Georgia Institute of Technology

Feasibility Study

Decentralized Water Reclamation & Reuse

This document explores the feasibility and economic viability of decentralized water reclamation and reuse using ecologically designed water treatment technologies at Georgia Tech's main campus in Atlanta, Georgia.

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SUSTAINABLEWATER

Feasibility Study: Black Water Reclamation & Reuse
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Atlanta, GA

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Executive Summary

~Abstract~

Sustainable Water was retained by the Georgia Institute of Technology (GT) to explore the feasibility of installing a decentralized water reclamation and reuse facility to help lower the Institute's dependence on potable water. This facility would have positive environmental and economic benefits for GT and the surrounding community, as well as multiple educational- and research-related benefits. The following summarizes the Blackwater Reuse Feasibility Report, which validated the practicality and economic viability of a water reclamation program on campus. The study confirmed that decentralized water reclamation using ecologically-based treatment technologies is both feasible and economically viable. In total, GT uses over 420 million gallons of water per year, of which approximately 177 million gallons is considered non-potable demand. Displacing 60% of this demand (112 million gallons per year) presents the Institue with nearly $24 million in potential savings over a 20-year period, with no upfront capital requirements. The findings in this study recommend pursuing a two-phase water reclamation and reuse program to address a majority of GT's non-potable water demand.

Currently in the midst of environmental- and energy-related campus planning initiatives, Georgia Tech is in an ideal position to incorporate innovative best management practices to improve water management. Water reclamation and reuse is an impactful water management tool that can help de-risk campus operations by providing a stable alternative water supply for utilities and irrigation. With high water utility rates, bulk water reuse will also present significant economic savings to the Institute.

In 2012, GT used an estimated 424 million (M) gallons of water at an average rate of 1.16 M gallons per day (GPD). Nearly 44% of campus water use, over 177 M gallons annually, is considered non-potable demand and can thus be replaced with alternative sources of water. Approximately 84% of non-potable demand (148 M gallons annually) is used for campus HVAC (Heating Ventilation, and Air Conditioning) and utility functions. GIS-based flow modeling indicates a substantial volume of wastewater feedstock available for reuse on-site. Conservative estimates indicate an average of 570,000 GPD of flow from Institute-owned campus buildings. If non-Institute-owned buildings are included, the total available volume of reclaimable wastewater is conceivably much higher.

Based on the immediate cost savings available for reclaiming campus wastewater, Sustainable Water recommends designing a two-phase water reclamation facility that serves both current and future needs. An expandable system would allow GT to begin reclaiming water today and provide additional capacity at a later date. Based on siting considerations, available wastewater feedstock, and end-use water demand, a Phase I facility is recommended to be designed at a capacity of 150,000 GPD and utilize a passive Tidal Flow Wetland (TFW) technology patented by Living Machine. Over the next five years, an additional 250,000 GPD of capacity can be added using hydroponic reactors, as part of a Phase II expansion.

In Basin A, the 10th Street Chiller Plant becomes the logical end-use destination for reclaimed water. It currently uses 160,000 GPD on average, with projected demand exceeding 230,000 GPD in the next five years. A 150,000 GPD TFW would displace approximately 70% of future demand at the 10th Street Chiller Plant (after its Phase I expansion). With the addition of the 10th Street Well, 86% of the plant's make-up demand would be satisfied saving 46 M gallons annually.

The Phase I TFW requires approximately 11,000 square feet of open space, which can be flexibly integrated into the existing landscape around the proposed Eco-Commons lawn. A wastewater extraction point located along an 18 inch sanitary collector at State Street should provide sufficient feedstock for a 150,000 GPD facility. However, flow rates one block to the west on Atlantic Drive should be larger, with added discharge from the Marcus Nanotechnology Building.

A proposed Phase II facility can be designed to accommodate an additional 250,000 GPD of capacity, at only 2,100 square feet of building space. The proposed Phase II facility would utilize hydroponic reactors housed in a greenhouse-type structure in order to minimize the total footprint of the system. The structure would also house mechanical elements and provide additional research or academic space if requested by GT. The location of the Phase II facility is recommended as a lamination to the parking deck proposed in conjunction with the EBB II building. Section 6.1 of this report shows concept drawings and site plans of the complete two-phase build-out integrated into the Eco-Commons site.

Despite its distance from the proposed Eco-Commons area, the Holland Utility Plant utilizing 154,000 GPD on average is the second largest single consumer of water on campus, and a logical location to displace potable water with minimum infrastructure costs. A 400,000 GPD facility, used in conjunction with the 10th Street Well, will displace 90% of demand at both the 10th Street Chiller Plant (after its Phase II expansion) and the Holland Utility Plant. The expanded system would reclaim approximately 112 M gallons annually. A more robust wastewater extraction location will be needed to accommodate the Phase II Facility. The most attractive alternate extraction point is along the Orme Street Relief Sewer.

Sustainable Water offers to build the proposed two-phase water reclamation system as a turn-key construction project through a Water Purchase Agreement (WPA). A WPA requires no upfront capital and offers the lowest risk to GT. Under a WPA, the Phase I Facility could immediately save GT over $380,000 dollars in year one. Factoring in a conservative 3% rise in annual water costs predicts annual savings exceeding $630,000 in year 20. Over the course of 20 years, this facility would produce approximately $9.75 M in cumulative savings with zero upfront capital requirements. If savings from the 10th Street Well are incorporated into this scenario, total savings reach $480,000 annually in year one alone.

Assuming similar economic conditions, a 400,000 GPD facility could produce an estimated $925,000 in annual savings in year one, and produce in excess of $23.5 M cumulative savings over the course of 20 years. Total cumulative savings, which include savings from the well, amount to $25.4 M over 20 years. Section 6.2 of this report shows annual and cumulative savings associated with the Phase I and II facilities. In both scenarios, savings are predicated on the assumption that the City of Atlanta honors a 100% rebate on sewer services.

The ecological treatment system proposed for GT provides tangible synergies with the proposed Eco-Commons theme in the North Campus. Implementation of this project will greatly reduce reliance on city water, protect the Institute in periods of drought, significantly decrease annual water costs and improve the Institute's overall environmental footprint. As a result, Sustainable Water recommends that GT move forward with the detailed engineering design of a decentralized water reclamation and reuse facility. Before proceeding to Engineering and Design, Sustainable Water recommends performing the following tasks:

1. Perform a detailed flow-measurement study to validate available feedstock;
2. Evaluate and validate economic models for various financing scenarios; and,
3. Present this project to the City of Atlanta Department of Watershed Management.

1.0 Introduction

1.1. Project Description & Study Area

Georgia Tech (GT), located on approximately 400 acres in the City of Atlanta, Georgia, is a top-tier public research institution recognized for its engineering school and various professional programs as well as its commitment to environmental sustainability. Growing in both enrollment and physical footprint, Georgia Tech is currently in the midst of multiple capital planning initiatives and campus improvements, which include:

- A sector plan for the new Engineered BioSystems Building (EBB) (which includes an "Eco-Commons" concept for the north-central portion of campus);
- A Stormwater Master Plan for Drainage Basin A; and,
- An expansion to the 10th Street Chiller Plant

The planning phases of these campus initiatives present a unique opportunity to evaluate complementary projects. Pushing for a higher level of campus sustainability, the office of Capital Planning and Space Management retained Sustainable Water to explore the feasibility of large-scale blackwater reclamation and reuse on Institute grounds. Water reclamation provides an integrated, more strategic, approach to campus-wide water management and complements the goals of the Stormwater Master Plan.

On-site water reclamation will help de-risk operations by providing a stable alternative water supply for the campus. Due to local water supply issues, large-scale water reuse can provide significant environmental and economic benefits to both the Institute and community at large. Sustainable Water specializes in the planning, design and building of ecologically-based water reclamation and reuse facilities. As a technology integrator, Sustainable Water assesses the most appropriate technologies for a client's needs and deploys "turn-key" solutions with financing options available for immediate project execution.

This study is designed to provide a comprehensive understanding of campus water use and assess the overall feasibility and economic viability of integrating a blackwater reclamation system into the campus fabric. If feasible, this report will help lay the groundwork for implementing a sustainable system in-line with the Institute's mission.

