

RECIRCULATING CONSTRUCTED BIO FILTRATION IN SITE DESIGN
by

REID FERRERO

(Under the Direction of Brad Davis)

ABSTRACT

It is well documented that urban development has negative effects on water quality (Haney and Huber, 1982) (Baker, 1992). This thesis explores creating recirculating constructed biofilter systems as an added solution to this problem while providing opportunities for aesthetic enjoyment. These manmade solutions provide habitat that harness naturally occurring microbial activity minimizing water contaminants thus providing the ecological benefit of improved water quality. To address these issues in an integrated and systematic way, this study utilizes a design research methodology to investigate the incorporation of a recirculating upflow spring biofilter into a closed, manmade water feature. By analyzing this built experiment at the micro level, water quality improvements are identified including water clarity, lessened turbidity, and the ability to sustain life. These findings are then applied to a broader macro level filtration system proposed as part of site water management programs.

INDEX WORDS: Recirculating Constructed Biofilter, Biofiltration, Water, Urban
Runoff, Water Quality, Phytofiltration

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MASTERS OF LANDSCAPE ARCHITECTURE

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DEDICATION

This work is dedicated to my lovely wife and two daughters. You all have been my rock. I cannot express the gratitude you are owed...YO ALLY! WE DID IT!!!

ACKNOWLEDGEMENTS

It is with great pleasure I acknowledge the University of Georgia and the College of Environment and Design. As Uncle Ben stated in Spiderman: With great power comes great responsibility. The role this institution has played in my life has not only challenged me to become a better landscape architect, it has created a never ending pursuit of creative solutions and watered an intriguing mind.

Although many members of the faculty and staff have played a pivotal role in my education, I would like to personally thank Bill Ramsey for finding value in a rough, nail driving carpenter.

Cla, trading stories with you specific to water has never gotten old. I hope to continue...

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CHAPTER 1

OVERVIEW

Recirculating Constructed Biofiltration Systems have many forms. The recirculation refers to the principle that water will pass through a system more than one time. These filters cleanse water in two main ways, by mechanical filtration and biological Upflow Spring Filtration (USF).

A mechanical filtration system means removing suspended particulate material in water by mechanically pulling out or trapping these solids thus removing the suspended solid from the water. This process acts as “screening” the water. Mechanical filters can also offer biological filtration by providing habitat and structure for organisms to metabolize contaminants in water. Koi ponds, aquariums, commercial aquaculture and hydroponic agricultural closed systems often incorporate various forms of mechanical filters. The organisms carrying out this type of filtration range from bacteria to aquatic and marginal plants.

One high tech form of a mechanical filtration system is a bead filter. Bead filters are typically a pressurized filtration system that are compact and incorporate highly engineered materials. A plastic, clog resistant media traps solids and provide a habitat for beneficial bacteria.

This study focuses on a lower tech solution referred to as “Upflow Spring Filter.” These filters have a more sizable footprint in the landscape and work by pushing water up through rock. The rock provides home for microphylla and bacteria, but unlike the bead

filter, it can also provide habitat for plant fauna. This Upflow Spring Filter system has not been widely acknowledged as a viable filtration system due to inherent limitations of the design and implementation processes. Limitations of this approach center on the inability to patent, produce, ship, or easily promote this filtration process by commercial distributors. Although this filtration system does not lend itself to a one size fits all solution, testimonials of the success of USF systems have been numerous.

The research question that this paper seeks to resolve is “How would the addition of an Upflow Spring Filter to an existing site water program, especially in polluted areas, be helpful at providing improved water quality downstream?”

There is a commonly held assertion that fresh water availability may be one of the greatest challenges humankind will face due to over population and resource scarcity.

According to Susan Hockfield, President of MIT:

Water Purification has been critical to human survival for a very long time. Paintings from ancient Egypt as early as 1500 BC illustrate water purification by filtration, and Aristotle described purification by distillation. Although we’ve gotten much better at water purification since then, we still primarily rely on those basic two technologies. And even after four thousand years of refinement, water purification by distillation and filtration is too slow, too expensive, and too energy inefficient to meet our growing demands. We need dramatically new approaches to purifying water. (Hockfield, 2018)

All water filtration solutions are welcome, such as the one resulting from research at the Massachusetts Institute of Technology (MIT) with the development of Aquaporin,

a synthetic protein that purifies water. However, this thesis will examine a current; low-tech solution of water treatment present today: Upflow Spring Filters. Glamorous, groundbreaking, high tech solutions have the potential for financial profits if widely promoted, but in the real world, product distribution and robust availability typically lags. Less exciting, but easily available, solutions to water filtration do not generate comparable revenue, neither on the design, shipping, and production side nor on the installation, implementation, and usage side of the application. Landscape architecture is definitely one profession that can and should promote simple, low-tech solutions to water filtration systems for use in site planning. Whereas a business school graduate may not find profitable benefit in an unmarketable solution, it is the purview of the landscape architect to do just that in regards to water filtration systems. While a new retractable awning is a solution for providing shade, so can a tree. The temptation in the planning process is to overlook solutions that do not have the maximum financial incentive and opportunities to realize a significant profit margin.

In the United States during the 1990s, the availability of flexible water retaining membranes spurred a surge in construction of water feature projects by homeowners and in small-scale commercial projects. This influx of water specific projects led to informal, casual research conducted by hobbyists, common homeowners, and contractors into water treatment methods. As the introduction of water for enjoyment into the landscape expanded, so did the emergence of various ingenious filtration methods. This variety gave rise to many “home spun” techniques in water management. It is the intent of this thesis to suggest that the implicit knowledge generated and tested by the implementation of these smaller scale water projects may have important value to the profession of

landscape architecture as a source of creative solutions to larger scale site designs. The greater goal of this thesis is to evaluate one example of a USF built experiment utilizing a research by design methodology.

While excess nutrient contamination and pollutants of landscape waters has been an identified global issue for centuries, the more recent chemical impurity of landscape water bodies cited as a universal public health crisis has resulted in adverse effects on the health, safety and welfare of society. An article published in 2020 by Lynne Peeples in *The Guardian* clearly states, “More than 200 million Americans may be drinking PFAS-contaminated water, suggests research by the nonprofit Environmental Working Group (EWG), an advocacy group which is collaborating with Ensia on its Troubled Waters reporting project.” (<https://www.theguardian.com/us-news/2020/dec/22/forever-chemicals-pollute-water-dozens-of-sites-in-every-us-state>, December 2020)

Polyfluoroalkyl substances (PFAS), valued by industry for their inability to break down, are very dangerous over time in the quality of site water. Peeples states the problem as “Once PFAS gets into the environment, the chemicals are likely to stick around a long time because they are not easily broken down by sunlight or other natural processes.” Current stormwater conveyance systems are unable to treat chemical contamination of site water. Conventional “green infrastructure” does facilitate the natural processes that can break down molecular bonding of chemicals by digesting the chemicals with microbes, which ultimately removes the impurities from water. According to the Environmental Protection Agency (EPA) the definition of green infrastructure is:

Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits.

While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits. (10/09/2020, <https://www.epa.gov/green-infrastructure/what-green-infrastructure>)

Note, the above definition clearly states green infrastructure “treats” stormwater. Treatment is the design of systems that incorporate some or all of the following processes: sedimentation, filtration, thermal attenuation, absorption, phytoremediation, and volatilization (Strom, Nathan, Woland, 2013).

However, it could be that the passive flow of a green infrastructure filtration in some scenarios may not be aggressive enough or have the ability for system modification. Conventional green infrastructure is defined by the EPA as 11 specific treatment methods. (<https://www.epa.gov/green-infrastructure/what-green-infrastructure> 2022)

All other forms of green infrastructure shall be considered unconventional as they are not recognized, by and large, as conventional means of treatment. These systems can include proprietary vortex water quality improvements. These systems are proprietary in nature because their treatment science is kept secret in order to market the device for specific applications. An upflow spring filter shall be considered an unconventional means of treatment.

With a recirculating filter system, the water flows repeatedly through a treatment cycle until achieving the desired quality. Designers can creatively utilize USFs to

supercharge those ecological processes and use the water movement as an aesthetic site addition, while the water containment can provide needed habitat in an urban environment. Conventional green infrastructure is typically designed to accommodate a “treatment train,” meaning many best management practices as strung together and act as a whole to treat water through sequential processes. This can come at a cost. The landscape footprint required to achieve the multiple levels of treatment may not be available for every project. Utilizing one footprint for multiple stages of treatment is an advantage of space efficiency and cost.

Recirculating filtration process requires energy, equipment, and maintenance. However, simply said, almost any ecological water treatment system long neglected is going to require energy, tools, and effort to clean and restore. Some of the most advanced technology, machines, and energy production on the planet have created global water quality issues. It may not be enough to expect existing, passive stormwater systems to counter the pollutants generated by modern urbanization. It is also possible in the future, as sustainable technology advances, these input requirements may decrease, making these type of unconventional treatment more attractive and financially feasible. .

Application and Relevance to Landscape Architecture

Landscape architecture should aim to utilize naturally occurring ecological processes to remediate water quality. The crowning achievement of Frederick Law Olmsted’s Emerald Necklace in Boston, for example, provides beautiful open, green space for the public. Olmsted park design also utilized ecological processes and the microbial activity of constructed wetlands to consume nutrients that Boston’s

overwhelmed, inadequate sewer system could not handle. The Back Bay Fens, an area flanking the city of Boston consisting of undevelopable wetlands, became a festering quagmire of raw sewage. The creation of a natural “biofilter”, although manmade, of constructed wetlands provided ecological remediation of the sewage filled Fens making neighborhoods of the inner city livable again. The book Frederick Law Olmsted and the Boston Park System categorized site conditions as:

The initial problematic situation in the mid-19th century arose in the lower downstream reaches of the Muddy River where a combination of intense real estate development pressures and landfilling of coastal marshlands blocked natural drainage and directly discharged raw urban sewage into the tidal floodplains. This created worsening flood and sanitary health hazards, as well as an aesthetic nuisance particularly in the Back Bay neighborhood of the city (Zaitzevsky, 1982).

