

# Emory University Atlanta, GA

Estimated Completion: Early 2015

System Capacity: 400,000 GPD

Reuse: Chiller Plants, Steam Plant, Toilet Flushing



## OVERVIEW

Emory University (Emory), located on approximately 700 acres in DeKalb County, Georgia, is a top-tier institution recognized for its medical school and various professional programs, as well as its commitment to environmental sustainability. Over the last decade, sustainable water management has become a critical issue for the metro-Atlanta region, which has struggled with drought, legal disputes over water supply, and EPA consent decrees on water quality issues. As a pioneer, community leader, and home of the world renowned Center for Global Safe Water, Emory is seeking to comprehensively address local and global water challenges. With a variety of water conservation initiatives deployed on campus, Emory is on the leading edge of water efficiency and continuing to search for ways to minimize its environmental footprint and safeguard community water supplies.

In 2011 and 2012, Emory used an estimated 390 million gallons of water per year, equating to approximately 1.1 million gallons per day (GPD). Nearly 40% of this use (over 400,000 GPD) is considered non-potable water demand, and can thus be replaced with alternative water supplies. In order to further reduce its dependence on potable water, Sustainable Water and its partners designed a 400,000 GPD capacity ecological treatment facility that will reclaim campus wastewater for non-potable reuse applications. The facility will extract wastewater from the municipal sewer system and treat it through a proprietary process utilizing Sustainable Water's technology. Once treated, reclaimed water will be reused as process make-up at three central chiller plants and the campus steam plant. Additional uses for reclaimed water will include toilet flushing at select residence halls, all compliant with stringent Georgia plant regulations.

Reclamation and reuse helps extend the life cycle of water by turning a waste into a resource. It provides a number of environmental, social, and economic benefits, which include cost savings, risk mitigation, pollution abatement, and a reduced dependence on community water infrastructure. WaterHub™, which relies on complex adaptive ecosystems to break down nutrients and pollutants in water, is the most sustainable form of treatment available. The robust ecological treatment process produces a very high quality effluent that meets all federal, state and local regulations while consuming very little energy. Flexible site integration, a compact footprint and a natural aesthetic also complement Emory's campus and sustainability goals.



# Project Overview



The WaterHub at Emory University will be integrated into the current campus fabric – utilizing underdeveloped parcels and existing open space. The selected site is co-located between a large sewer collector and multiple central utility plants. The hydroponic greenhouse facility, comprising only 2,100 ft<sup>2</sup>, will be located in a small facilities parking lot at the intersection of Peavine Creek Drive and FM Drive. In addition to reclaiming wastewater, the facility will displace existing impervious surface and harvest rainwater on-site for reuse. Across the street, additional hydroponic cells and a reciprocating wetland will be sited on a small vacant parcel behind the left field fence at Chappell Park. (below left).

As the largest point-source users of non-potable water on campus, central utility plants present the most impactful opportunity to displace potable water. Emory has six major utility plants and five satellite plants that provide heating and cooling services to campus. Together, these extremely efficient utility plants comprised nearly 34% of total campus water use in 2011– averaging 370,000 GPD. The Michael Street Chiller Plant, in the north section of campus, is the single largest consumer of water at Emory – having used an average 73,000 GPD or nearly 27 million gallons annually in 2011.



At commissioning, the reclamation system has the capability to recycle an estimated 146 million gallons annually or approximately 40% of total current campus water demand. It will displace 100% of the utility water demand at the campus steam plant, Michael Street Chiller Plant, Woodruff Memorial Building Chiller Plant and Quad Energy Plant. Designed with expandable capacity, the facility is capable of replacing subsequent demand at the Hospital Chiller Plant and Woodruff Library Chiller Plant at a later date. Operating at 100% capacity will allow Emory to displace 90% of all utility water use on campus, while reducing wastewater discharge to the county's already stressed system.

In addition to its functional use as a water reclamation facility, WaterHub can be used as an immersion learning tool to enhance curriculum and advance research in a number of fields. The University believes this facility can help advance disciplines directly related to botany, microbiology, engineering, public policy and urban planning among others. The Rollins School of Public Health has already demonstrated interest in performing research associated with reclaimed water quality. Emory's faculty believes this facility will also bring in additional research funds and enable the University to qualify for new grants in the future.

## TREATMENT SYSTEM DESIGN

The WaterHub at Emory University, powered by Sustainable Water's technology is comprised of a number of innovative and proven processes that collect, treat, and distribute water to reuse locations across the campus. Influent and effluent data is presented in the table below. A Process diagram is provided on the next page.