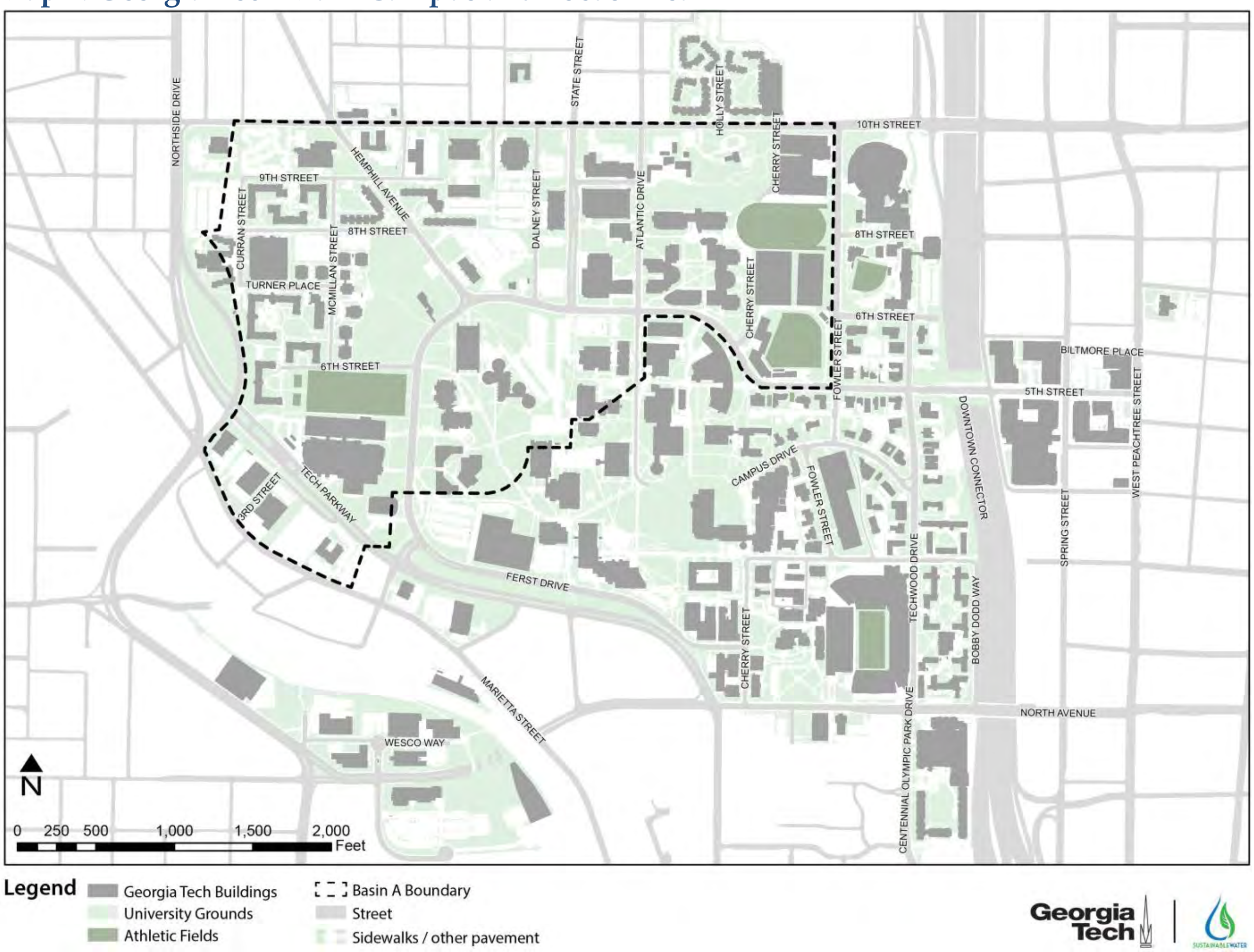
The ensuing study set out to accomplish four major objectives:

1) Analyze water use and identify opportunities to reuse wastewater streams;
2) Validate the ability to safely reuse water at bulk consumers;
3) Develop a reuse program that fits into the development plans of the Institute; and,
4) Determine the economic impact and lifecycle costs of said program.

This study's geographic focus area is limited to Drainage Basin A on Georgia Tech's main campus. Drainage Basin A (identified in Georgia Tech's Stormwater Master Plan) is located in the northern section of campus, where a majority of the EBB & Ferst Sector Plan development will take place. Map 1 shows the location of the study area relative to Georgia Tech's main campus.

In many cases the study area is expanded to the broader campus to accommodate for inter-basin wastewater and stormwater flows, as well as large volumes of non-potable water demand located outside the immediate study area. In addition, understanding water use at a gross level helps set baseline standards for water consumption and relate the focus area to the remaining parts of campus. As a result, some recommendations in this report may pertain to areas outside the immediate focus area in an attempt to maximize value for the Institute.

Map 1: Georgia Tech Main Campus and Focus Area



1.2. Water Reclamation and Reuse

Water reclamation involves treating wastewater to standards that can be safely re-used for non-potable applications. These applications usually involve irrigation, fire protection, groundwater recharge, utility process-water or industrial applications, and even toilet flushing, among other things. Water reclamation usually refers to the treatment of black-water streams, not just gray-water or stormwater. Water reclamation can be performed through a number of wastewater treatment techniques, but usually includes supplemental nutrient removal, polishing and disinfection steps to produce a safe, high-quality water stream.

Water reuse provides a variety of environmental, economic and social benefits, including risk mitigation, cost-savings, pollution abatement and habitat protection.[1] Reusing water helps extend the lifecycle of water by turning a waste into a resource. The benefits of water reclamation and reuse may vary from region to region, but usually fall under three themes:

1) Increasing available water supply and de-risking drought;
2) Pollution prevention and abatement; and
3) Cost savings and/or positive long-term economic impact.

Since a majority of water use in commercial or industrial settings does not require potable water, water reclamation becomes a practical way to reduce demand on potable water supplies. Irrigation, heating and cooling, industrial processes, and even toilet flushing do not necessarily require drinking-quality water and can thus be supplemented by alternative water supplies. Reusing water on-site will significantly decrease potable water intake, saving money and energy. By providing a stable and reliable source of water for campus operations, reusing water can act to mitigate anticipated long-term cost increases associated with escalating water rates.

Since many utilities have been unable to adequately keep pace with necessary infrastructure demands, distributed or decentralized utility models have become increasingly popular based on a number of benefits. According to a report sponsored by the Water Environment Research Foundation and underwritten by the U.S. Environmental Protection Agency:

> Distributed water management has been shown to have exceptional triple-bottom-line benefits when implemented within the proper context...A primary environmental benefit of distributed systems includes their greater efficiency compared to traditional approaches. Treatment close to the wastewater or stormwater source and reclaimed water reuse area requires less energy for conveyance. Additionally, urban reuse retrofits are more feasible and less disruptive. Per traditional practice, providing reclaimed water to areas with established infrastructure, such as roads and buildings with existing plumbing systems, can be extremely difficult and disruptive if not impossible; use of distributed building- or neighborhood-scale systems makes delivering reclaimed water viable. Additionally, the use of passive—less mechanical—systems is more feasible at the smaller scales associated with decentralized treatment.[2]

[1] Source: *Guidelines for Water Reuse*. U.S. Environmental Protection Agency, 2004.
[2] "Distributed Water Infrastructure for Sustainable Communities." Water Environment Research Federation. 2010.

1.3. Ecological Treatment Technology

In the 1980s, a new theme emerged centering on ecological design. Companies like Living Machine began designing ecology-based water treatment facilities that attempt to mimic natural processes. Ecology-based water treatment technologies greatly enhance conventional biological treatment by introducing suitable habitats for complex, adaptive ecosystems to breakdown waste. The main benefit of ecologically-based water treatment systems is a significant reduction in energy requirements resulting from natural aeration methods and more robust biological activity. Eventually, it became clear that these systems offer many strategic advantages relating to effluent quality, appealing aesthetics, and low implementation costs making them very competitive decentralized water treatment solutions.

1.3.1. Hydroponic Treatment Systems

Hydroponic or reactor-based wastewater treatment relies on complex adaptive ecosystems to break down organic waste in water. This technology incorporates a series of interconnected, sequentially-operated biological reactors with lush vegetation growing above them. The process involves circulating water through both aerobic and anaerobic chambers, in which fixed-film and suspended biomasses remove contaminants from water. Plants and their root systems provide a natural habitat for microbial organisms breaking down waste. In many cases, artificial media, mimicking the natural root system, is utilized to provide more surface area for fixed-film growth. The increased biodiversity of hydroponic treatment systems allows significant reductions in physical footprint, sludge production, energy use (operational costs), and improved effluent quality compared to traditional biological treatment systems. Figure 3 shows the hydroponic treatment process.

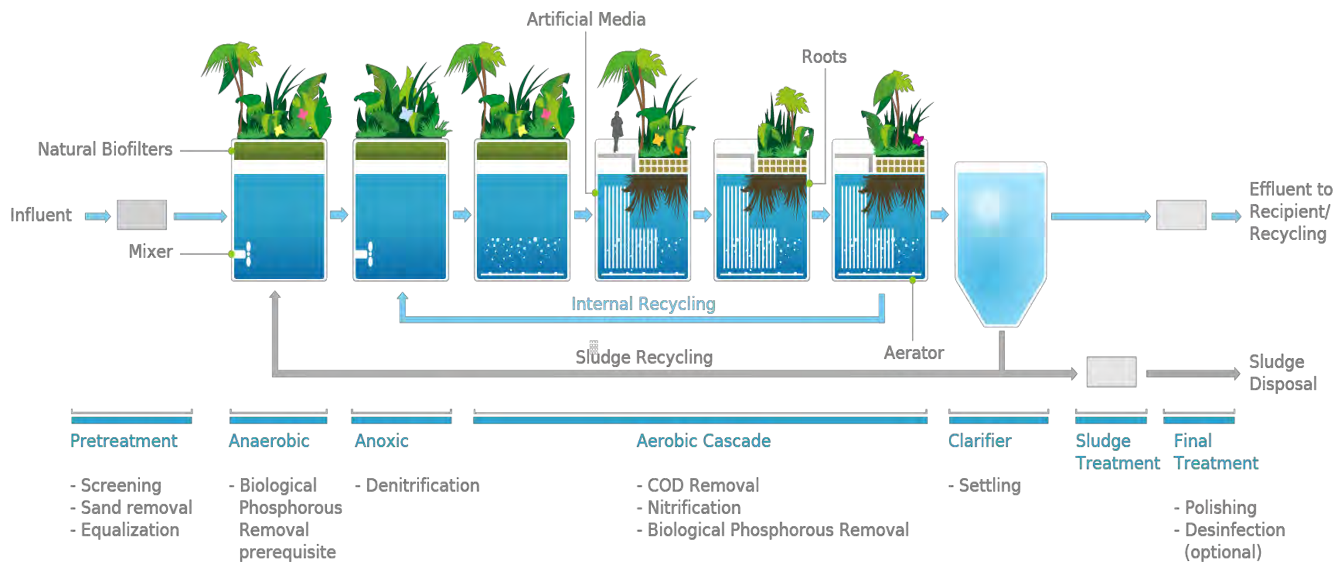
Figure 2: Exterior of Enclosed Ecological Treatment System

Figure 1: Inside Enclosed Ecological Treatment System

These treatment systems are monitored by Supervisory Control and Data Acquisition (SCADA) software in order to track the treatment process and provide real-time data as to influent/effluent quality and any potential threats to the system. The software also allows for remote monitoring of the facility to ensure proper operation at all times. In addition, misters, shading, and air quality are all automated within the greenhouse to produce an environment conducive for plant growth and optimization of the facility.