To make matters worse, Eisenmen also clearly states, “When the Boston Park Commission surveyed the area in 1877; animal life could no longer survive in the waters of the Back Bay.” (2013)

Since Olmsted’s work in Boston predates the systematic study of ecological sciences, we are unable to ascertain whether he fully understood the natural processes he employed as a solution. Regardless, documentation exists that creating the Emerald Necklace water feature alleviated polluted water downstream of urban development and positively affected the health, safety and welfare of the Boston public. Whether this

outcome was a happenstance of chance is debatable, but the outcome merits close consideration and study. According to Marks, “Olmsted’s correspondence underscored that the Back Bay Fens was an “urban improvement” or a “sanitary improvement”, but not a “park.” (2015) This does illustrate Olmsted’s own awareness of the ecological functions he was attempting to master. According to Anne Whiston Spirn, the Back Bay project is “the first attempt anywhere, so far as I know, to construct a wetland.”(1995)

Today’s landscape architects are equipped with advancements in the ecological sciences to understand Olmsted’s ecological assumptions and create plans that maximize beneficial ecosystem functions utilizing current technology. This allows landscape architects to remove luck from the equation and purposefully expand on the instincts of Olmsted, mimicking key characteristics of his capstone design by utilizing Upflow Spring Filters in site design that may outperform current expectations and treatment standards.

Other professional fields have made this connection, perhaps by chance, and have designed systems to treat water through ecological means as opposed to conventional chemical sewage treatment. Sustainable Water is a company that utilizes ecological processes to remediate raw sewage, i.e. black water. Because urban runoff is considered grey water, it is fair to assume decontamination of urban runoff would be less intensive than treating black water. Upflow Spring Filtration does not produce water meant for human consumption. Therefore, the level of treatment required by USF systems would be considerably lower than those systems created by Sustainable Water. This can lead to increased feasibility for implementation of this type of USFs in site design. However, this application can still potentially reduce chemical contamination of landscape waters that

ultimately become the source for drinking water, albeit a reservoir or recharging ground water that supply wells.

Today, green infrastructure is prevalent in almost every urban setting. The success of conventional green infrastructure principles, commonly incorporated into landscape architectural site design, demonstrates the ability to treat site water. Turenscape, a famous Chinese landscape architectural firm, utilizes constructed wetlands for water quality remediation downstream of urban development. One particular park design is noteworthy: Shanghai Houtan Park: a water treatment facility built as an Expo for the Olympic Games. Although this site plan has meaningful impact on landscape water quality, their typical design still only harnesses flow through systems. They have summarized the benefits of one specific project as:

Constructed Wetland and Regenerative Design through the center of the park, a linear constructed wetland, 1.7 kilometers (one mile) long and 5- 30 meters (16.5 – 100 feet) wide was designed to create a reinvigorated waterfront as a living machine to treat contaminated water from the Huangpu River. Cascades and terraces are used to oxygenate the nutrient rich water, remove and retain nutrients and reduce suspended sediments while creating pleasant water features; Different species of wetland plants were selected and designed to absorb different pollutants from the water. Field testing indicates that 2,400 cubic meters (500,000 gallons) per day of water can be treated from Lower Grade V to Grade III. The treated water can be used safely throughout the Expo for non-potable uses, and save half a million US dollars in comparison with conventional water treatment.

(2021)

Figure 1 illustrates water quality improvement from samples taken at input and output.

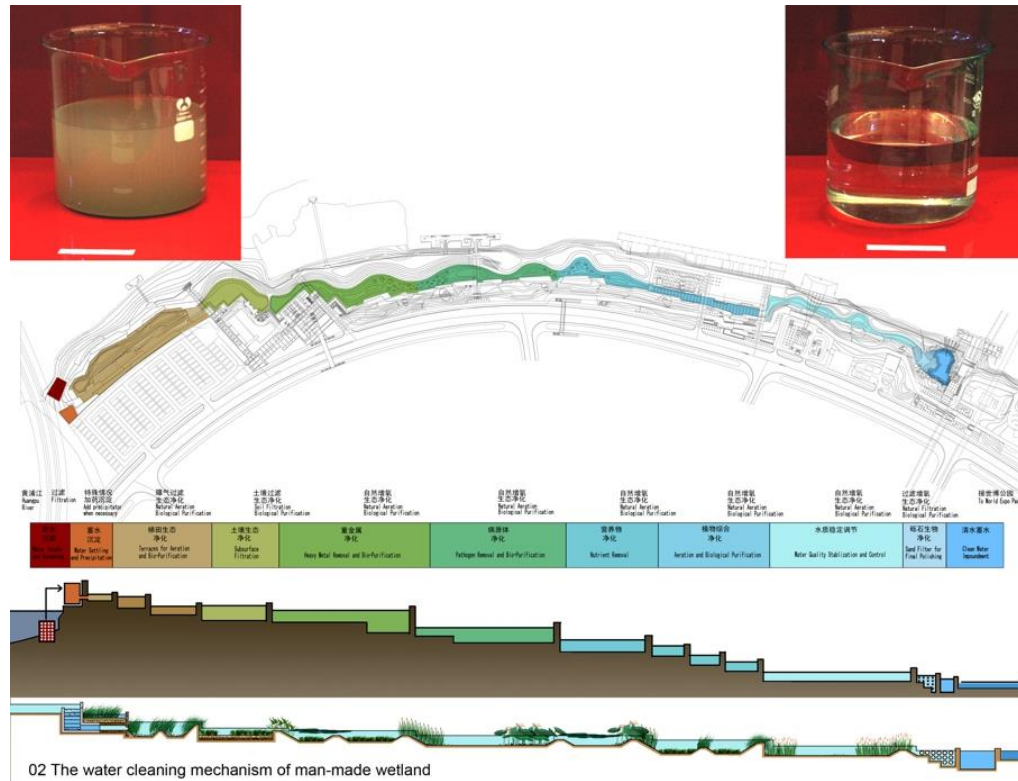


Figure 1. Water Quality Illustration (<https://www.turenscape.com/en/project/detail/4647.html>)

The water remediation is noteworthy as illustrated above. The visual inspection of the water sample leaving the system is much cleaner compared to water entering the system prior to traversing the treatment course. This thesis will utilize a similar visual inspection developed by the EPA to determine improvement of water quality.

Although this is an encouraging development in site water management, there may be opportunities for improvement. This park was created to divert water from a main river system, treat through the watercourse, and return the treated water back to the main, polluted system. Although this management plan was revolutionary in 2013, is possible

that creating multiple USF's along the entire stretch of the river would have provided additional positive impact to water quality?

This thesis will also focus on green infrastructure bioretention systems, “a technique whereby parking lot islands, planting strips, swales, and other landform depressions are used to collect and filter storm runoff. Through the use of grass filters, shallow ponding, infiltration, and plant uptake, this technique takes advantage of an underutilized portion of the landscape for water quality enhancement.” (Strom, Nathan, Woland, 2013). Creating bioretention cells provides site capabilities of infiltrating excess stormwater runoff on site, allowing water to enter groundwater. This aligns with the natural hydrologic process.

When water percolates into the soil, microbial action further treats water by consuming excess nutrients accumulated in urban runoff. By providing space for this infiltration to occur and capitalizing on naturally occurring microbial activity, landscape architects are treating water. There are however, potential shortcomings of bioretention as currently utilized, because water only traverses the course one time as a flow through system. This paper promotes recirculating site water through the biofilter multiple times, thereby multiplying the benefits of bioretention and the natural microbial activity as a water treatment system. The premise of this paper is that this recirculating site water will enhance and expand the natural water treatment processes and could lead to enhanced water quality prior to release from the site.

Methodology

To explore this concept, this thesis will study an Upflow Spring Filtration design and installation built in 2013 at Cox Media Group's corporate headquarters located in Sandy Springs, Georgia. This experiment was constructed as a landscape architectural site design/ build effort. Utilizing a research design methodology, individual examination and discussion of specific components of the system is presented. The overall product evaluation is based on industry-accepted criteria set forth by L.T.M. Blessing, A. Chakrabarti & K.M. Wallace (1995, 1998).

Blessing et al points out that research of design processes is a woefully neglected topic. Seeking significant improvement to the overall design process by understanding the process and its influencing factors led to the development of three questions. Each question focuses on a specific research evaluation technique. These questions include:

1. What do we mean by a successful product?
2. How to create a successful product?
3. How do we improve the chances of being successful?

Question 1 involves the evaluation of criteria used during the design phase to determine its success; Question 2 explores the influences on success; lastly, Question 3 seeks to understand the design methods and tools that ultimately lead to the validation of the methods embraced. Application of this methodology allows an evaluation of the design and application of biofiltration and form our research question in a substantive way. Figure 2 illustrates the overall biofilter design, examined in this inquiry and methodology.

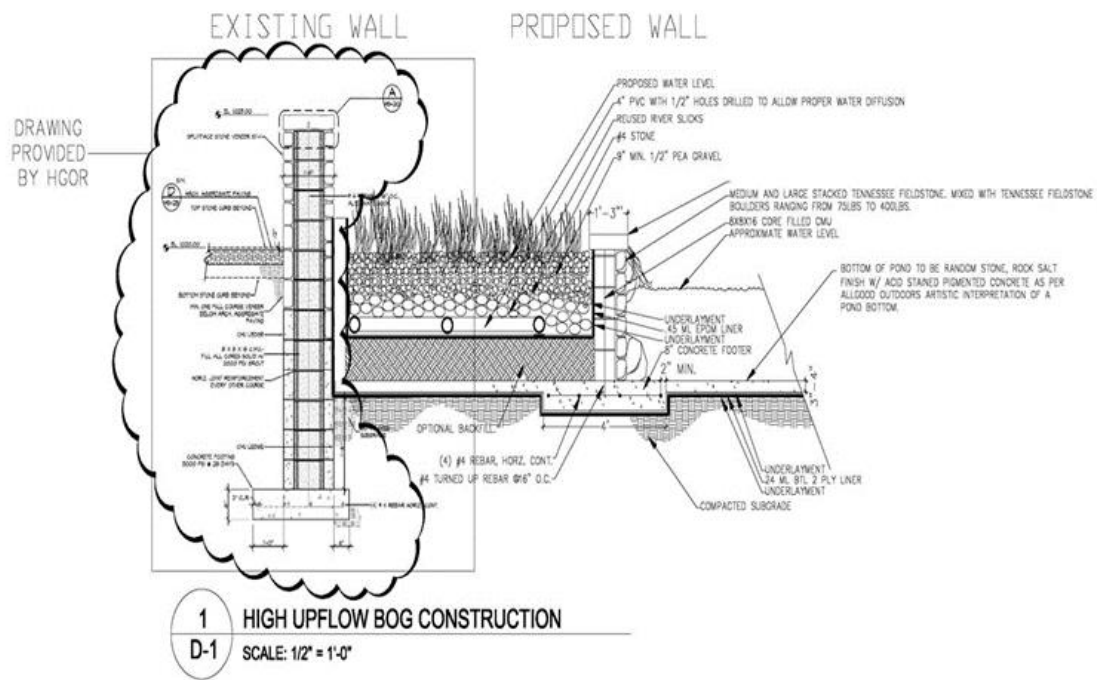


Figure 2. Construction Detail of USF (Allgood Outdoors 2013)

Chapter Summaries

Chapter 2 explores the existing conditions of the site and pond. This chapter illustrates not only the desire for water quality remediation, but also the requirement for action. The pond was in disrepair and unable to function as a healthy ecosystem which affected natural surroundings, economic impact, and people whom utilized the space.