Units (mg/l)	Design Influent	Design Effluent
BOD	266	<5
TSS	350	<5
TKN as N	65	<5
Turbidity (NTU)	N/A	<3

## SEWER MINING

A below grade duplex pump station pumps influent through a 6 mm primary screen to remove any trash entrained in the wastewater. Influent flows from the screen into the primary treatment reactors.

## PRIMARY TREATMENT REACTORS

Primary treatment is needed to settle and digest biological solids. The most passive systems utilize large settling tanks similar to septic tanks that use little supplemental energy, but require a large footprint and frequent pumping of settled solids. To significantly reduce footprint and maintenance, aerated primary treatment tanks with attached growth media, commonly referred to as moving bed bioreactors were chosen.

The three moving bed bioreactors are located behind the hydroponic greenhouse on the upper site. The attached growth media in these reactors, a floating plastic substrate, is colonized by a community of bacteria called a biofilm that begins the biological treatment process. These reactors have coarse bubble diffusers and mixers that supply oxygen and scouring energy to achieve optimum biofilm growth. Stainless steel screens on the inlet and outlet pipes retain the media inside the

reactors. Moving bed bioreactors (MBBR) are a commonly used technology to efficiently remove carbonaceous material as a primary treatment step. The Waterhub system uses attached growth media designed by Entex that has an industry-leading surface area of 550 m<sup>2</sup> m<sup>-3</sup>. This results in a total surface area of over 500,000 ft<sup>2</sup> for biofilm growth, resulting in high treatment efficiency and stability, as outlined in US patent # 7,854,843.

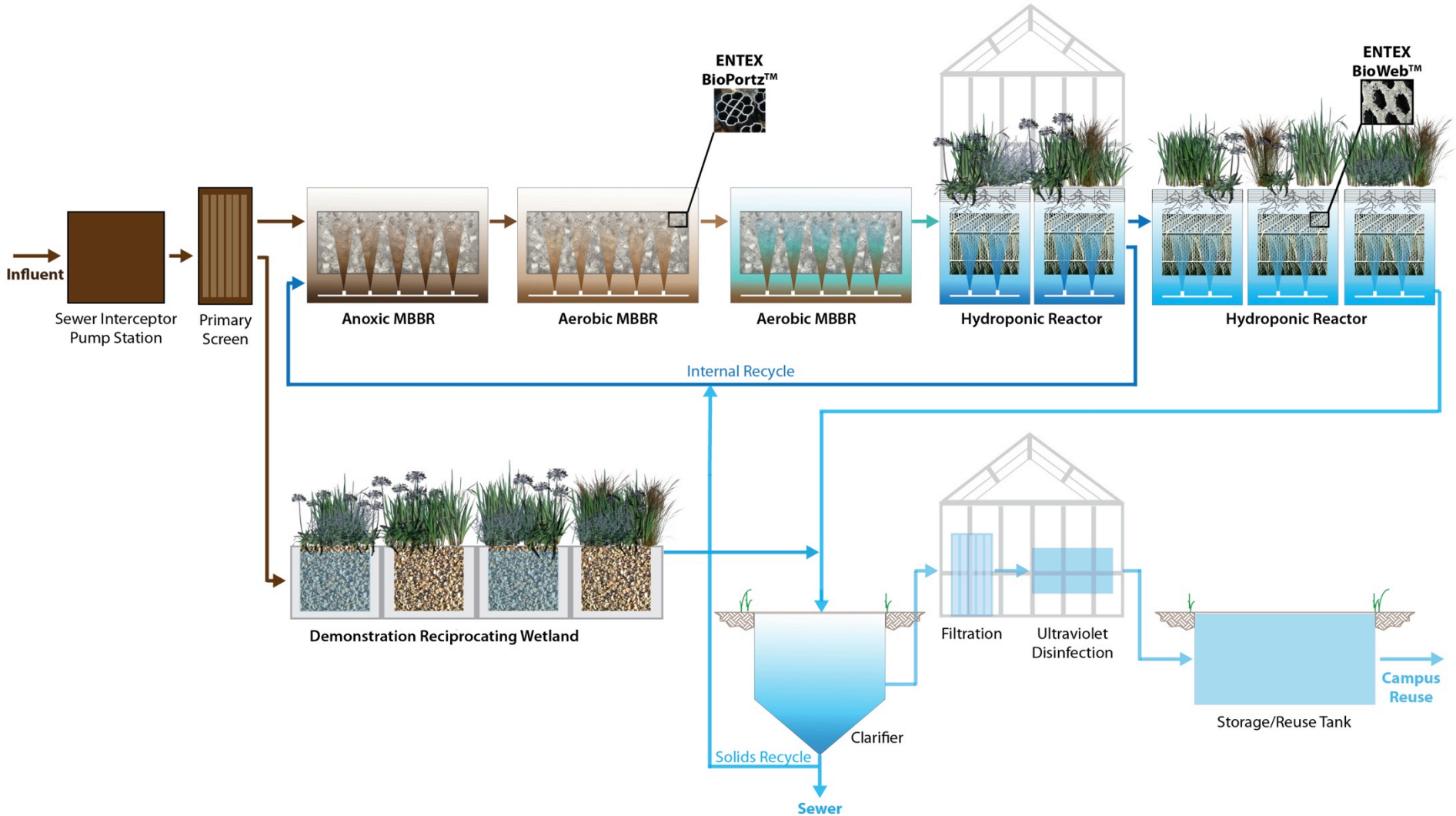
The first reactor is an anoxic reactor. Its purpose is to "select" for the growth of floc-forming microorganisms, convert nitrate to nitrogen gas (denitrification) and remove Biological Oxygen Demand (BOD). The anoxic environment is between anaerobic and fully aerobic, in terms of the oxygen content in the wastewater. There is no free oxygen (O<sub>2</sub>) in the wastewater; oxygen is present in bound forms of nitrates, sulfates, and other compounds.