Because of its advantage in terms of footprint and aesthetics, hydroponic technology can be found in a variety of different environments, from historic, countryside neighborhoods to dense urban or industrial settings. To date, at least 30 hydroponic installations have been deployed around the world, and a number of additional facilities are under construction. These facilities are located in as diverse places as North America, western and central Europe, and Asia. As a scalable technology, these facilities have been designed in an array of sizes ranging from thousands to millions of gallons per day.

Figure 3: Hydroponic Treatment System Process Schematic



1.3.2. Tidal Flow Wetlands

Tidal-Flow Wetlands (TFW) is modular wetland-based decentralized wastewater treatment technology that utilizes plants and microbial fixed-film ecosystems to break down waste in water. Living Machine Systems is a pioneer of ecological water treatment systems and the only company that offers a tidal-flow treatment system. These systems use the principle of "tidal cycling," which involves repeated filling and draining of an artificial wetland area to mimic tidal events.

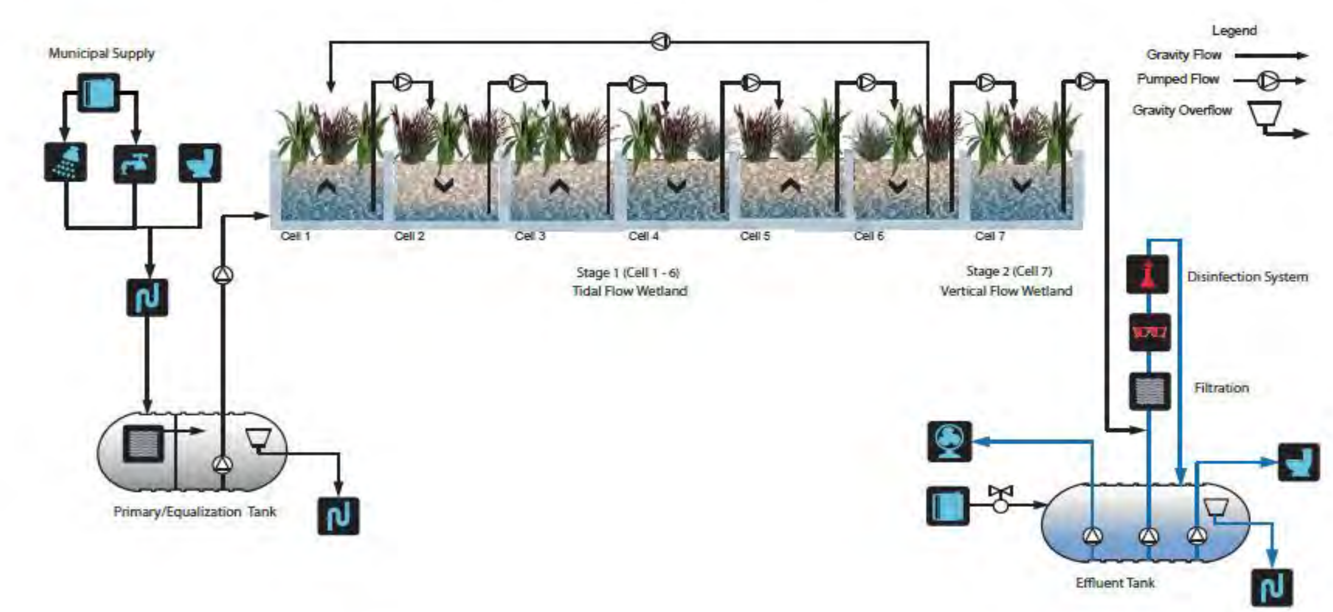
Figure 4: Tidal Flow Wetland, San Diego, CA

Tidal Cycling is known to enhance aerobic and anoxic treatment processes, providing energy-efficient passive aeration and simultaneous nitrification and denitrification. Overall, this design is extremely energy-efficient, robust and scalable; it can treat from thousands to hundreds of thousands of gallons of wastewater per day. Typically, TFW systems use 2 to 4 times less energy than aerated wetlands or conventional mechanical treatment plants, respectively. In these systems, tertiary quality treatment can be attained with a significantly smaller footprint compared to other engineered wetland systems.

Figure 5: Living Machine in building atria, Lake Worth, Florida

Living Machine Systems reflect the balanced integration of engineering and information technology with the robust fixed-film ecosystem, which provides a stable treatment environment year-round. The system includes many well-understood processes of conventionally engineered biological treatment systems, such as sedimentation, filtration, adsorption, nitrification and denitrification. Figure 6 shows the TFW treatment process. A diversity of macro vegetation is planted in the gravel surface to harvest residual nutrients and treat other water- and air-borne pollutants, while providing a natural habitat and aesthetic appearance. Advanced controls and information technologies automate cycles, ease operational adjustments, and enable remote monitoring and control of the system.

Figure 6: Tidal-Flow Wetland (Living Machine) Process Diagram



The latest generation of this technology does not require a greenhouse and is well suited to both temperate and tropical locations. Wastewater is kept well below a gravel earth layer, which mitigates odors. This enables these systems to be used as landscaping and design features in close proximity to human activity. More recently, parts of these systems are being incorporated into the interior of buildings, providing a unique natural ambiance for lobbies and atria. Living Machines have been placed in a variety of development applications, from schools and universities to military bases and resorts. To date, over 30 facilities have been built.

2.0 Natural & Built Watershed

2.1. Campus Development & Planning

Georgia Tech's main campus consists of about 220 buildings, spanning 400 acres, in downtown Atlanta. In 2012, Georgia Tech boasted an enrollment of 21,557 students, of which 7,030 were postgraduate or professional students. In addition, Georgia Tech employs more than 4,000 people.

Currently in the midst of environmental- and energy-related campus planning initiatives, Georgia Tech is in an ideal position to incorporate innovative best management practices to improve campus water management. A few of the campus planning initiatives, relevant to this study, are described in greater detail below.

Engineered BioSystems Building (EBB) & Ferst Sector Plan

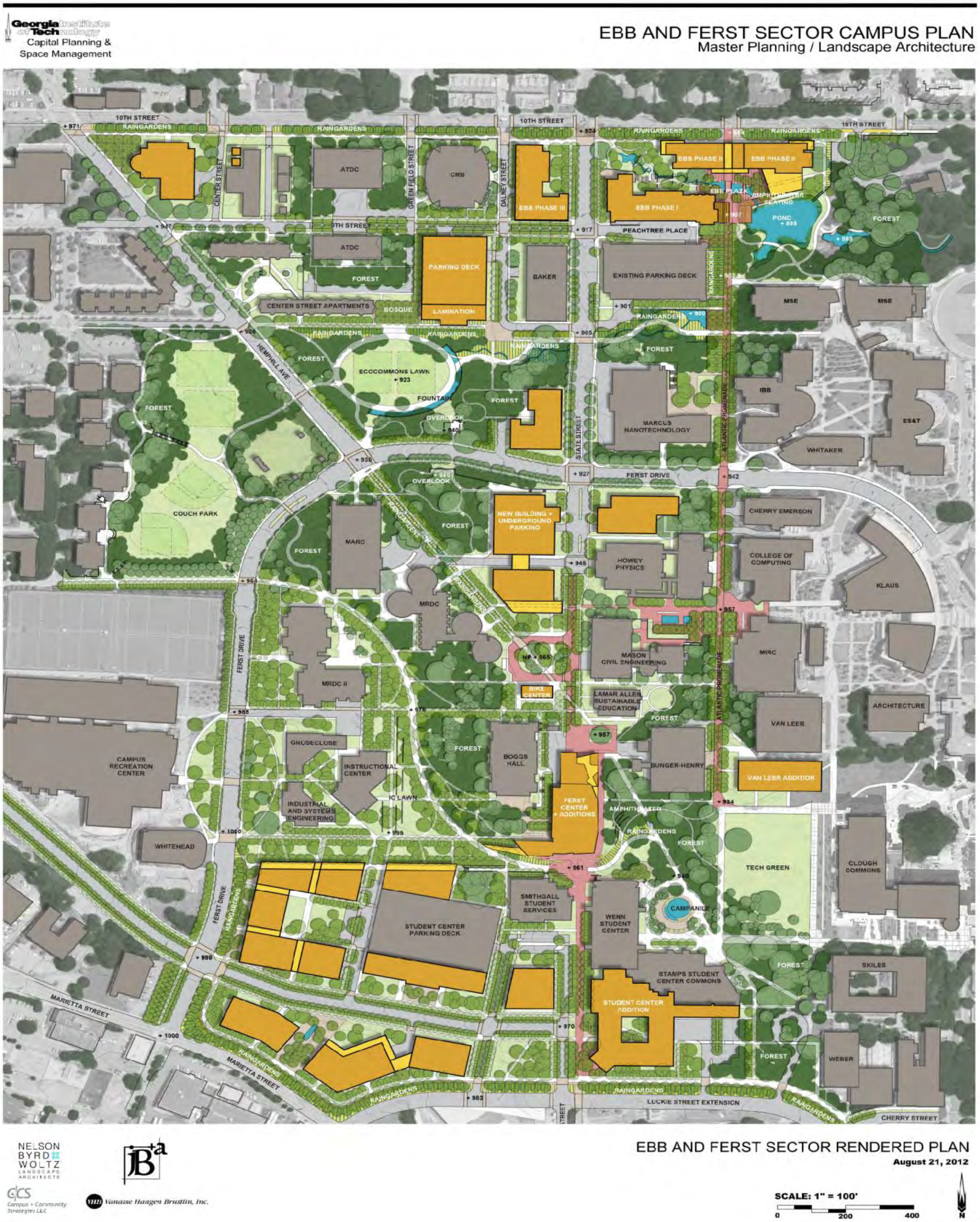
Initiated in 2011, the EBB Sector Plan encompasses 45 acres of land along the northern portion of campus in Basin A. The borders that define the EBB Sector Plan area include 10th Street to the north, Hemphill Avenue to the west, Ferst Street to the south, and the Atlantic Promenade to the east. The EBB Sector Plan evolved from concepts initially presented in the Campus Master Plan Update and Campus Landscape Master Plan. The goal was to create a functional landscape that incorporated the addition of a three-building research complex while integrating sustainable design for the buildings and physical landscape.