Chapter 3 examines the construction of the individual components making up the built USF. Subchapters touch on filter sizing, media choice and components required that are outside of the filter itself but connected as supply.

Chapter 4 evaluates the design and outcomes to assess project's success. It should be noted that this filter has been installed and in operation for a number of years.

CHAPTER 2

DESIGN INTENT

Allgood Outdoors, hired as a subcontractor for a well-recognized landscape architectural firm based in Atlanta, Georgia, HGOR, needed to find a solution to an existing, distasteful landscape pond. The site amenity was no longer a centralized focal point for the corporate campus due to poor water quality. Allgood Outdoors suggested the incorporation of an Upflow Spring Filter. The specific goals for this addition would allow for active biofiltration that consumes excessive nutrients, add aesthetic value by the creation of a waterfall incorporated into the current composition of the pond, and returns ecological function to an aquatic ecosystem in an urban environment.

Existing Conditions

The existing pond had no active filtration system, poor water quality, and an abundance of plant material. The pond's aquatic unbalanced habitat filled with algal blooms and overpopulated by aggressive aquatic flora. To remediate the identified problems, Allgood Outdoors suggested the addition of an upflow spring bioactive filtration system. This solution was accepted and design began in summer of 2013. Construction began in late summer. Figure 2 and Figure 3 illustrate existing site conditions and display the pond's lack of ecological health. Unfortunately, the contractor at the initiation of the project did not conduct water quality tests so no data is available or

comparative purposes. It should be noted that the presence of aquatic fauna were not witnessed, confirming water quality was degraded.



Figure 3. Photo of Existing Conditions (HGOR 2012)



Figure 4. Photo of Existing Conditions (HGOR 2012)

CHAPTER 3

UPFLOW SPRING FILTER DESIGN

Upflow spring filters are landscape areas dedicated for site water recirculation and treatment. USF's generally push water from a landscape water body, cycling through rock media which acts as a mechanical and biological filter by screening for particulate matter and providing habitat for plant fauna and film forming bacteria, which consume nutrients and pollutants removing the two from water. Differing from conventional rain gardens or bioremediation cells which typically work with gravity flowing downward, USF's generally pump water to the bottom of the filter to the top. This allows the water to "fill up" the filter and overflow at specific locations called weirs.

To design the filter, it will be necessary to:

1. Size the filter
 - a. Determine the square foot requirement of the footprint
 - b. Establish the depth of the filter
2. Understand the components to make up the filter:
 - a. Structure
 - b. Media
 - c. Pumps
 - d. Aeration unit

Sizing the Filter

To begin sizing the biofilter for the existing pond, the first step is to determine the square footage of surface water. An industry standard for sizing an Upflow Spring Filter is allocating roughly thirty percent of the existing, or planned, surface water square footage to become the footprint of the proposed USF. There is no current scientific research available to substantiate this standard. Nelson Water Gardens has an advertised 18 years of experience dealing directly with the installation and maintenance of water gardens advises, “For water gardens 10 – 15% of surface area should be bog, and for koi ponds there should be 25 – 30%” (Nelson Water Gardens, 2020). This suggests that because this composition the USF will filter water in an open system including organic by-products from wildlife and the nutrient loading associated with urban runoff examined in the literature review, the Allgood Outdoors team decided to utilize the thirty percent footprint recommendation. Both of those contributing inputs aligned with the requirements of a koi pond that consists of living organisms that produce an unnatural amount of waste into those closed systems. An image of Nelson’s basic upflow spring filter (what they refer to as bog filter) design is provided below in Figure 5.

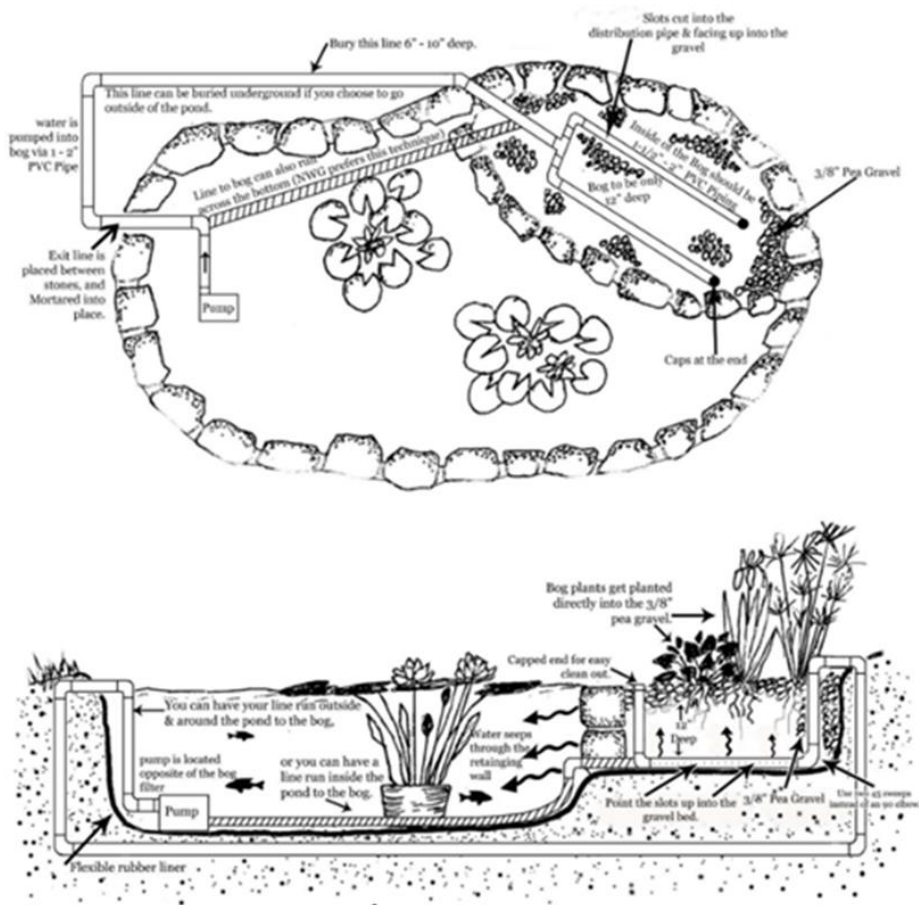


Figure 5. Typical Kio Pond Filter (https://nelsonwatergardens.com/wp-content/uploads/2020/02/Pond.Build_.Pack_.04.07.2017.pdf, December 2021)

Bionova, the world leader in design and construction of natural swimming pools (NSP), offers this information on filter sizing:

NSP BioSwimPonds™ incorporate the use of aquatic vegetation hydroponically rooted in carefully selected substrates to allow the water from the swimming area to flow through the planted environment. The biological filter (a.k.a regeneration zone, bog filter, constructed wetlands, etc.) is approximately the same surface area as the swimming zone.

Extrapolated, a 16'x32' swimming zone (~500 ft²) would require the same amount of area (~500 ft²) for the regeneration zone.

It is worthy to note that the suggestion of a one to one ratio of square foot of water body to biological filter (what they refer to as regeneration zone) is exacerbated due to the fact that a swimming pool is designed for full human immersion and consumption. To achieve code compliance, swimming pool water must meet potable standards and be tested rather frequently. The goal of the design at Cox Media is limited to treating nutrient and chemical contaminants of site water, as opposed to producing potable water, so it should be reasonable to downsize the recommended footprint suggested by BioNova without compromising the desired functionality of the USF. Figure 6 shows a typical natural swimming pool installation built by BioNova.



Figure 6. Natural Swimming pool by BioNova (<https://www.pinterest.com/pin/443886106997383426/>, December 2021)

Depth of Filter

Once the square footage under filtration by the USF is established in two dimensions, the depth of the filter is chosen. Nelson Water Gardens states, “Too deep a bed of gravel – this is the most common mistake made, you need no more than 12” of gravel substrate. If you are adding a Gravel Bog to an existing deep pond area; construct a false bottom using grating” (December 2020). The suggestion of only one foot of gravel substrate in water depth makes sense because the desired bioactivity is action created by aerobic bacteria. Any greater depth can morph into an anaerobic environment and that would not allow habitat for naturally occurring aerobic bacteria we wish to establish for their nutrient consuming and chemical digestion. This one-foot suggestion of depth necessitates future study.