*Interior WaterHub*

# Treatment Process

## The WaterHub Utilizing Sustainable Water Technology





*WaterHub Rendering*

The anoxic state is maintained by mixers and by varying the process recycle rate, which optimizes nitrogen removal and minimizes formation of hydrogen sulfides. The constant recycle of process water from the hydroponic reactors to the anoxic reactor returns nitrate for conversion to harmless nitrogen gas.

The next two moving bed reactors are aerated with coarse bubble diffusers and are the first fully aerobic portion of the treatment process. The purpose of these reactors is to remove a large fraction of the carbonaceous material, measured as BOD, in the influent and to strip odorous gasses from the wastewater. The first three reactors are enclosed, with access through air-tight hatches. All gasses are vented through activated carbon air filters to prevent any odors from escaping by applying proven solutions to ensure odor-free operation.

## **HYDROPONIC REACTORS**

The hydroponic reactors follow the primary moving bed reactors and are located within the greenhouse and on the lower portion of the site. These reactors reduce remaining BOD to secondary levels and complete the nitrification process.

The surface of the hydroponic reactors is covered with vegetation supported on racks. These reactors are aerated with fine bubble diffusers, which provide the oxygen required for treatment and keep the tank contents mixed. Plants have evolved over millions of years to maximize root surface area for increased nutrient and water uptake. The roots of the vegetation provide ideal surfaces for the growth of attached microbial populations. Similar to the moving bed reactors, greater surface area provides greater habitat for biofilm formation, resulting in more efficient and stable treatment.

Research indicates that, for a given surface area, microbial biofilms are more efficient than biofilms grown on plastic or other artificial substrates. The vegetation serves as habitat for beneficial insects and organisms that graze on microbial biomass, as well. This grazing reduces the sludge volume and maintains the microbes at optimal growth rates, resulting in less solids discharge to the municipal sewer. Also, the vegetation and racks decrease the surface turbulence in the reactor, which reduces the formation of aerosols and volatilization of odor compounds. A layer of light-weight expanded shale aggregate is placed on top of the racks, creating a natural biofilter colonized with bacteria that remove any residual odor compounds. A ventilation system with activated carbon scrubbers provides a secondary layer of protection within the indoor Hydroponic Reactors. Direct access to the wastewater is only through secure hatches.

The current hydroponic reactor design includes Bioweb® modules suspended above the fine bubble diffusers on the floor of the reactors. With the inclusion of these modules, a total of over 3,500 ft<sup>2</sup> additional surface area is provided. The design of the hydroponic reactor is detailed (above top left).

To optimize total treatment volume and to accommodate shallow bedrock on the upper site, additional hydroponic reactors were provided on the lower portion of the site. These reactors are designed to seamlessly blend in with the demonstration reciprocating wetland cells. They utilize native and naturalized plant species found to be effective in designing previous outdoor hydroponic reactors.