The plan area is currently developed at a lower density than the historical sections of campus. Georgia Tech reports that 40% of the land in the sector plan area is either undeveloped or underutilized. The Sector Plan is attempting to address many functional, aesthetic, academic and sustainability issues in this section of campus. The centerpiece of the Plan is the Eco-Commons concept, which attempts to integrate a "performance landscape system." The EBB Sector Plan describes the goals of the Eco-Commons:

> To slow, filter, and collect stormwater [and] provide an alternative for pedestrian circulation through the campus that contrasts with the urban grid. The Eco-Commons creates new recreation and educational opportunities and is central to redefining and connecting the landscape to social and educational spaces on campus.

The Eco-Commons Plan calls for decreased impervious surfaces, increased tree canopy coverage, a number of stormwater improvements (which functionally comprise the Stormwater Master Plan), increased woodland zones and biodiversity, enhanced connectivity with the rest of the campus, and future building zones that are appropriate with the land development goals of the Institute. The centerpiece of the Eco-Commons Concept is an oval-shaped green space, lined by woodland zones, which lies between Hemphill Avenue and State Street. Currently a surface parking lot, the plan calls for developing the location into an open and natural recreational space illustrated in Figure 7.

Figure 7: Georgia Tech EBB and Ferst Sector Plan



Stormwater Master Plan

Jacobs Engineering has worked alongside Georgia Tech's Capital Planning and Space Management to finalize a Stormwater Master Plan for the Institute. [3] The goal of this plan is to create a comprehensive inter-parcel approach to reducing the quantity and enhancing the quality of stormwater runoff leaving campus. Its overarching goals include:

- Reduce stormwater discharge to the City's combined sewer system by 50% over 2003 levels;
- Improve surface water quality;
- Reduce consumption of potable water for non-potable uses; and
- Harvest stormwater for non-potable uses such as irrigation.

Over the last decade, Georgia Tech has made an effort to separate its stormwater and wastewater streams to minimize the occurrence of combined sewer overflows. To date, approximately 95% of wastewater and stormwater infrastructure has been separated. The stormwater Master Plan seeks to improve upon this effort in order to minimize the Institute's environmental impact on the community. As a part of the plan, the Institute has divided the campus into separate drainage basins, labeled A, B and C. The Institute plans to integrate stormwater improvements into each respective Basin; however, initial efforts will be focused in Basin A, which comprises much of the territory associated with the EBB Sector Plan and the Eco-Commons Concept.

The Stormwater Master Plan incorporates both man-made structures and ecological systems to provide stormwater retention, detention, and reuse on-site. The plan calls for a series of cisterns and stormwater reuse systems, infiltration basins, rain gardens, increased canopy cover, bio-swales, and storage ponds. In addition to these improvements, the Plan calls for a blackwater reclamation system to help reduce wastewater flows leaving campus while simultaneously providing a local source of clean water. Appendix B provides a process diagram and preliminary plan schematic for stormwater improvements. Implementation of the Plan is set to occur in the immediate future.

10th Street Chiller Plant Expansion

As it anticipated an addition of nearly 1.1 million gross square feet (GSF) of academic and research space over the next 10 years, concerns regarding the ability of the existing chilled water system to support future campus air conditioning needs prompted the Institute to commission an evaluation of the 10th Street Chiller Plant. RMF Engineering was retained to assess the existing chilled water system's ability to meet future campus build-out. RMF's evaluation included a visual inspection of the existing equipment, review of existing operating schemes, an analysis of energy consumption and capacity modeling of the chiller systems. The RMF study recommends an additional 2,500 tons of chiller capacity at the 10th Street Chiller Plant to accommodate peak cooling load estimates for EBB Phases I and II. An additional 7,300 tons of cooling capacity is anticipated for post EBB I and II build-out. This effectively doubles the overall cooling capacity of 10th Street Chiller Plant, and has significant implications for the volume of make-up water required to run the plant.

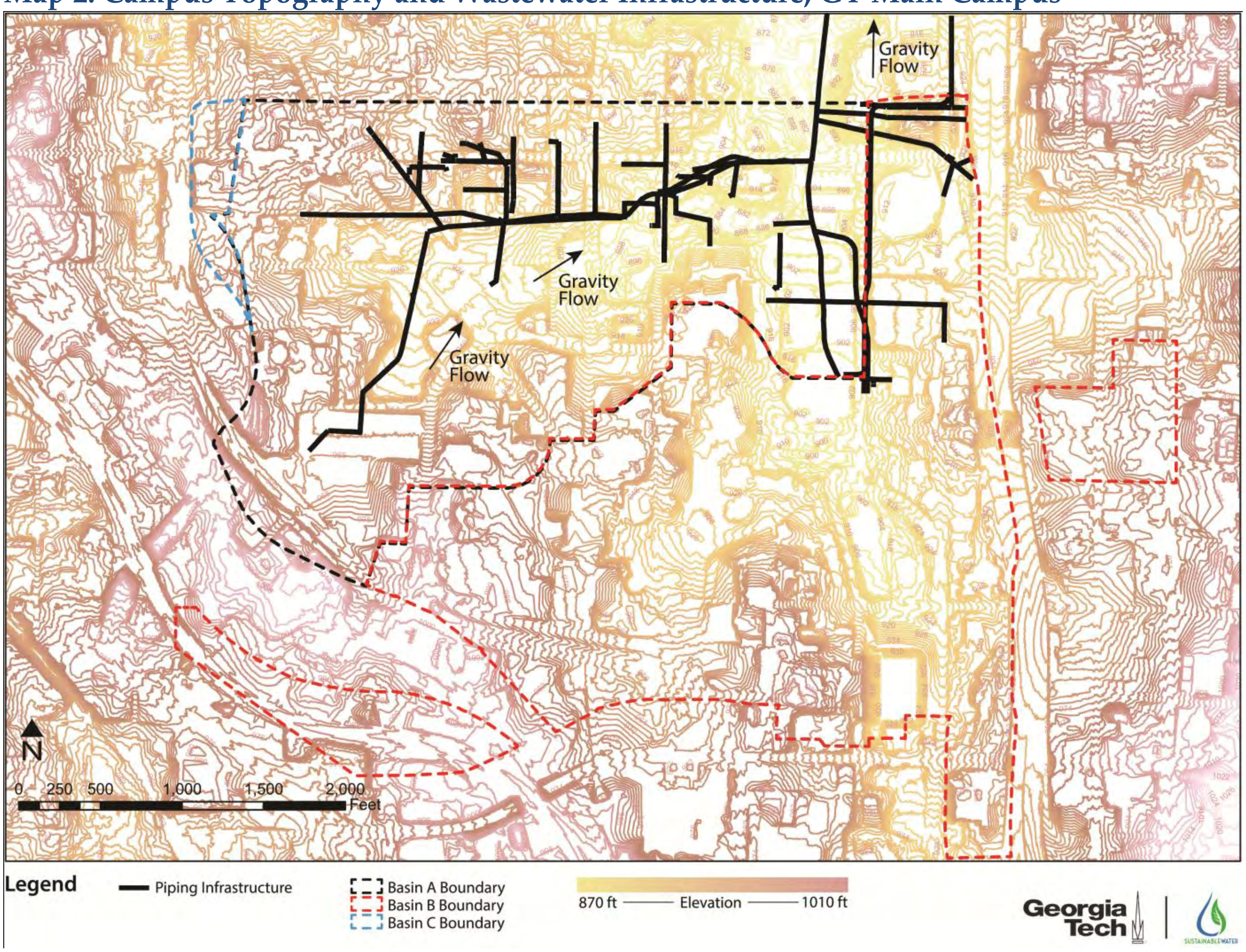
[3] Georgia Tech Landscape Master Plan

2.2. Topography & Hydrology

Georgia Tech's campus is located within the Piedmont physiographic province of Georgia, which is known for its hilly terrain. However, significant urban development has altered the natural topography substantially. The modern topography lends itself to three natural drainage basins, identified as Basin's A, B, and C in Figure 2 below. All three of the drainage basins once held natural streams that flowed year-round. There are no longer any surface streams on campus – all streams have been buried as part of Atlanta's combined sewer system and other campus development projects.

The highest elevation exists along Marietta Street located in the southwest section of Georgia Tech's campus. The lowest elevation exists at the Glade near the Molecular Science and Engineering Building in the northeastern section of campus. The net vertical elevation change across campus is approximately 130 feet, lending a natural drainage flow toward the northeast. Map 2 depicts the contour lines defining the topography of Georgia Tech's campus, along with the sewer infrastructure that accommodates gravity water flow through Basin A.