Another challenge of additional substrate depth is plant roots, which will not grow deeper, based on available oxygen levels. Depleted oxygen levels can cause quite a dilemma if the footprint required for the filter exceeds the available space on site. Depth can provide the needed volume while reducing the area required. The Water Hub at Emory University, built by Sustainable Water as a water treatment facility in an urban campus environment, has recently discovered a way to combat this challenge. Because this system design in an existing urban campus, the site presented constraints with limited availability of suitable real property. In order to “shrink” the footprint to the size needed, Sustainable Water developed a similar biologic filter system that exceeds the depth constraint by adding oxygen to the system via a compressor. This allows the aquatic environment to remain aerobic beyond one foot in depth. They have also cleverly developed what they call synthetic rootstock. “The roots are augmented by a BioWeb

synthetic root system (Entex) to provide more surface area for bacteria” (Water Saver: The Hydroponics Experiment at Emory University, TPO Magazine, March 2016). They have created a synthetic mesh net that mimics those of a natural root system. With the application of oxygen, mycorrhizal action can occur at depths previous believed impossible.

The Upflow Spring Filter built at Cox Media also took advantage of this increased opportunity for depth. The filter design depth is two feet. Installation of two compressors and aeration units at the same two feet depth in the pond body maintains an aerobic environment and supercharges the oxygen levels. Please reference the aeration unit in the figure 7.

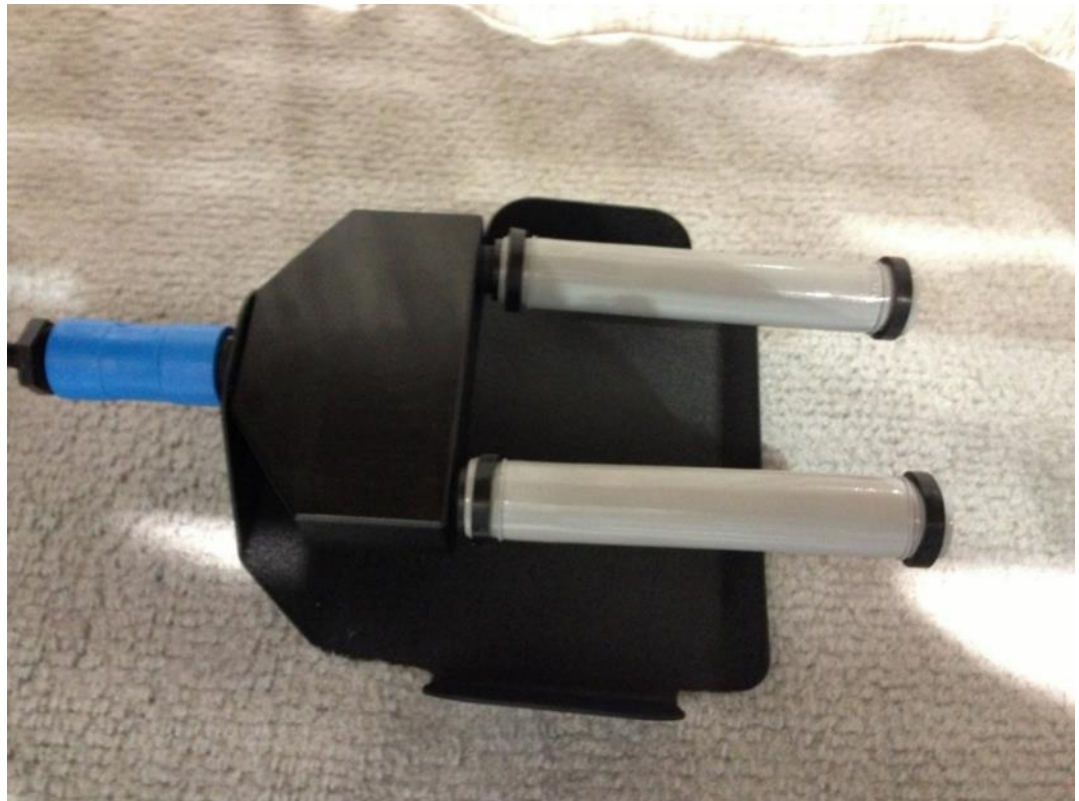


Figure 7. Typical Aeration Unit (Photo taken by Reid Ferrero 2013)

Sending the oxygenated water through the USF allowed the filter to achieve oxygen levels suitable for aerobic activity. This also provides potential for plant root growth to exceed one foot in depth. To maximize the oxygen levels inside the filter, a soaker hose added to the pond's aeration lines and buried inside the bottom of the filter media, increasing the amount of oxygen distributed throughout the system. Future research to confirm the USF hypothesis is advisable. Although, adding a soaker hose inside the filter has been implemented in multiple applications utilizing the same techniques with no known adverse outcomes, further research is needed to confirm this as a best practice. Cla Allgood specifically said on site, "This will allow more oxygen to get into the filter and provide the ability to adjust air flow in order to combat water tracking through the filter". These projects provide encouraging evidence of real world success and useful application to the USF system.

Filter Structure

Once the depth of the filter is determined for each application, forming of the floor and walls to contain the filter initiates the construction phase. Project needs may dictate construction material. Any structurally engineered materials suitable to handle the load are sufficient. For Cox Medial Upflow Spring Filter, the construction materials selected are concrete masonry unit block, steel rebar, concrete, and natural stone veneer. The stone veneer will act as a weir and the face of the waterfall. A dark colored Tennessee fieldstone was selected for its aesthetic properties. Biological material will grow on the rock's surface that is in contact with pond water. Those lifeforms will stain a lighter colored material. The existing pond was veneered with an Indiana limestone that

is much lighter in shade and would discolor quickly by the formation and staining properties of the biology. This also helps tell the architectural story that these components have different functional aspects with a subtle change in material. It is noteworthy that the existing pond is to remain. Allgood is only adding a upflow spring filter to the pond.

It should also be understood that the depth of the filter will not need to increase based on the designer's desire for an elevation change. The filter's outfall can be ten feet above the pond's water level. A base can be built to any height in the design process and decorated to fit the site to become part of the composition as a whole .The filter can also reside under the water level of the pond body. It is advantageous to have an element above the water level, so that one can easily confirm the pumps are in operation by visually seeing a waterfall.

Waterproofing

After the cast in place base and walls for the filter are built, the waterproof membrane is installed to ensure no water will escape through the floor and sidewalls. Rather, water will exit at predetermined weirs creating a waterfall at the top of the filter structure. This exit location guarantees the water will traverse the filter from bottom to top. The walls of the filter should extend above the pond's water level. The three main reasons for this are: 1. the elevation change will provide visual confirmation that the pumps are operating; 2. the sound created by the water falling into the pond will provide positive impact for end users; and 3. the falling water will provide aesthetic value.

The waterproofing may be any number of products. The application at Cox Media utilized a pond liner. Designers can choose traditional pool gunite, liners of a variety of

materials (EPDM to name one), or a sprayed on coating. The two core specifications for the waterproofing material extrapolate down to: Does the waterproofing fulfill the project's design intent and does it function properly? Figure 8 shows initial placement of the liner for this particular project.



Figure 8. Waterproofing installation (Photo taken by Reid Ferrero 2013)

Filter Water Supply/ Pump

Upon completion of waterproofing, the installation of the filter supply on the floor of the filter occurs. This is typically PVC (polyvinyl chloride) piping. A pump, or multiple pumps, from the floor of the pond body, and on an opposite side of the pond from the filter, sends pond water through the Upflow Spring Filter. There can also be the incorporation of skimmers. This maximizes filtration potential by collecting surface, solid contaminants from the pond and removing them by mechanical means. This lessens the

biological filtration needs by removing foreign biological inputs prior to their breaking down and becoming part of the water column.

The pump and pipe size is dictated by the amount of water the designer wishes to send through the USF. The Cox Media pond “turned over” every two hours. Turned over means the pump will supply the filter with the amount of water held in the pond.

Swimming pools typically turn over once an hour. This pond, not designed for full human immersion and consumption, does not need to turn over every hour according to Cla Allgood.

The amount of water determines the weir length of the waterfall. Consultation with a pump supplier for specifications is crucial, as there are multiple options to select. Pond pumps, typically considered low head, high volume pumps are not as common as the pumps designed for high head, high volume. There are not many applications for pond pumps and it is prudent to defer to the expertise of a pump specialist to most accurately size and select the pump for an USF project. Figure 9 below shows a typical pump installation.



Figure 9. Typical Pump Installation (Photo taken by Reid Ferrero 2013)

Supply Dispersion Pipe

The pumps connect to PVC dispersion piping with multiple pre-drilled holes along its length. The pump moves the pond water with its impeller through the PVC pipe. These dispersion pipes are installed in loops, as opposed to legs, on the floor of the USF to ensure water does not find a path of least resistance and provides the greatest opportunity for equal dispersion on the floor of the filter. The pipes will terminate in the bottom of the USF.

This particular site needed four-inch PVC pipe and two pumps in order to cycle the water every two hours. The holes are spaced at six inches on center. The holes are three eighths of an inch in diameter and drilled in straight lines running the length of the pipe. Six equally spaced drilled rows of holes allow for proper dispersion of the water throughout the bottom of the filter. The pipe can enter through the base of the filter,

penetrating the waterproofing, or be plumbed to enter in a discrete location above the waterproofing. This scenario allows for fewer penetrations, which removes another potential point of failure. Either method is acceptable. In some applications, it is too difficult to hide a four-inch PVC pipe above water level, so routing the pipe from below grade will be more appealing. At Cox Media, the filter itself is located in the overall pond's waterproofing, so any leaks created by this penetration would essentially remain inside the system. A leaking penetration will lessen the overall performance of the filter. For this installation, four inches of concrete poured over the floor of the filter protected the liner from damage during filter media installation. The interior sides of the filter have a nonwoven geotextile layer and a CMU treatment to provide the liner protection where it would otherwise directly contact angular rock. This is not a requirement for every USF, though in this installation it provided the greatest level of security. It also provides protection during any planned maintenance. Figure 10 shows the dispersion pipe. Please note there are two main independent loops pictured fed from separate pumps.



Figure 10. Installation of Dispersion Pipe (Photo taken by Reid Ferrero 2013)

Filter Media

The depth of the media is important and may vary depending on the material selected. As mentioned, designers have become quite creative in their selections using both natural and synthetic rootstock. For this study, we will focus on utilizing graded granite aggregate base material (GAB). This aggregate necessitates grading, and this step cannot be overlooked. This process separates pieces of granite into similar sizes using a mechanical sieve. When filling a space, the size uniformity allows for room between each individual piece of rock. One can imagine filling a room with the same size beach balls would allow for more void space than if one filled the same room with varying size balls. The void space between the balls would be much less. This void space allows room for water to travel, roots to grow, and supplies a habitat for film forming aerobic bacteria.