## POLISHING AND DISINFECTION

Following the hydroponic reactors, BOD and ammonium concentrations have been reduced to meet or exceed standards. While a significant portion of the suspended solids have been consumed by protozoa and microcrustaceans in the hydroponic reactors there is a need to remove the remaining solids and remaining dissolved phosphorus. The first step in this process is to passively settle these solids in the quiescent clarifier tank. The addition of naturally occurring iron or aluminum and the inclusion of vertical plates in the clarifier increase the removal of phosphorus and passive settling of suspended solids. During this process solids are removed to less than 10 mg/l. A portion of these solids are pumped back to the beginning of the treatment process to provide ample bacterial communities to begin the treatment process. A small amount is discharged back to municipal sewer.

After the clarifier a disc filter located between the greenhouse and MBBR tanks removes any remaining suspended solids through a felt filter membrane. At this point effluent is very clear with no remaining nutrients but small amounts of microorganisms may remain. An Ultraviolet Disinfection (UV) process is utilized to remove any remaining microorganisms. UV at high intensities is able to disrupt the DNA of a variety of microorganisms allowing for energy efficient and chemical free disinfection. To maintain a disinfection residual in the water reuse piping back to the cooling towers and reuse applications, a small amount of chlorine is added. Online instrumentation verifies turbidity and UV transmissivity assuring that reuse criteria are being continuously met. Periodic microorganism and nutrient testing also is performed to verify performance.

## REUSE

Finally, the fully treated, reclaimed water is stored in an underground storage tank at the lower site, providing reliability and redundancy, that allows the campus heating and cooling to safely operate in the event of a major utility disruption for 3-6 hours. Reclaimed distribution pumps send the reclaimed water through the northern part of Emory's campus to the various reclaimed water users, including the steam plant, various



*WaterHub Site*

chiller plants and planned future use in residence halls for toilet flushing. By reclaiming and extending the life cycle of water, this project helps Emory meet its sustainability vision to help conserve Georgia's precious water resources and reduce the University's impact on the local environment.

## RESEARCH AND DEMONSTRATION SYSTEM

In addition to providing reclaimed water, the WaterHub offers numerous educational opportunities. The innovative treatment design combining moving bed bioreactors, textile modules, and hydroponics provides exciting opportunities for microbiological and botanical research. The various reuse applications provide public health research opportunities, as well. While science and engineering research is generally very narrowly focused and often performed at the benchtop scale, this system provides opportunities for synthetic research projects that study the interaction between different microbiological and ecological systems. Sampling locations are located throughout the system and integrated control systems compile online instrumentation and flow data.

# Treatment Process

While there are many research studies that can be accomplished using the treatment system, there are studies that are not possible at these large flow rates or without manipulating the treatment process. As a result, a small-scale demonstration system is also included on the lower portion of the site that can be manipulated in a variety of ways to answer research questions not addressed with the larger system.

A small side stream (about 2,000 GPD) of screened influent is pumped from the first primary treatment reactor on the upper site to the demonstration reciprocating wetland. A robust fixed-film microbial ecosystem is contained in a series of watertight fill-and-drain wetland cells. The treatment cells also contain a static under-drain system where anoxic degradation of sloughed biofilm, suspended solids and other recalcitrant organic compounds are treated through a process that relies upon the rapid filling and draining of the cells.

The treatment cells are filled with a series of selectively graded aggregates that optimize surface area, cation exchange capacity and

hydraulic conductivity. A diverse array of naturally occurring microbial organisms comprise the fixed-film, which grows on and adheres to the exterior surface and within micro-pores of the aggregate.

Water movement and ensuing wastewater treatment is controlled by high efficiency pumps, automated valves and integrated computer control systems. Fill-and-drain cycling occurs from 8 to 18 times per day, according to wastewater strength, wastewater type and treatment requirements. These fill-and-drain operations provide cost-effective passive aeration of the biological fixed-film and plant roots and enable development of alternating anoxic and aerobic treatment environments accordingly.