Map 2: Campus Topography and Wastewater Infrastructure, GT Main Campus



2.3. Water Supply & Distribution

Georgia Tech is supplied potable water by the City of Atlanta Department of Watershed Management (DWM). The City's drinking water is provided by the Chattahoochee River. There are currently three water treatment plants (WTP) that provide potable water to the city. The facility closest to Georgia Tech is the Hemphill WTP, located only 1.6 miles from campus. Two reservoirs, with a combined capacity of 525 million gallons, provide raw water to the Hemphill WTP. Upgraded twice since 1923, the treatment plant has a current capacity of 136.5 million gallons per day (MGD).[4]

Large water distribution mains (30-inch and 36-inch, respectively) run to the border of campus at Hemphill Avenue and 10th street. These large transmission mains supply a grid of smaller six- to eight-inch distribution lines buried beneath the street. Campus water consumption is tracked by city-owned meters found at individual buildings. Some locations also have dedicated city-owned irrigation meters deployed separately so that wastewater charges are not incurred. In addition to these meters, the Institute uses a number of independently owned sub-meters to track utility water at specific buildings. These meters track make-up and blow down at cooling towers, make-up at boiler systems, and water use by building level irrigation systems that are not currently metered separately by the City. In all, Georgia Tech sub-meters approximately 50 other locations around campus.

2.3.1. Water Stress and Drought

Over the last two decades, the Atlanta MSA has encountered fairly consistent drought conditions and water supply challenges as a result of these conditions. Between 1998 and 2003, Georgia witnessed a prolonged 5-year drought. In the fall of 2007, drought once again hit Georgia along with the entire southeastern United States. The drought of 2007, considered one of the worst in Atlanta's history, resulted in record lows in precipitation. In all, Atlanta received nearly 20 inches below typical rainfall levels, causing Lake Lanier—a major drinking reservoir for the city—to drop to all-time lows.

In 2012, another serious drought plagued the region. Much of the Atlanta MSA experienced "exceptional" hydrologic drought conditions for the majority of the year the most severe drought classification provided by the U.S. Drought Monitor.[5] Despite the seasonal increase in rainfall typically experienced in the winter months, approximately half of the Atlanta MSA is still experiencing abnormally dry to moderate drought conditions as of March 2013.

The state of Georgia has developed various water management plans to address water conservation and water supply planning. Two of these reports, including the Georgia Comprehensive State-Wide Water Management Plan and the 2010 Georgia Water Conservation Implementation Plan, are provided in Appendix B of this report. Both plans reference water reclamation and reuse as a viable solution to Georgia's water-related stresses. In addition, the City of Atlanta's Department of Watershed Management reminds residents that the state of Georgia has water restrictions currently in effect, and that drought episodes are cyclical; therefore, residents can expect another drought episode in the future.[6]

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[4] Source: "Hemphill WTP." Atlanta Department of Waterhsed Management, 2013.
[5] Source: 2013 U.S. Drought Monitor, http://www.droughtmonitor.unl.edu/archive.html
[6] Source: City of Atlanta Department of Watershed Management, http://www.atlantawatershed.org/WaterRestrictions.htm

2.4. Wastewater Treatment & Collection

The DWM's Bureau of Operations for Wastewater Treatment and Collection is responsible for the management, operation and maintenance of four wastewater treatment plants, four combined sewer overflow treatment facilities, 16 pump stations, and more than 1,500 miles of sanitary and combined sewers within the City. Of the four treatment facilities in City limits, the RM Clayton Water Reclamation Facility, located only 5 miles from campus, is the closest treatment facility to the Institute. This facility is designed to treat 122 MGD. Discharge from RM Clayton is received by the Chattahoochee River under a National Pollutant Discharge Elimination System (NPDES) permit.

Atlanta has both combined and separate sewer systems. The combined area, in downtown Atlanta, represents only about 15% of Atlanta's total system. Within this 19 square-mile area, the city has six Combined Sewer Control Facilities that discharge into the South & Chattahoochee Rivers. These CSOs surround the downtown area and overflow into several streams. The area outside of the downtown center has a municipally separated storm sewer system (MS4).

Overall, the city is struggling with aged and over capacity infrastructure. Combined sewer and stormwater overflows are fairly frequent events. Over the last decade, the City has made great strides to improve its water management system. Largely a result of two federal consent decrees and one state consent decree, the city has invested over $3 billion into a water-related capital improvements plan called Clean Water Atlanta (CWA).[7]

On campus, a series of combined and separated sanitary sewers collect and convey wastewater and stormwater. Over the last few years, Georgia Tech has made an effort to separate its stormwater and wastewater streams as they develop and rehabilitate buildings. To date, Basin A is considered 95% separated; however, stormwater and wastewater are once again co-mingled in the City's combined sewer system once flow approaches the edge of campus. As outlined in Section 2.1, the Institute is currently in the midst of a stormwater master plan to help minimize stormwater flows leaving campus.

In Basin A, a large combined sewer main ranging from 30 to 72 inches collects a majority of the Basin's stormwater. This large collector runs from the southwest corner of campus to the northeast, starting at a high point along Marietta Street until it reaches the Orme Street combined trunk line located adjacent to the Byers Tennis Complex in the northeast quadrant of campus. According to Jacobs Engineering, this collection system installed in the mid-1930s evolved along a natural stream channel. Installation of the collection system allowed the former stream valley to be filled to the topographic profile evident today.[8]

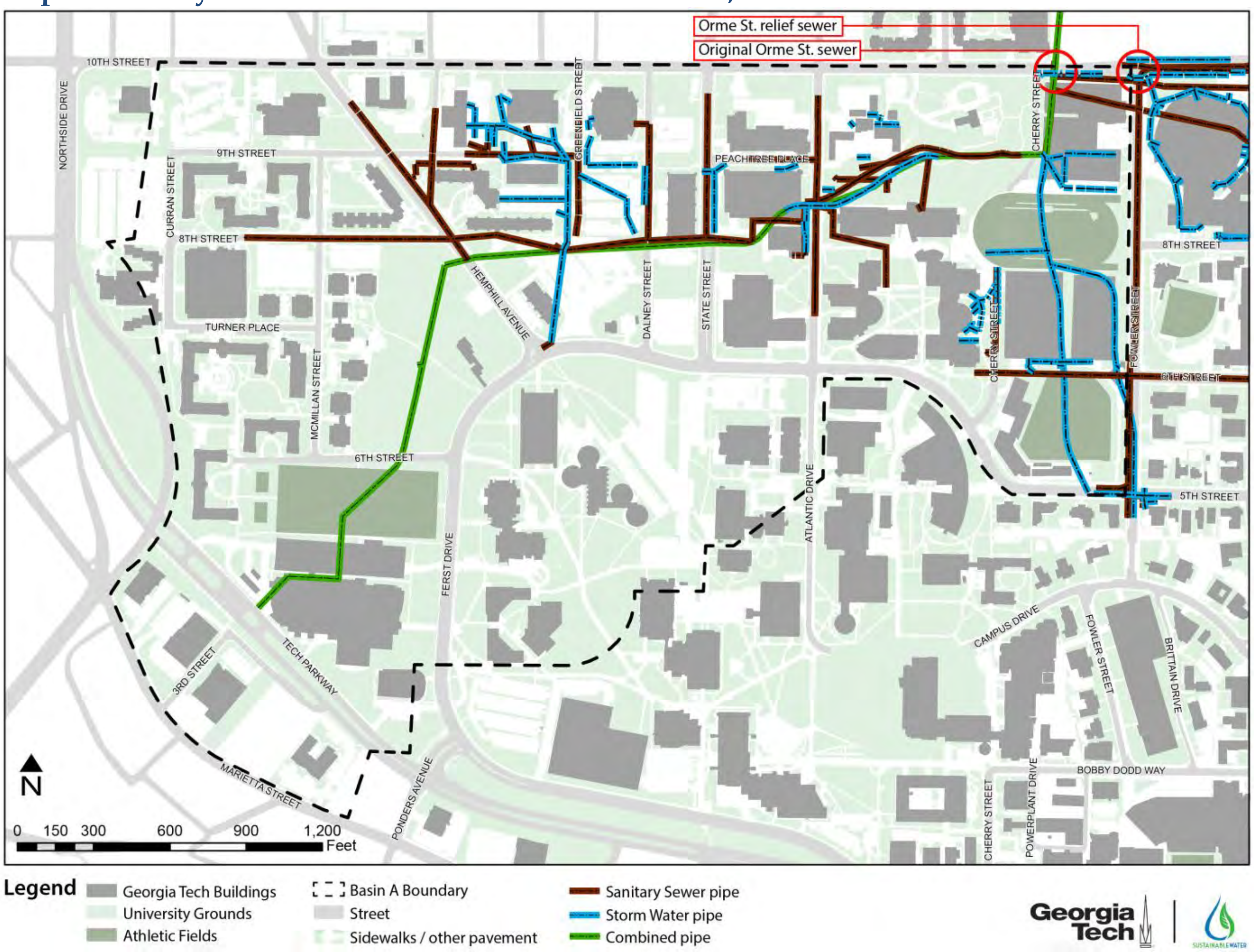
A majority of the sanitary effluent from campus buildings has been disconnected from the combined collector in Basin A. Today, this line is primarily used for stormwater conveyance. Most wastewater in Basin A flows into a separated 18-inch main, which runs parallel to the larger combined collector. A few wastewater connections, including a sanitary lateral from Center Street Apartments, still currently

[7] http://www.cleanwateratlanta.org/overview/History.htm
[8] Source: "Utility and Development Assessment: Georgia Tech EBB Sector Plan." Jacobs, August 20, 2012.

exist along the combined collector so it is not completely separated at this point in time. The parallel 18-inch main should contain 100% wastewater, however. Once both pipes reach the Original Orme Street Sewer, separated effluent is combined once again. The combined collector and separated wastewater main are shown in brown and green on Map 3.

Various smaller diameter sewer pipes, ranging from 8 to 42 inches, feed the parallel wastewater and combined collectors. Map 3 shows the overall wastewater collection system in Basin A. This map was created from various survey drawings for Basin A, as well as campus utility maps (U-Map) compiled by the Institute over the years. The drawings produced on this Map were interpolated among multiple data sets, and cannot be confirmed by this study. Although formally requested, the City did not provide sewer and stormwater drawings to help confirm these projections.