The film forming bacteria provides the means of biologic filtration. The microbes consume nutrients in the water, thus making it unavailable for algae. This is what prevents algal blooms and green colored water.

As an aggregate, granite was chosen for its regional availability and for the angular nature of crushed granite, which provides additional surface area for the aerobic bacteria to develop which will lead to greater colonization. The more bacteria a USF can house, the greater amount of nutrients the bacteria will consume.

Typically, it is best to layer the substrate in varying sizes of rock. The decreasing size of the material used in layers as the filter is filled, from bottom to top, with media creates the best opportunity for bacterial development. Each layer should be roughly six to twelve inches in height. For the Cox Media site, the first layer of rock was comprised of riprap; granite pieces that are irregular in shape but consistently eight to twelve inches in length. This covers the water source piping and provides the greatest amount of void space around the pipe. This decreases the chance of clogging as biological matter accumulates in the system. The next layer of media consisted of number four stones. This is a much smaller stone size. These pieces are consistently four to six inches in length. The next layer consisted of number eighty-nine stone. These stones are the smallest in the filter ranging from one-eighth of an inch to one-half of inch. The smaller size helps provide a structure for roots to grow through providing support for plants as they increase in size. Always specify the rock to arrive cleaned, washed, and free of fines which can clog the system.



Figure 11. Installation of Filter Media (Photo taken by Reid Ferrero 2013)



Figure 12. Installation of Filter Media (Photo taken by Reid Ferrero 2013)

Because the top layer size of the rock is smaller, over time, there is increased potential of clogging. This layer should be at the top in order to perform recommended maintenance by periodically replacing this layer of stone to ensure water does not begin “tracking” in pathways that require less pressure to traverse. The goal is to have the water uniformly travel from the source through the filter. The final layer can be any of the designer’s choice based on their aesthetic desires. This installation utilized a mixture of boulders, egg rock, and pea gravel to give a more rustic aesthetic for the finish, exposed material. Exit weirs are elevated slightly lower than the rock level, so water will not be visible on top of the filter. This helps alleviate biology from growing on top of the filter and the rock mulching will remain visually pleasing.



Figure 13. Installation of Filter Top Dressing (Photo by Reid Ferrero 2013)

Plant Material

The final step to complete the filter is to plant aquatic species. Plants can uptake known chemicals and lock them into their structure, similar to the way plants lock carbon from the atmosphere through respiration of their leaves. Plants can draw chemicals into their roots removing the contaminants from water in a process known as phytofiltration, and this process is amplified by mycorrhizal activity. Fungus grows on a plant's rootstock and symbiotically relies on the plant to supply it with carbon while becoming a source of nutrients for the plant. Svenningsen and Watts-Williams (2018) suggest that "arbuscular mycorrhizal fungi (AMF) colonize roots of most plants; their extra-radical mycelium (ERM) extends into the soil and acquires nutrients for the plant".

Plant selection can vary to achieve the aesthetic qualities desired to meet the project's composition. The selection should be based on aquatic and marginal species appropriate for the growing conditions. The root crowns will remain inundated with pond water, so species adapted for full emersion are required. Although scientific data has not confirmed this as a best practice, wash the root ball of plants arriving potted from nurseries to bare root. This removes additional organic material from the pond and forces the plants to begin drawing nutrients directly from pond water moving through the USF. This facilitates the desired phytofiltration process. Phytofiltration, coupled with the emergence of the bacterial colony growing in the substrate of the filter, will remove nutrients from the water making it unavailable for algae. This process will continue as long as the filter is running. The results will be visually clear pond water.

Because the filter can only treat water that passes through the filter, it is likely a biologic sludge will form on the bottom of the main pond body. There is no current

measure for preventing this. A biological treatment that can selectively remove such unwanted lifeforms and still allow desirable organisms to live is not currently available. The sludge is more an aesthetic nuisance and does not typically have negative impacts to the system's functionality.



Figure 14. Installation of Plant Material (Photo taken by Reid Ferrero 2013)

Once the filter is completely constructed, it is time to fill the pond with water. Fully immerse the sump pump locations in water. Once fully immersed, the pumps can be operated. It is important to test the pumps prior to fully filling the pond. In the event of a malfunction, quick drainage of the pond is an option. As long as the pumps remain submerged, the pumps can run without any damage.

Upon completion of plant installation, fill the filter with water as quickly as possible to submerge the exposed roots. Allowing air to contact the roots will likely

cause damage to the root system and compromise the health of the plants. Irrigate the plants from another water source if the pump start up process is taking longer than anticipated or a problem with the pump develops.



Figure 15. Photo of Pump Start Up (Photo taken by Reid Ferrero 2013)

CHAPTER 4

EVALUATION

Criteria

To evaluate the biofilter design and infer positive influences to natural water bodies, we are utilizing the rubric established for design as research. There are three main points set as criteria to evaluate the design:

1. What do we mean by a successful product?
2. How is a successful product created?
3. How do we improve the chances of being successful?

Evaluation

To answer Question 1 we will investigate what product will make the design a success. This is the design intent. What does the customer desire? What product will best provide that outcome? Based on multiple consultations, 1. The existing pond water was turbid and end users desired improved water clarity. 2. The existing pond experienced algae blooms and had an unpleasant odor. 3. The aggressive aquatic flora was also growing in an uncontrollable manner. For this specific experiment, the criteria for a successful product would be: 1. One that allowed for water clarity improvement, which can be attributed to water quality improvements. 2. Removed odors from the pond.

3. Selectively removed unwanted organisms while still allowing desired aquatic biota to live and thrive.

Although many types of solutions are available, the addition of a USF was clearly a viable product. The filter consumed nutrients and potentially fixed known pollutants. The concrete floor allowed the designer to select where plants would grow by making permanent planters. The plants cannot grow through the concrete, so the plantings are contained in predetermined locations. Adding chlorine to the system would remove the ability for algae to grow, but it would also kill the plant life and other aquatic lifeforms. A successful product must allow biological lifeforms to exist while selectively removing unwanted ones. The fact that all chlorinated pools must drain into a sanitary sewer system because of the negative effects the chlorinated water has on ecological systems is evidence that chlorine use in this system is not an option. The pond at Cox Media is not chlorinated and it can run into a storm sewer system because it will not adversely affect the natural system, lifeforms and other inhabitants. It can potentially alleviate similar conditions of a natural system.

Question 2 is theoretical: How is a successful product created? Again, although multiple solutions may exist, the inherent goals of the product will drive the possibility of success. Blessing describes it as:

. . . design research is that it not only aims at understanding the phenomenon of design, but also at using this understanding in order to change the way the design process is carried out. The latter requires more than a theory of what is; it also

requires a theory of what would be desirable and how the existing situation could be changed into the desired.

For this specific experiment, the criteria for creating a successful product would be: 1. One that allowed for positive impacts to the aquatic ecosystem. 2. Remove the possibility of future undesired algal blooms. 3. Provides increased aesthetic pleasure.

Understanding the desired outcome is paramount to a product's success. Based on the design problem identified by the end user, water clarity, will the USF product alleviate that issue and the associated unpleasant odor? Based on theory of past performance, this USF design does provide positive impacts to an aquatic ecosystem, improve water quality while eradicating algae overgrowth odors, and provides increased aesthetic pleasure.

Question 3 is an inherent issue for design professionals. Because these systems reside out of doors, they do not provide the controls available in a laboratory setting. For this specific experiment, the criteria for maximizing the chance of creating a successful product would be: 1. One that conducts a thorough site analysis. 2. A product designed that identifies site constraints and maximizes opportunities for success. 3. Builds on past knowledge forged through a "guess and check" rational.

Each site may have microclimatic differences as well as other outside influences. Topography and space availability may not provide enough space to house the filter at the standard size identified early in this paper. The possibility of heavier contaminate loads entering the system could have adverse effects. Can these influences change the design

process? Yes. There are many ways to adapt designs to specific challenges identified through thorough site analysis.

For example, this specific system at Cox Media incorporated air lines in the filter media. Upon further discussions with the distributor, they suggested the aeration benefits occur as a bubble meets the water's surface. They also suggested, the bigger the bubble is at that point, the more positive impact it has on water quality. Bubbles created inside the filter media do not allow the bubbles to meet the water surface at a large size, thus rendering the aeration less effective. The aeration incorporated in the pond body and outside of the filter achieved aeration requirements.

Overall, this system did meet the design intent but also identified a question: Is it possible to identify through further research a bacterial agent to perform the ecological functions at a more desirable rate? Moreover, a corollary to that question is a need to establish water quality sampling and testing regiment. This testing should be conducted pre and post construction to further understand the impacts UFS's have on water quality and how those impacts may translate to larger site design. A bacteriologist should also be consulted, as further research, to identify specific bacterial additions to the pond that may increase water quality.

This Upflow Spring Filter installation helped alleviate nutrient loading and provided potential pollutant removal through biological means. The filter has been in operation for eight years. Visual water quality is improved and algal blooms have been minimal since the installation. The benefits of the addition of this Upflow Spring Filter to this aquatic ecosystem are impactful. The customer and end users often visit the space to relax and take breaks. The sound of water and the aesthetic beauty provide relief for a

rather large urban corporate campus. It is unknown the monetary value this water feature now adds to the site, but a failed water feature will certainly negatively impact value. Maintaining high visual quality by using a fully functional bioactive water feature will likely bring greater value to the real estate property. Photos taken five years after completion illustrate the improvement to the site.



Figure 16. Photo of Pond (Photo taken by Reid Ferrero 2018)



Figure 17. Photo of Pond (Photo taken by Reid Ferrero 2018)

Fish are currently living in the pond and thriving in the habitat. The plants are also prospering. The new concrete pond floor keeps the plants contained and the system remains balanced as the designer intended.