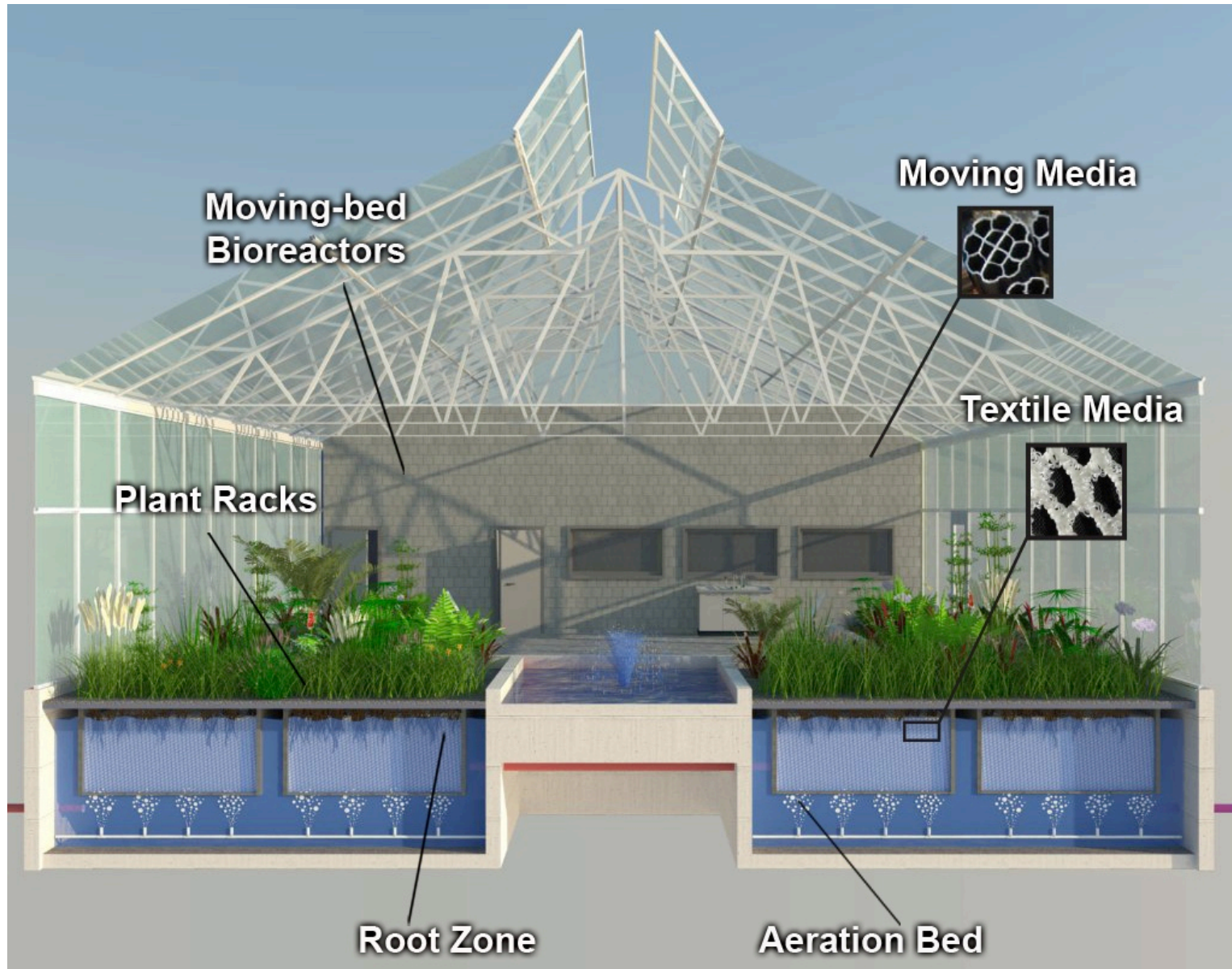
During recurrent fill cycles, ammonium ions ( $\text{NH}_4^+$ ) and dissolved organic matter adsorb to negatively charged aggregate surfaces and the biofilm consumes carbohydrates and other wastewater compounds. During the drain cycles, as oxygen depleted wastewater is pumped from one cell to an adjacent treatment cell, atmospheric gases (21% oxygen by volume), are passively drawn into the gravel substrate to replace the exiting water. Oxygen diffusion in air is up to 10,000 times faster than oxygen diffusion in water, and therefore the fill-and-drain process provides a near-limitless supply of oxygen for exposed plant roots and biofilms during the drain cycle. Passive aeration is very energy efficient, and is the major factor responsible for significantly enhancing aerobic treatment processes. Passive aeration also provides oxygen to the root zone and promotes rapid growth of many emergent and terrestrial plant species.

While the water is anoxic (without oxygen), reducing conditions are near optimum for microbial-induced reduction of nitrate. Nitrate-nitrogen ( $\text{NO}_3$ ) is biologically reduced to  $\text{N}_2$  gas by free-living and fixed-film denitrifying bacteria. In the denitrification process, residual organic carbon is consumed by the bacteria and converted to  $\text{CO}_2$ .