Map 3: Sanitary and Stormwater Sewer Infrastructure, Basin A



A majority of the separated and combined system is in good to fair condition. A portion of the combined sanitary line between State Street and the Orme Street Trunk connection was rehabilitated in the beginning of 2012. A Cured in Place Pipe (CIPP) liner system was installed, which should greatly extend the service life of this portion of the combined sewer. During its analysis of the system for the EBB Sector Plan, Jacobs found only one area of concern: an old culvert beneath Hemphill Avenue. A Utility and Development Assessment report, produced by Jacobs Engineering, states:

> The condition of this culvert and particularly the transitions between the differing materials and shapes at the upstream and downstream ends is a concern. A failure of the sewer in this area puts the city of Atlanta's Water transmission mains in Hemphill Avenue at risk.[9]

Wastewater from south campus primarily flows into another large collector, known as the Orme Street Relief Sewer (shown in Map 3), located beneath Fowler Street. This 11-foot diameter tunnel, installed in the late 1990s, was primarily built to resolve flooding issues that occurred during rain events. A majority of stormwater flow leaving south campus continues north through the Original Orme Street Sewer. The Original Orme Street Sewer is mainly separated stormwater until it intersects the 18-inch collector, conveying wastewater from Basin A, near Byers Tennis Complex. The two circled references to the Original Orme Street Sewer and Orme Street Relief Sewer on Map 3 are the locations where a majority of campus wastewater and stormwater leave campus.

2.5. Cost of Water

The City of Atlanta's Department of Watershed Management currently utilizes an increasing tiered rate to bill for water and sewer. Water is charged based on monthly meter readings and sewer charges are based 100% on these readings. Table 1 shows the unit cost of water for each usage class broken down between water and wastewater. In addition to a usage charge, a base charge of $6.56 is billed for each water and sewer account, respectively. Institute water bills for select buildings were reviewed to verify these rates. These bills are provided in Appendix B of this report.

Table 1: Current Unit Cost of Water in Atlanta ($/CCF)

Usage Class	Water	Wastewater	Combined
1-3 CCF	$2.58	$9.74	$12.32
4-6 CCF	$5.34	$13.64	$18.98
7 CCF & Above	$6.16	$15.69	$21.85

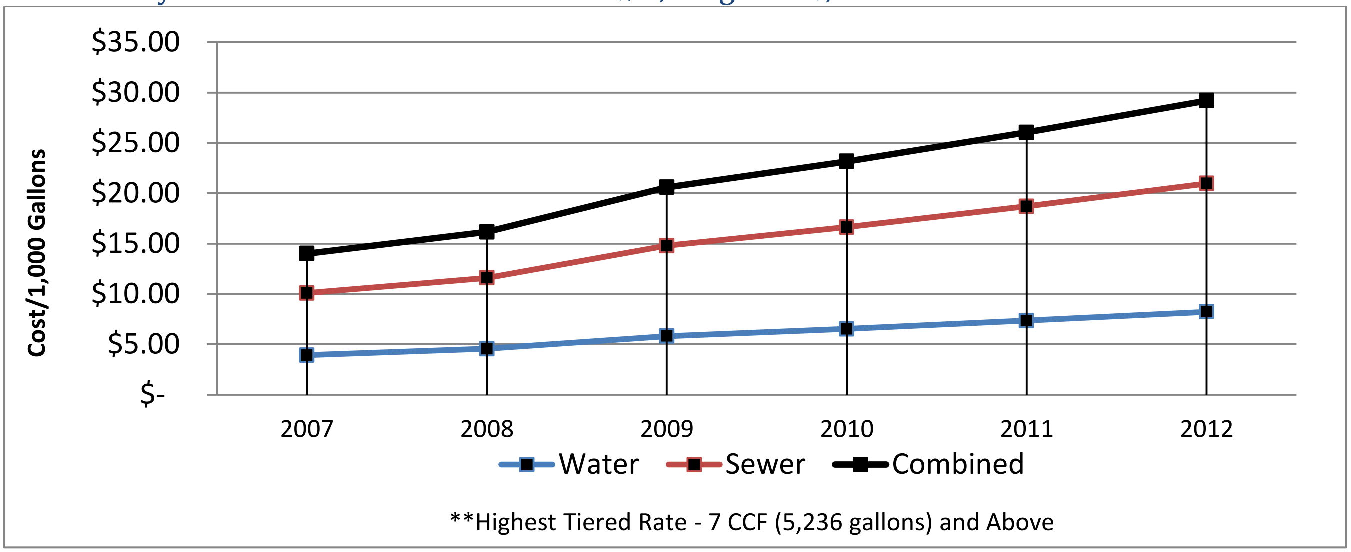
DWM uses 100 cubic feet, equivalent to 748 gallons, as a standard billing unit of measurement. If converted to gallons, the Institute pays approximately $0.03 per gallon at the highest tiered rate or about $29.21 per 1,000 gallons. This rate is one of the highest unit costs for water and sewer in the country.

The current rate structure deployed by DWM serves as an incentive for water conservation, as the cost of water increases with higher usage. Local water stress, especially in summer months, is a large driver

[9] Source: "Utility and Development Assessment: Georgia Tech EBB Sector Plan." Jacobs, August 20, 2012.

of this type of rate structure. Water stress in conjunction with extensive capital improvement requirements has caused the cost of water to increase dramatically over the last decade. Nationally, combined water and sewer rates rise by about 9% annually to compensate for these expenses.[10] In Atlanta, rates have risen from $12.09 per 100 cubic feet (CCF) in fiscal year 2007-2008 to $21.85 per CCF in fiscal year 2011–2012—a rate increase of nearly 81% in just five years. Chart 1 shows annual water and sewer rates for the City of Atlanta between 2007 and 2012.

Chart 1: City of Atlanta Water & Sewer Rates ($/1,000 gallons), 2007 – 2012



2.6. Current Water Conservation Strategies

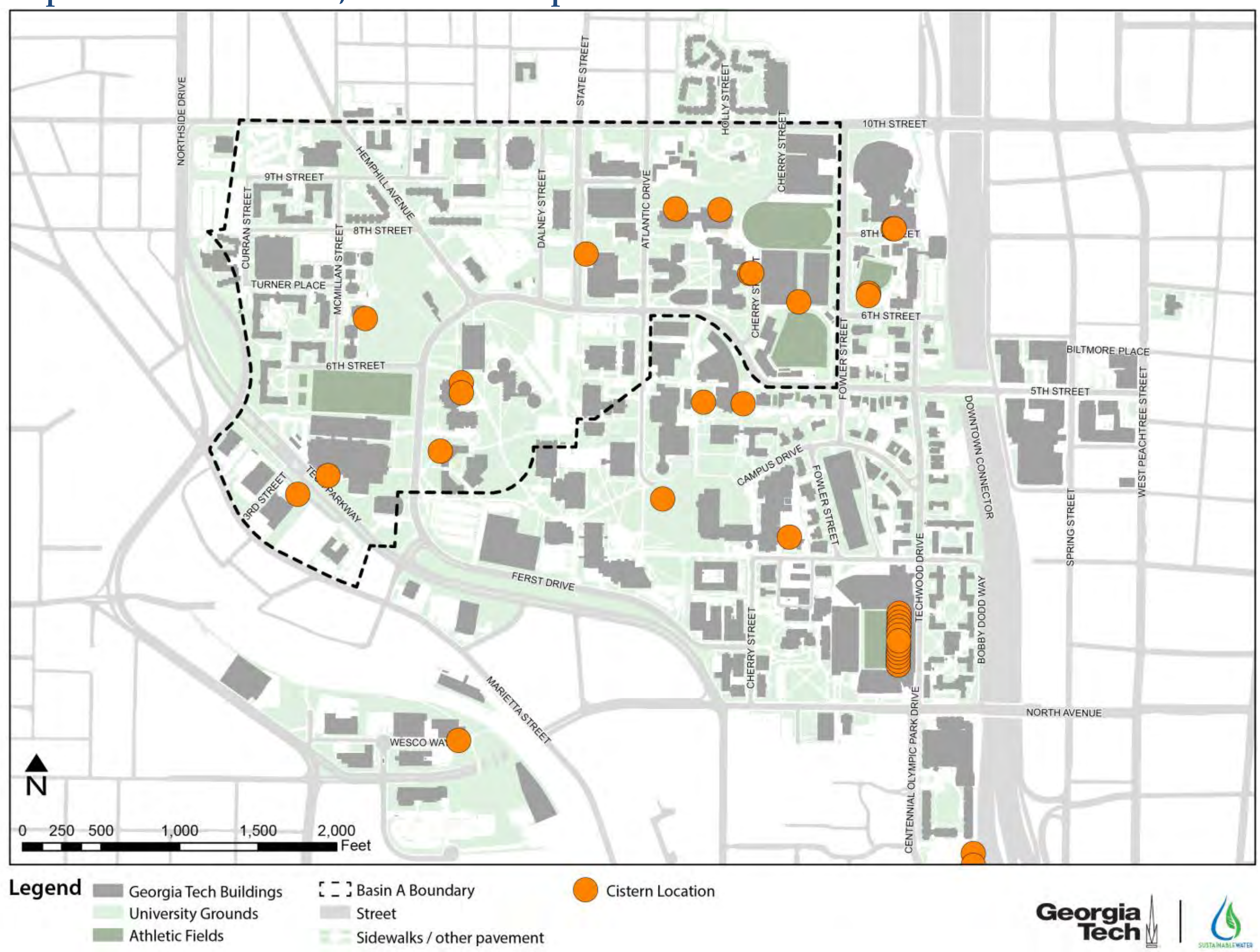
As a result of numerous water-related challenges, Georgia Tech has taken very progressive steps in conserving water on campus. Campus conservation measures include retrofitting buildings with low-flow fixtures, utilizing water efficient appliances, tray-less dining halls, rainwater harvesting and reuse, laboratory water conservation techniques, water meter replacements, and an updated landscape plan that focuses on xeriscaping and native plantings. The Institute's water conservation criteria exceed requirements of the Georgia Code, and meet the California Water Conservation Code. Despite numerous water-related initiatives, Georgia Tech is still committed to improving campus water conservation and extending its leadership in water sustainability.