Limitations

There is no lab based water quality testing data available prior to the installation of the USF in this study; therefore, this researcher was unable to perform a before and after water quality assessment for comparison purposes. Future studies of USF systems should initiate lab based water quality monitoring of the site prior to the installation of an USF to analyze the differences after installation and operation. In addition, alterations to the USF design and materials should be tested for varying outcomes, visual quality, cost, and water quality.

While formal lab based water quality testing could not be performed, amphibious lifeforms have been observed utilizing the pond and these are widely recognized by scientist as indicator species. According to Waddle (2006), “Amphibians are generally considered suitable as indicator species in a variety of systems. Their biphasic life cycle and semi-permeable skin are two justifications often given for this use of amphibians”. Systems with poor health cannot sustain amphibians because of their hypersensitivity to pollutants. Their presence implies a positive impact on water quality is a potential result of the Upflow Spring Filtration system. This beneficial potential, if incorporated to an open natural system, should yield the same results. The visual clarity of the water also implies an improvement

to water quality. The absence of algae is a correlation to improved water quality, meaning the water is not carrying excessive nutrient contaminants needed for algae to thrive.

Water quality comparisons using established EPA BMP's illustrates an improved water quality. Please refer to website:

<https://nepis.epa.gov/Exe/tiff2png.cgi/200044CU.PNG?-r+75+-g+7+D%3A%5CZYFILES%5CINDEX%20DATA%5C95THRU99%5CTIFF%5C00001323%5C200044CU.TIF>



Storm Water Management Fact Sheet Visual Inspection

DESCRIPTION

Visual inspection is a Best Management Practice (BMP) in which members of a Storm Water Pollution Prevention Team visually examine material storage and outdoor processing areas, the storm water discharges from such areas, and the environment in the vicinity of the discharges, to identify contaminated runoff and its possible sources.

In a visual inspection, storm water runoff may be examined for the presence of floating and suspended materials, oil and grease, discoloration, turbidity, odor, or foam; and storage areas may be inspected for leaks from containers, discolorations on the storage area floor, or other indications of a potential for pollutants to contaminate storm water runoff.

Visual inspections may indicate the need to modify a facility to reduce the risk of contaminating runoff.

APPLICABILITY

The U.S. EPA has recognized visual inspection as a baseline BMP for over 10 years. Its implementation, however, has been sporadic. Implementation may increase as more facilities develop Storm Water Pollution Prevention Plans. Implementation may also increase as facility management recognizes visual inspection to be effective both in protecting water quality and in reducing costs.

ADVANTAGES AND DISADVANTAGES

Visual inspections are an effective way to identify a variety of problems. Correcting these problems can improve the water quality of the receiving water.

Limitations associated with visual inspections include the following:

- Visual inspections are effective only for those areas clearly visible to the human eye.
- The inspections need to be performed by qualified personnel.
- To be effective, inspections must be carried out routinely. This requires a corporate commitment to implementing them.
- Inspectors need to be properly motivated to perform a thorough visual inspection.

KEY PROGRAM COMPONENTS

Visual inspections for signs of storm water contamination should be performed routinely. Flows should be observed during dry periods to determine the presence of any stains, sludge, odors, and other abnormal conditions.

Visual inspections should also be made at all storm water discharge outlet locations during the first hour of a storm event, once runoff has reached its maximum flow rate. Inspectors should examine the discharge for the presence of floating and suspended materials, oil and grease, discoloration, turbidity, foam, or odor.

Figure 18. EPA Fact Sheet for Visual Inspection BMP.

Based on the above inspection, it is fair to state the USF addition to Cox Media corporate headquarters had a positive impact on water quality. Presence of floating and suspended material, discoloration, turbidity and odor where all prevalent prior to addition of the filter. The general appearance improvement suggest this product is successful. A water quality comparison is depicted in Figure 19.



Figure 19. Visual inspection of water quality comparison.

Adding recirculating constructed biofiltration to a site water management plan does improve water quality. This built experiment was observed carrying amphibious lifeforms, often considered as indicator species of ecological health, thus proving water quality improvement have been achieved after USF incorporation. It is fair to state that recirculating site water through upflow spring filters can improve water quality downstream.

CHAPTER 5

CONCLUSION

Conclusion

There is a commonly held assertion that fresh water availability may be one of the greatest challenges humankind will face due to over population and resource scarcity. Landscape architects are in a unique position to provide site specific solutions to alleviate this problem. Applying unconventional means of water treatment through ecological, naturally occurring processes will lead to enhanced water quality of receiving watersheds downstream of urban development.

Landscape architecture has a long history of remediating water quality issues by utilizing the landscape and constructing wetlands. This thesis identified those past capstone projects and explored the current trends at large scale city planning through a project completed by Turnescape.

This thesis also identified current conventional green infrastructure practices. By identifying key components of those designs and exploring opportunities to multiply the positive impacts they provide in regards to water quality, this thesis identifies a new system worthy of providing water quality improvements: Upflow Spring Filtration. By utilizing design as research, each component of an upflow spring filter is identified, analyzed and evaluated. The components that are considered and discussed at length are:

1. Size the area of the filter (footprint)
2. Assign the filter a depth (1', 2', or 3'?)
3. Design the structure of the filter
4. Specify a waterproofing
5. Size a filter water supply (pump)
6. Design a dispersion system (pipe)
7. Pick a filter media
8. Planting plan

By building on the current framework of industry standards for green infrastructure, this design does increase positive impacts to water quality by allowing site water to traverse the treatment course multiple times. Unlike conventional systems used today, which only allow site runoff to run the treatment course one time, USF's allow the ability to recirculate multiple passes a day through the course, thus providing more opportunities for treatment. Although conventional green infrastructure can be designed as a "train", linking multiple BMP's together to treat the water further, their landscape footprint can be larger than site area available. Utilizing USF's can shrink that required footprint to accommodate urban areas while still providing the benefits of multiple treatment cycles.

The design also improves the aesthetic properties of the water feature by providing a waterfall. This waterfall provides positive visual and audible impacts to an otherwise urban corporate campus. The area is meant for a break area and employees are seen rather frequently utilizing the pond as a break area.

Picture comparisons are utilized as water quality assessment of before USF installation and five years after install. Based on visual inspection, presented by the EPA, water quality improvements have been achieved. Incorporating USF into landscapes does in fact have a positive impact to downstream water quality of receiving watersheds.

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APPENDIX A

PROJECT OVERVIEW

In this manual, you will find useful information for the care and maintenance of your newly remodeled water feature.

Section 1

Electrical Connections.....	2
Submersible Pumps.....	3-5
Auto fill Device/Over flow.....	6-7

Section 2

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Skimmer Pump.....	9
Eyeball Jets.....	10
In-pond Bog Operation.....	11

Section 3

Skimmer Operation.....	12-15
Helpful Hints.....	16



Electrical for Pumps



Skimmer outlet (typ.) All outlet done by others

Sump pump #2 outlet (typ.) and aeration outlet



All skimmer pumps have their own outlets. Sump pump #1 shares an outlet with the auto fill device while Sump pump #2 shares an outlet with the aeration system.

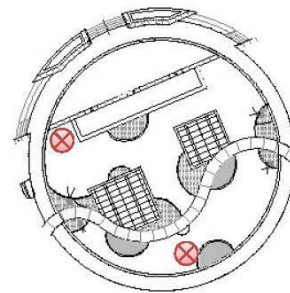
Submersible Pump Parts Breakdown



Sump Pump...



Site Key



⊗ -Sump Pump locations

**Atlantic Water Gardens
TidalWave L-Series Pump
Model:** L-310
Motor: 1 HP
Volts: 115

Amps: 10
Watts: 1105
Outlet: 3" MPT
Weight: 65 lbs.
Dimensions: 9"L x 9"W x 19¼"H

It is recommended that regularly schedule maintenance be performed on these sump pump at least once a week. This will consist of a physical examination of the pump intake grate to check for any debris or clogs. The main focus of this preventative measure is to ensure no foreign objects enter the pump vaults and water has unrestricted ability to enter the pump intake.

Monthly detach the power cable from the receptacle and turn off the power supply (circuit breaker). Disconnect the pump discharge and remove the pump from the water. Remove any accumulated debris from the surface of the pump, inlet screen and impeller. Make sure all nuts and bolts are fastened securely. Do not disassemble the pump for any reason. Disassembly will void the pump warranty. Refer operating and maintenance problems to a qualified technician.

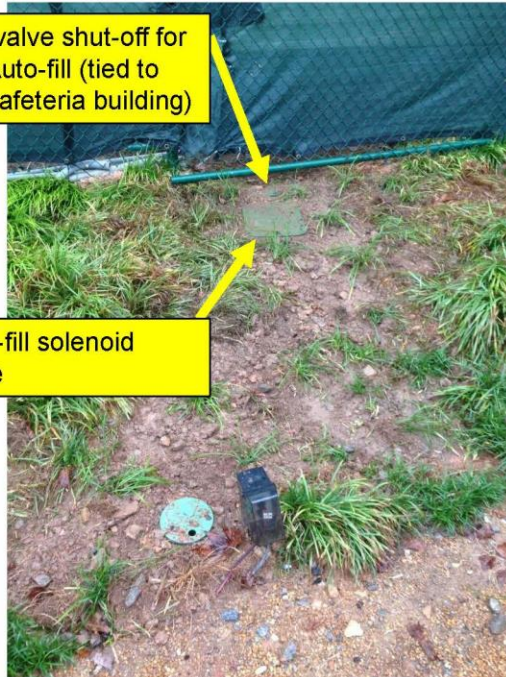
Auto-Fill and Overflow



The Auto-Fill controls are located on the side side of the pond along the existing retaining wall.

Ball valve shut-off for the Auto-fill (tied to the cafeteria building)

Auto-fill solenoid valve



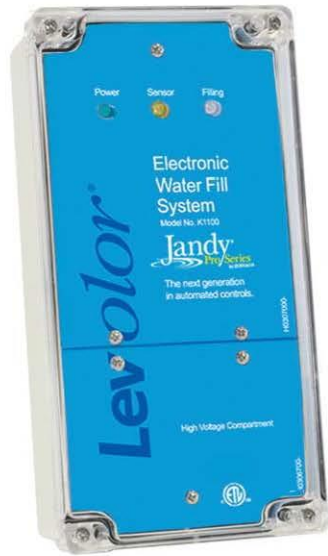
The auto-fill is used to keep the water level of the pond at a consistent depth. Allgood Outdoors has set the depth. To change the depth the sensor needs to be physically moved up or down to the desired depth. The lower the sensor, the lower the water level and vice versa. Once the desired level is changed, turn on the water at the shut off. If water is released into the pond then the level of the water is lower than what the auto-fill was set to. Once the auto-fill is set it will work on its own.

