid its waste into the municipal sewer system. Further research would be necessary to determine the feasibility of recycling the water back to natural flows.

## **5.0 Recommendations**

Recommendations from our research include:

1. Implement a recirculating system and adapt other water conservation technologies and practices for the current AquaLab.
2. To ensure the proper installation and operation of recirculating systems in the AquaLab and proposed Aquatic Facility, further investigation of technologies and engineering principles of should be conducted.
3. Continue dialogue between Dr. Brian Dixon and Rick Zalaganeas on the approval status of the Proposed Aquatic Facility.
4. Uses for grey water around campus should be explored through on campus initiatives groups such as WATgreen and ERS 250 Greening the Campus. These groups can explore the possibilities for grey water uses with the water reused from the AquaLab in B-1.

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**Appendix A: Floor Plan of Existing B-1 AquaLab Facility**

**Appendix B: Floor Plan of Proposed Aquatic Facility Addition  
to B-2**

**Appendix C: University of Waterloo Plant Operations Water  
Consumption and Expenditure Data for Fiscal Year 02/03**

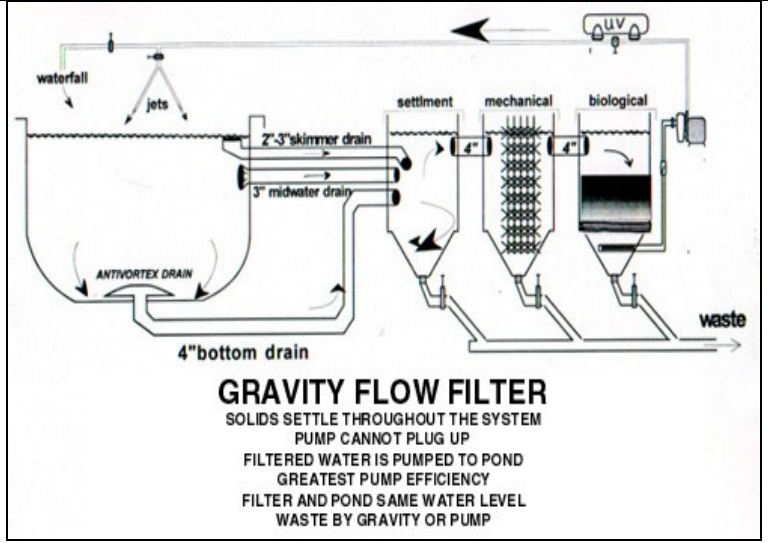
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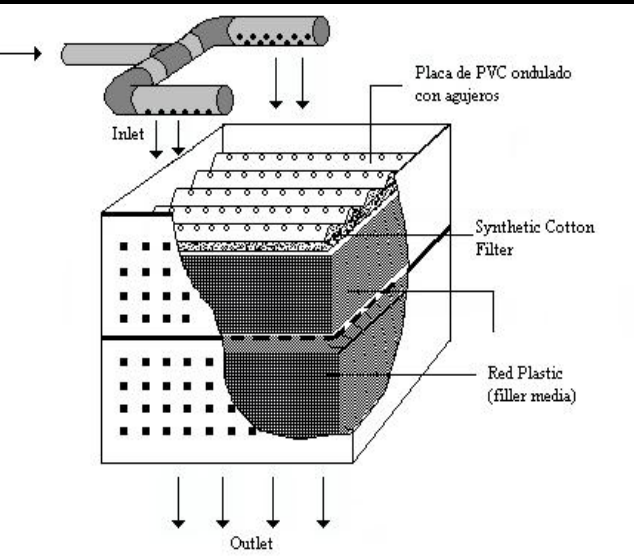
Recirculating Aquaculture Systems

Source: AWI, 2003



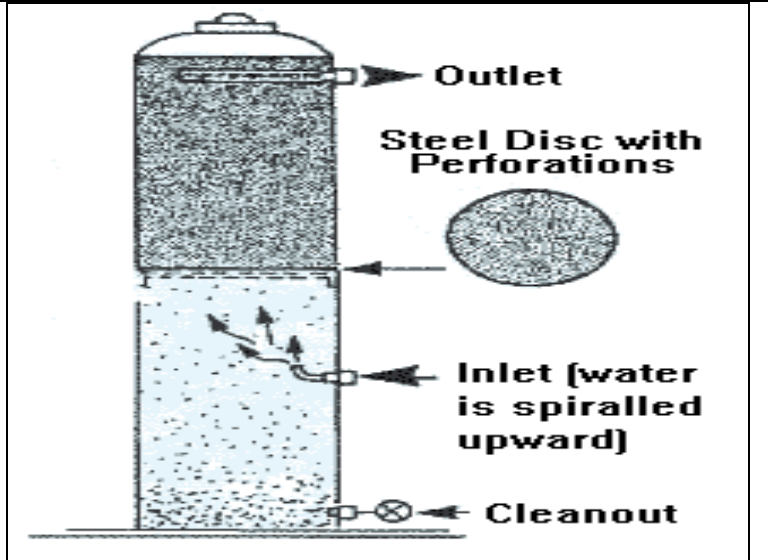
Profile to Recirculating Aquaculture Systems

Source: Southern Regional Aquaculture Center, 1998



Recirculating Aquaculture Systems Biofilter

Source: Southern Regional Aquaculture Center, 1998



Recirculating Aquaculture Systems Mechanical Filter

Source: ACTED, 2003

**Appendix F: Region of Waterloo Chemical Testing Data for  
Well W4, 2003.**

**Appendix G: Water Quality Parameter Standards for  
AquaLab Facility**