The most notable strategy has been the use of cisterns to collect and store rainwater for reuse. Incorporated as part of a Cistern Master Plan, the Institute has deployed cistern systems at 19 locations across campus. Together, these cisterns have a combined storage capacity of approximately 2.25 M gallons. Many of these systems recycle water for landscaping purposes or toilet flushing within buildings. Map 4 shows the locations of these cisterns on campus. Appendix B provides detailed information regarding the type, design capacity, and reuse applications associated with each cistern.

[10] Source: *AWWA Water and Wastewater Rate Survey*. American Water Works Association, co-produced by Raftelis Financial Consultants, 2008.

The most impressive cistern system is located at the Clough Undergraduate Learning Commons (CULC). This 1.4 M gallons cistern is one of the largest in the United States, and provides water for both toilet flushing and efficient landscaping around the building. Engineering projections estimate that 89% of the building's water demand is supplied by the cistern. Exact levels of potable water displacement are not known as a result of un-calibrated water meters on the system. Unfortunately this is true for most of campus. Overall, only two cisterns systems are metered–one system only measures HVAC condensate influent and the other system has an un-calibrated meter.

Map 4: Cistern Locations, GT Main Campus



3.0 Water Audit and Balance

The purpose of this section is to account for and analyze water use in its many forms at Georgia Tech. Understanding types of water demand and its spatial distribution across campus is critical for determining the general viability of water reuse and preferred siting locations of water reclamation facilities. Furthermore, wastewater flow analysis helps quantify the volume of water that can be easily collected and recycled to displace potable water use. The following sections outline total water use at the Institute (Section 3.1), total water use in Basin A (Section 3.2), non-potable demand (Section 3.3), future water demand (Section 3.4), and wastewater flow contributions (Section 3.5).

3.1. Gross Campus Water Consumption

Currently, all water use, except recycled HVAC condensate, captured stormwater, and the well for the Burger Bowl Field, is potable water provided by the City of Atlanta. Billing data was used to calculate gross water usage for 2011 and 2012. In total, there are over 200 individual water accounts with the City of Atlanta, including 50 irrigation sub-meters and 24 HVAC sub-meters.

In 2011, the Institute reported a total annual consumption of approximately 432 M gallons at its main campus. This usage equates to approximately 36 M gallons per month, or 1.20 M GPD. In 2012, water use stayed fairly consistent. Total water reported for only 11 months of usage in 2012 is approximately 399 M gallons, or about 1.21 M GPD. Chart 2 and Table 2 show total water consumption per month on Georgia Tech's main campus in 2011 and 2012. As demonstrated by Chart 2, total water demand peaks in the summer months, when the Institute averages 44 M gallons per month. Similar to most universities in the United States, water demand is much lower in the winter months. This is primarily a result of low irrigation and air conditioning demand – a relatively large percentage of the Institute's overall water demand.

Chart 2: Municipally Supplied Water Use by Month (2011, 2012), GT Main Campus

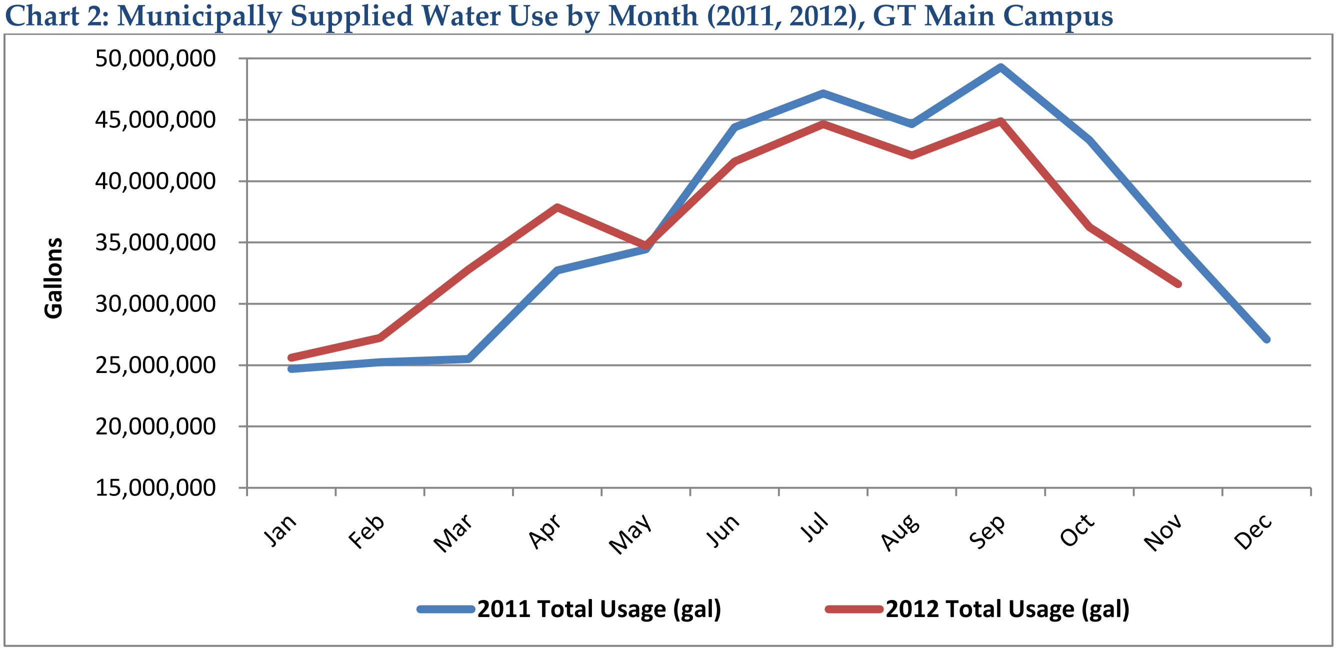
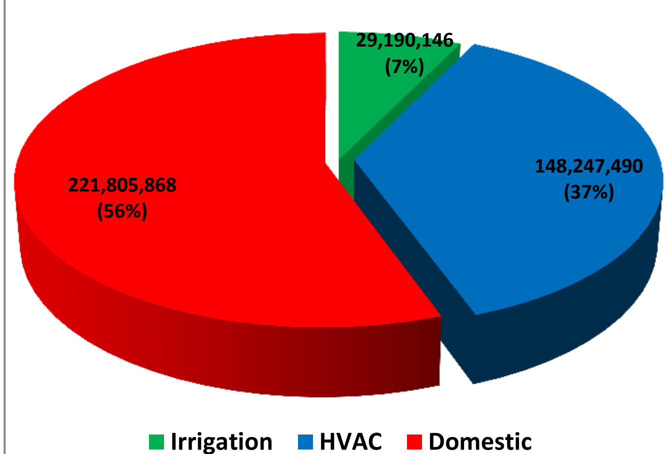


Table 2: Municipally Supplied Water Use by Month (2011, 2012), GT Main Campus

Month	2011 Total Usage (gal)	Average Daily Use (GPD)	2012 Total Usage (gal)	Average Daily Use (GPD)
Jan	24,684,748	822,825	25,603,292	853,443
Feb	25,248,740	841,625	27,224,956	907,499
Mar	25,509,044	850,301	32,802,792	1,093,426
Apr	32,734,724	1,091,157	37,854,036	1,261,801
May	34,436,424	1,147,881	34,725,152	1,157,505
Jun	44,392,304	1,479,743	41,580,572	1,386,019
Jul	47,137,464	1,571,249	44,643,632	1,488,121
Aug	44,645,876	1,488,196	42,083,228	1,402,774
Sep	49,289,460	1,642,982	44,874,764	1,495,825
Oct	43,354,080	1,445,136	36,254,064	1,208,469
Nov	34,964,512	1,165,484	31,597,016	1,053,234
Dec	27,094,056	903,135	*No Data*	*No Data*
Total	***433,491,432***	***1,204,143***	***399,243,504***	***1,209,829***