Overflow Drain

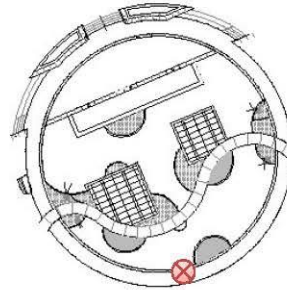


The overflow drain is located at the very north end of the out-of-pond bog. The overflow allows water an escape in the event of too high a water level. This ensures water will not spill out into the landscape and cause runoff. The overflow drain is tied into the preexisting stormwater infrastructure that drains the garden to the north.

Auto fill device...



Site Key



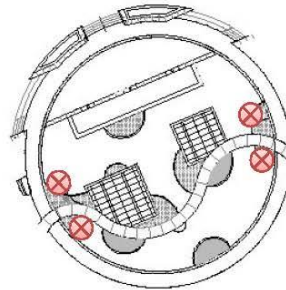
⊗ -Auto fill location



Skimmers...



Site Key



⊗ -Skimmer locations

**Atlantic Water Gardens
Pro Series Skimmer
Model: PS7000
Weir Width: 9"
Dimensions: 25"W x 30"D x 24"H**

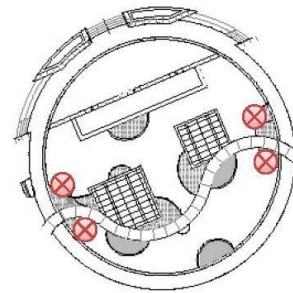
**Max Pump Flow: 7,000 gph
Sq. Ft. Rating: 900
Filtering: net, brush panel
Match to FilterFalls: BF2600**

It is recommended that regularly schedule maintenance be performed on these skimmer at least once a week. This will consist of a physical examination of the skimmer by removing the lid to check for any debris. The main focus of this preventative measure is to ensure no foreign objects enter the skimmer pumps located inside the skimmers.

Skimmer Pumps...



Site Key



⊗ -Skimmer Pump Locations

Atlantic Water Gardens
TidalWave2 Hybrid PUMP
Model: TW6000
Volts: 115
Amps: 4.15

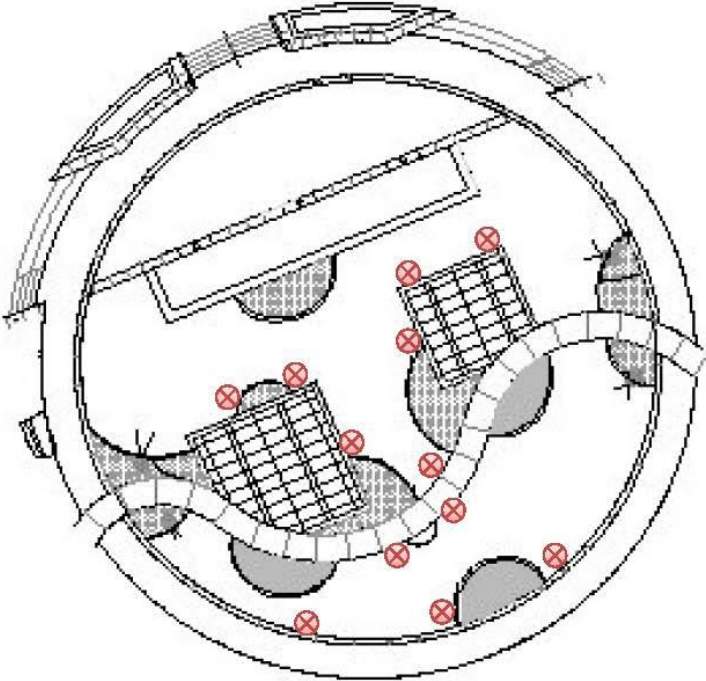
Watts: 495
Inlet: 2" MIPT
Outlet: 2" FIPT
Dimensions: 10"L x 6"W x 7"H

Monthly maintenance consist of checking on level of performance. Any lose of performance will most likely be caused by blockage in the inlet screen. Disconnect the power from the outlet. Disconnect the pump from the discharge line and remove the pump from water. Visually inspect the pump. Remove any debris from the surface and inlet screen. Remove the inlet screen and inspect the impeller. It should spin freely.

Eyeball Jets...



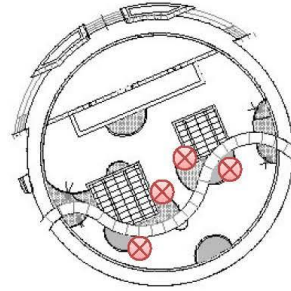
Site Key



⊗ -Eye Ball Jet Locations

In-pond Bog Operation...

Site Key



⊗ -In-pond Bog Locations



(typ.) Ball Valve



(typ.) Clean Out

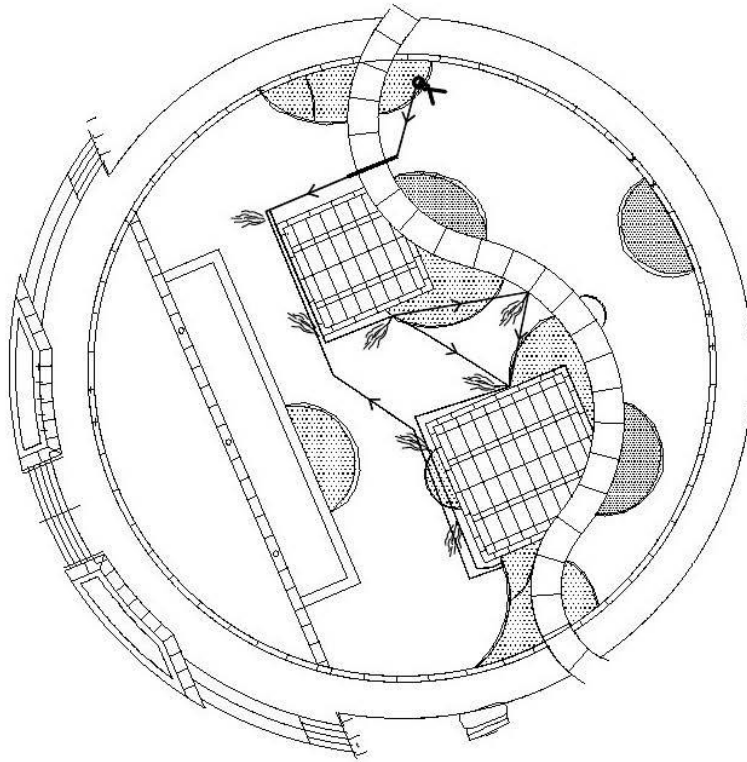


Skimmer #2 supplies water to the in-pond bogs on the East side of the pond. Skimmer #4 supplies two in-pond bogs in the west pond. All bogs have a ball valve to control/equalize flow. They each have been plumbed with a clean out in case of line blockage.

Skimmer #1 Operation...



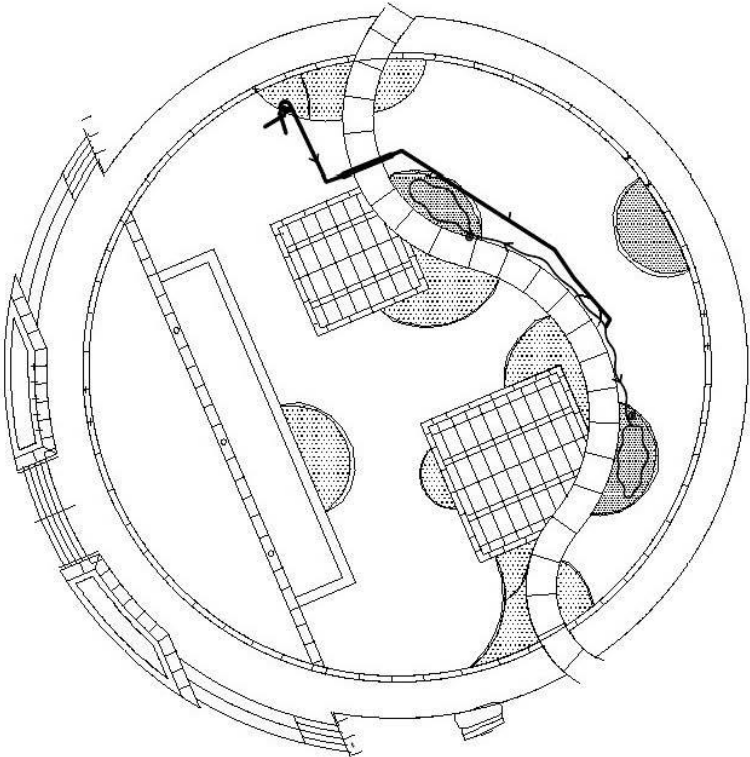
Site Key



**Skimmer #2
Operation...**



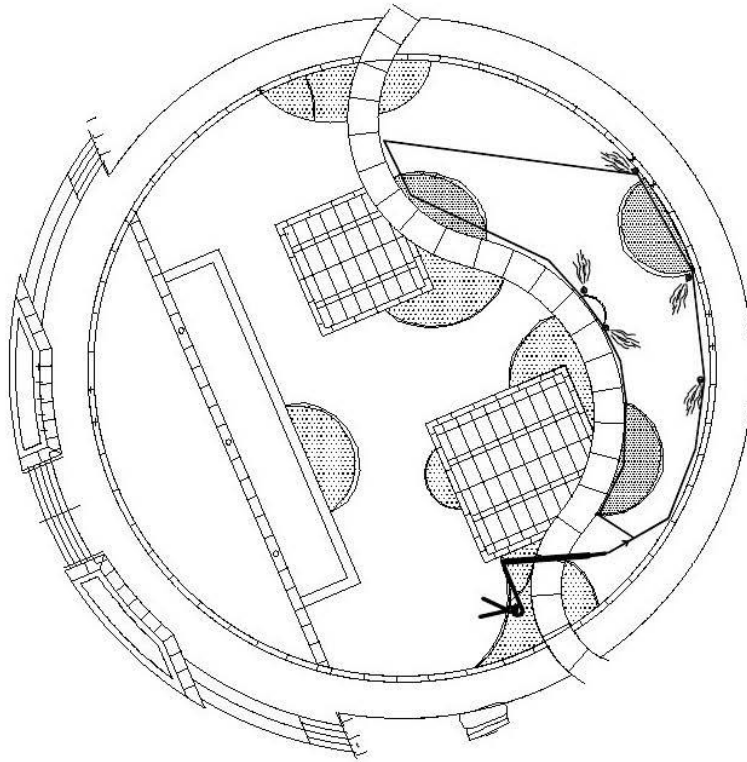
Site Key



Skimmer #3 Operation...