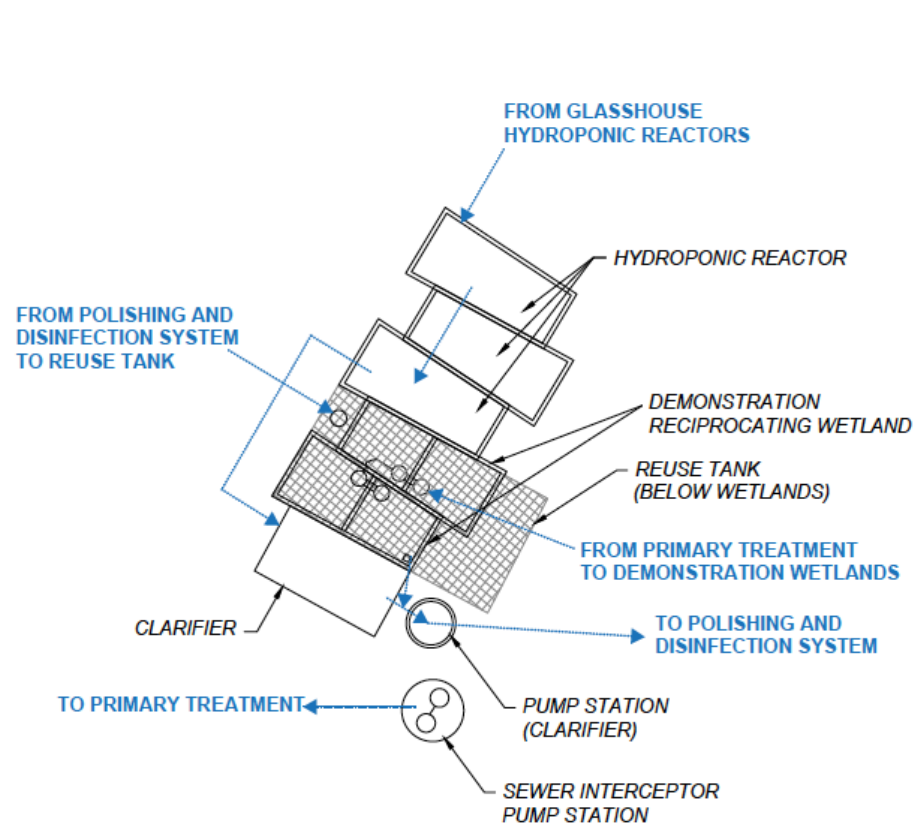
*WaterHub at Emory University*

# Hydroponic Reactor Diagram

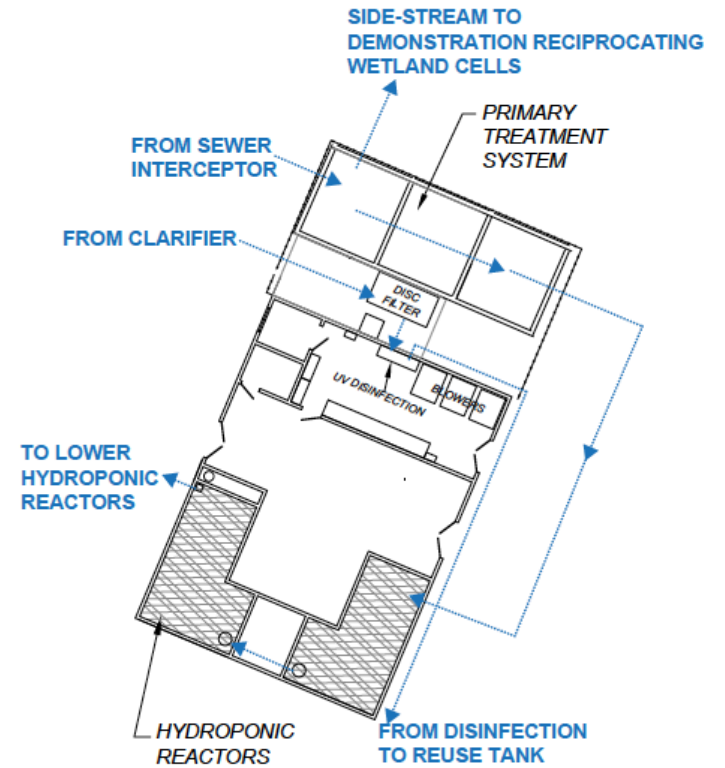




# WaterHub Site Plan at Emory University



WaterHub: Lower Site Plan



WaterHub: Upper Site Plan