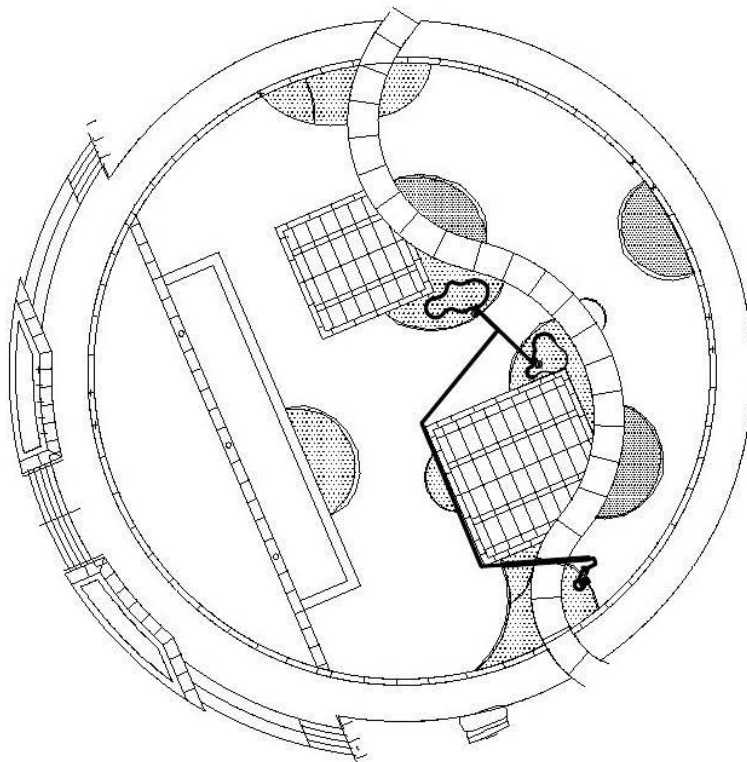
Site Key



Skimmer #4 Operation...



Site Key



Regular upkeep and routine maintenance of a pond is easy and will make a huge difference in the overall health of the water feature.

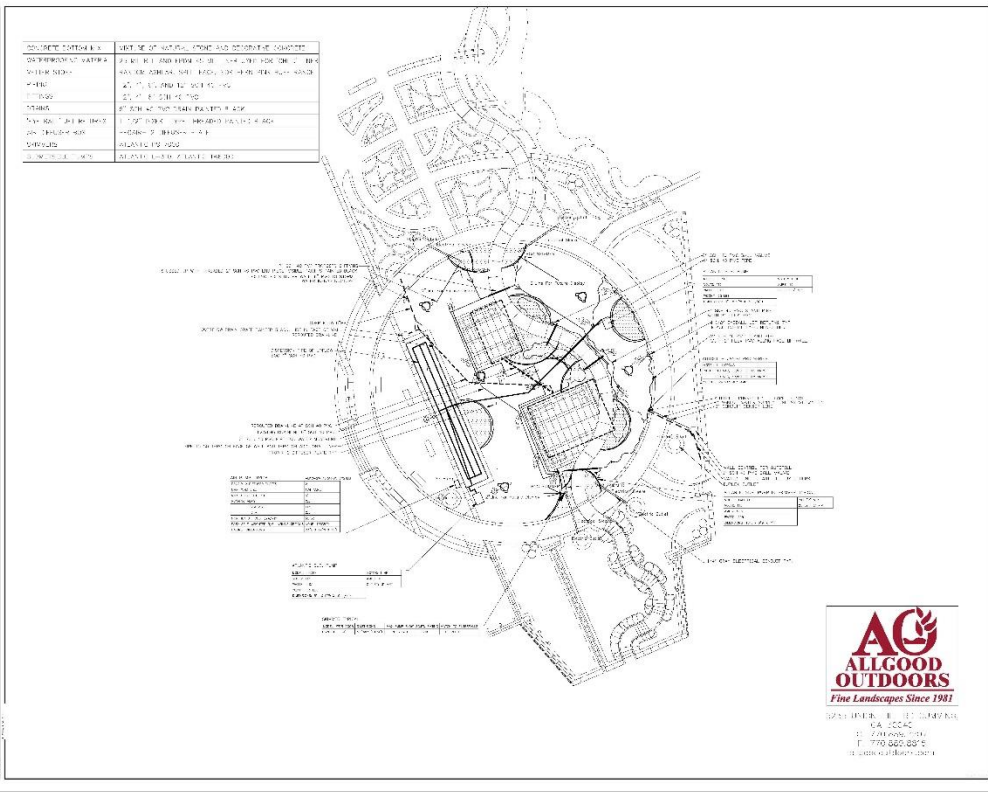
Monthly

- Add beneficial bacteria to the pond once a month. There are several different types of beneficial bacteria. We recommend **Bugs2Go**, a powder bacteria sold at Wakoola Gardens. These powder packets will dissolve when tossed into the pond to release the beneficial bacteria into the water system so that it can colonize on the filter material. Each Bugs2Go packet treats 1000 gallons – apply 6 packets every month for the pond. When cleaning the filter remember that it is a biological filter containing living bacteria. Six packets should be added after filter is cleaned.
- Add 6 packets of **Bugs2Go** after backwashing the filter. Backwash the filter at least once a month, or when waterflow through the jets has noticeably diminished.
- Manually remove leaves and debris from pond bottom. If too much sludge builds up on bottom, an enzyme can be added to help break down the solids. **Bugs2Go** pellets can be used for this.
- Check pH. We recommend testing the pH levels in the water on a monthly basis to ensure that the water is at the appropriate level. Neutral pH (7.0) is ideal and will promote a healthy environment. If the pH is elevated it will increase the likelihood of algae growth. Wakoola Gardens sells products that can help to regulate the pH levels in your water. Wakoola Gardens can test the pond water free of charge.

As Needed

- If an algae bloom occurs, Wakoola sells several types of algaecide that can be applied. Either a liquid algaecide (Algaefix) or a granular algaecide (**Laguna Algae Remover**) can be used to reduce algae. Algaecide can be added regularly as a preventative if desired.
- Add Accu-clear to clear up cloudy water if needed. Accu-clear binds suspended particles in the water into larger particles that can be filtered out.
- If fish are added, de-chlorinator will be needed at times of water addition or change.

For questions regarding the maintenance of the water feature contact Wakoola Gardens – (770) 844-0772. |



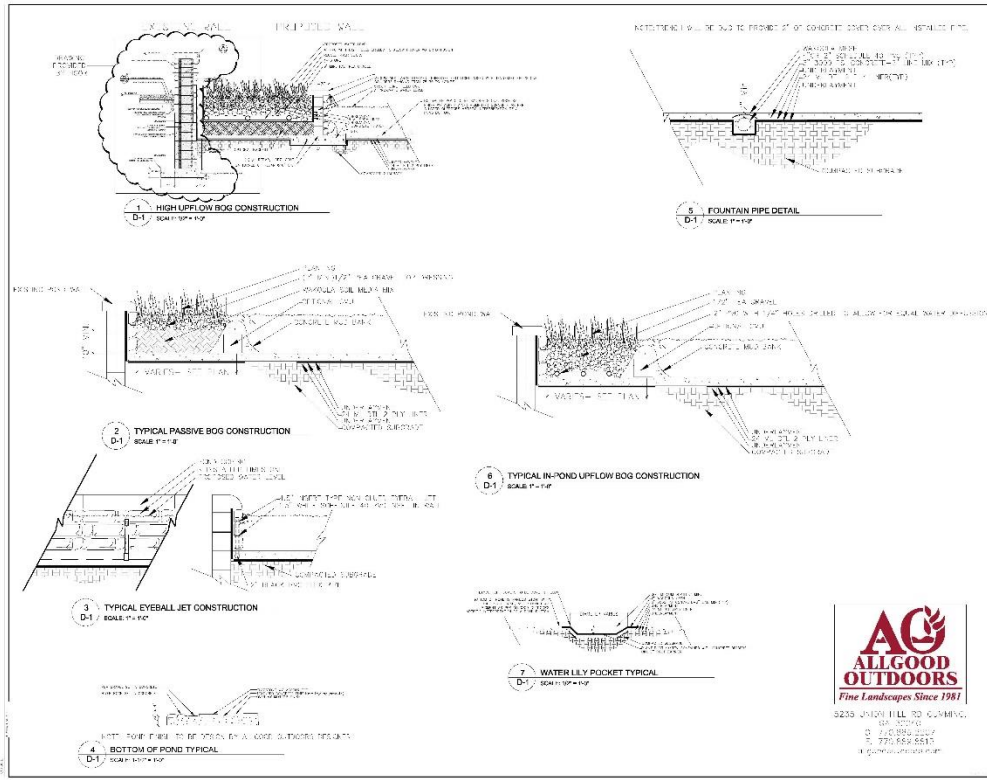
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PROJECT: T2 - CCI HEADQUARTERS
LOCATION: 10000 WINDY ROAD, SUITE 100, SPRING, TX 77481

T2 - CCI HEADQUARTERS
10000 WINDY ROAD, SUITE 100, SPRING, TX 77481

DATE: 08/14/2014
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