Chart 3: Water Use by Type (2012), GT Main Campus



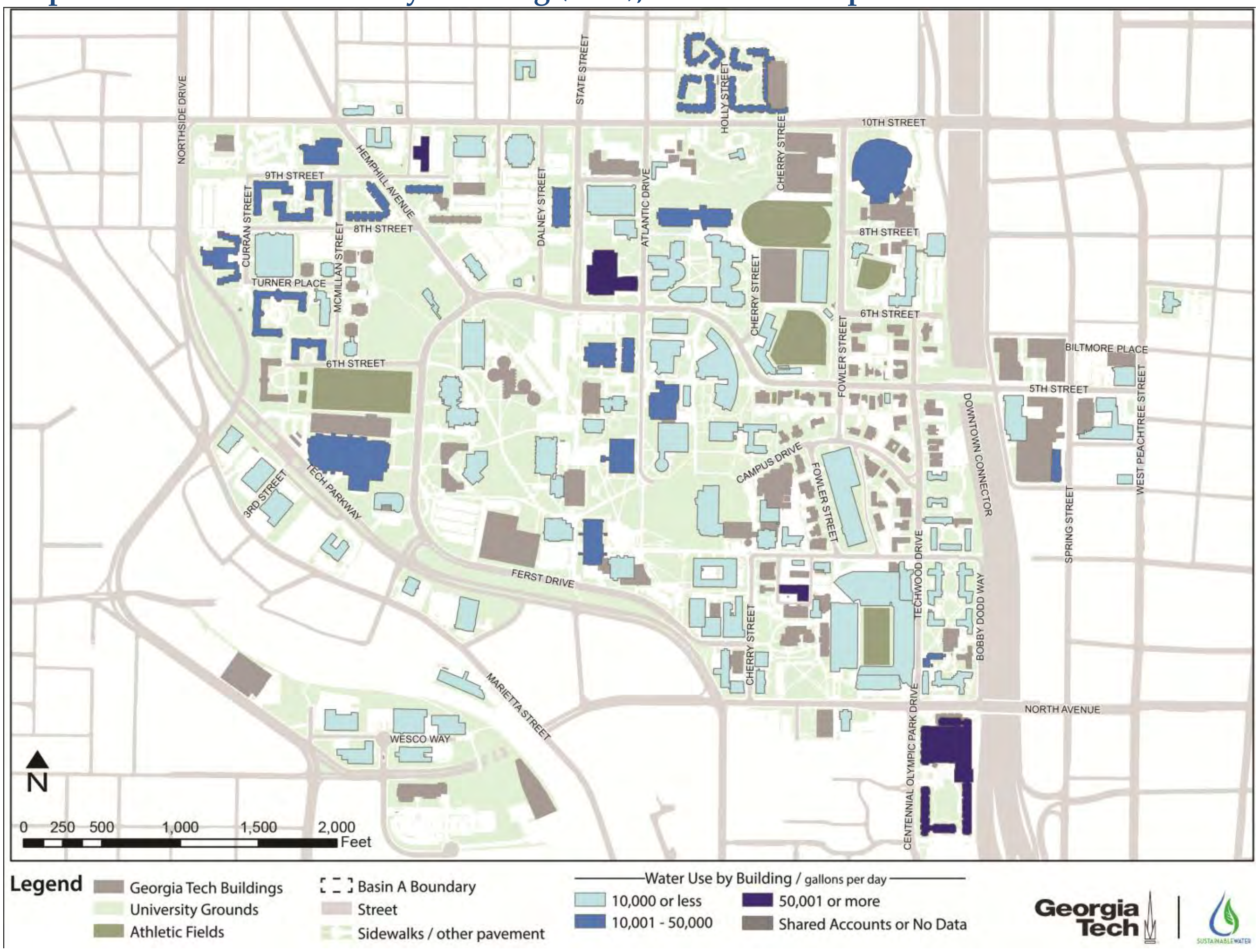
Water is used for a variety of purposes on campus. These uses range from sanitation to food production, heating and cooling, and labs and experiments, as well as grounds keeping. Using sub-metered water data, campus water use can be broken down into three major categories: domestic water use, irrigation, and utility or process water (depicted in Chart 3). The largest category of water consumption is for domestic uses, consisting of approximately 56% of total usage. HVAC, or utility process make-up, and irrigation comprise approximately 37% and 7%, respectively. Each of these categories is analyzed in further detail in subsequent sections.

When analyzing water use on a large scale, natural challenges arise pertaining to the overall accuracy of data. Sustainable Water found missing monthly meter readings, unbilled accounts, and data outliers, which bring up some accuracy concerns. However, these challenges are fairly common for municipal water authorities. In addition to billing and general reporting challenges, water meter calibration can also significantly alter water use reporting. As meters begin to age they have a tendency to underreport usage. The City of Atlanta is currently in the midst of a meter replacement program to resolve issues surrounding water that is unaccounted for in its billing process.

3.1.1. Domestic and Sanitary Use

Domestic, or sanitary, water includes water used for food preparation, laboratories, showering, dishwashing, laundry, and flushing toilets, among other things. In all, approximately 221.8 M gallons were used across campus for domestic/sanitary purposes in 2012. Much of this use occurs within buildings, and is therefore not easily separated into individual uses. Map 5 shows water use by building for Georgia Tech's main campus. Buildings in dark blue represent those with the highest overall water use. Almost all of the campus wastewater production originates from this category of water use.

Map 5: Domestic Water Use by Building (2012), GT Main Campus

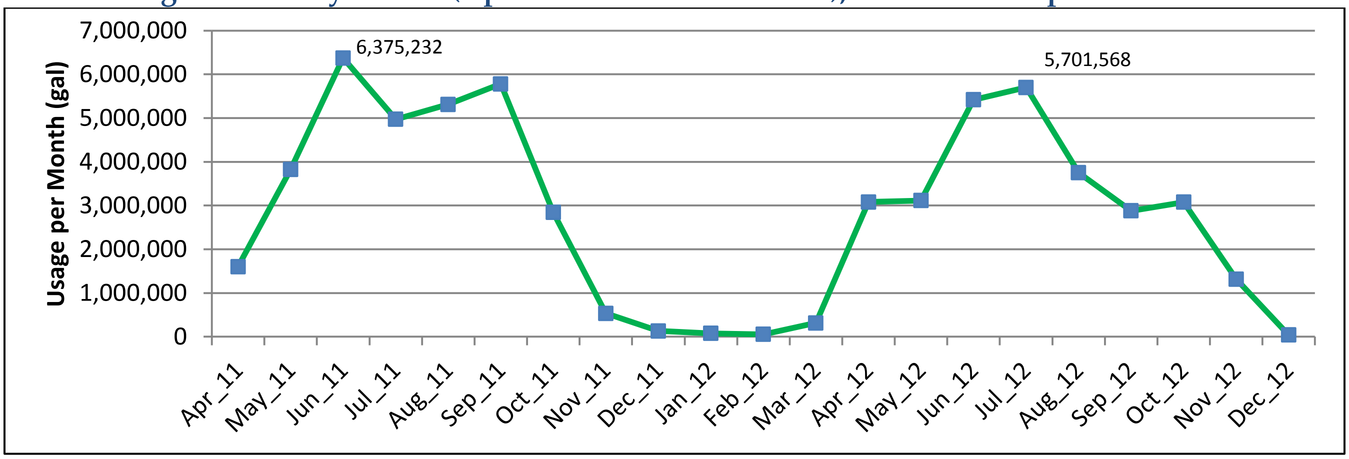


3.1.2. Irrigation

Irrigation comprises approximately 7% of total water use at Georgia Tech. Currently, there are approximately 50 locations where irrigation is applied, ranging from athletic fields to landscaping around buildings. Twenty-eight locations are metered directly by the city, with an additional 22 locations sub-metered by Georgia Tech. A spreadsheet provided in Appendix C shows all recorded irrigation consumption on campus from April 2011 through December 2012. Map 6 shows the location of irrigation meters on campus and their relative consumption. Chart 4 shows the total irrigation use for the campus by month from April 2011 through December 2012.

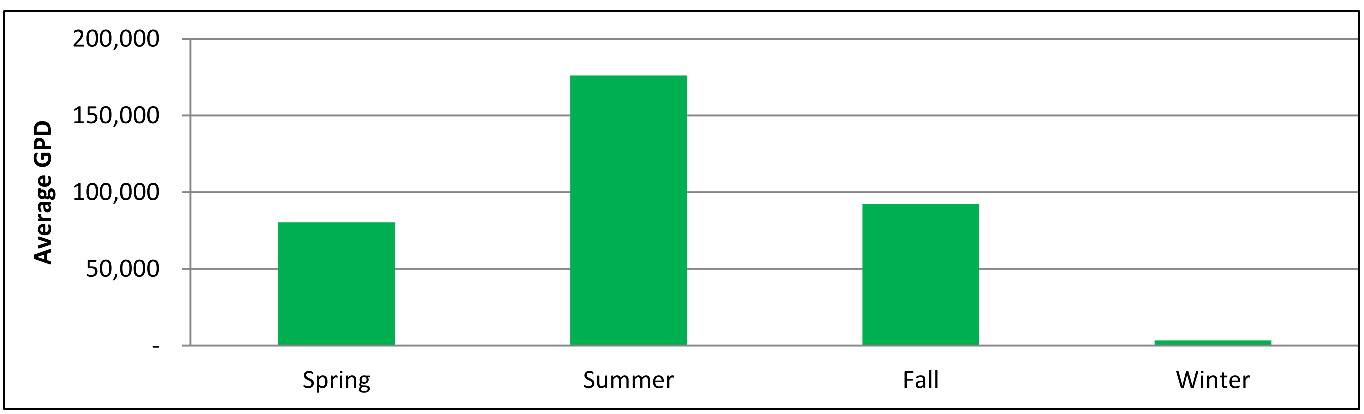
It is important to note that this consumption is not comprehensive to all irrigation use on campus. Rainwater cisterns supplement potable water use at a number of locations on campus. In addition, well water is used to irrigate the Burger Bowl field. As a result, the actual amount of water used by Georgia Tech for irrigation is higher than these reported values. The Institute currently performs limited metering of these systems. The Clough Undergraduate Learning Commons is the only cistern system that meters its effluent.

Chart 4: Irrigation Use by Month (April 2011 – December 2012), GT Main Campus



The greatest volume of irrigation use occurs in the summer months - peaking at nearly 6 M gallons per month. Conversely, irrigation drops to virtually zero in the winter months. Chart 5 illustrates the seasonal variation in daily irrigation use across campus. In addition to seasonal variations in irrigation use, climatic settings greatly affect irrigation use. Local water restrictions, resulting from seasonal drought, often decrease irrigation use in summer months.

Chart 5: Average Daily Irrigation Use by Season (April 2011 – December 2012), GT Main Campus



In 2011 and 2012, the largest irrigator was the Rose Bowl field, adjacent to the Brock Football Practice Facility (Chart 6). In 2012, this field used approximately 3.9 M gallons, or approximately 11,730 GPD when irrigation is applied. Love Building Irrigation System was the second largest irrigator, using 2.4 M gallons, or approximately 7,414 GPD.

Map 6: Irrigation Account Locations and Usage (2012), GT Main Campus

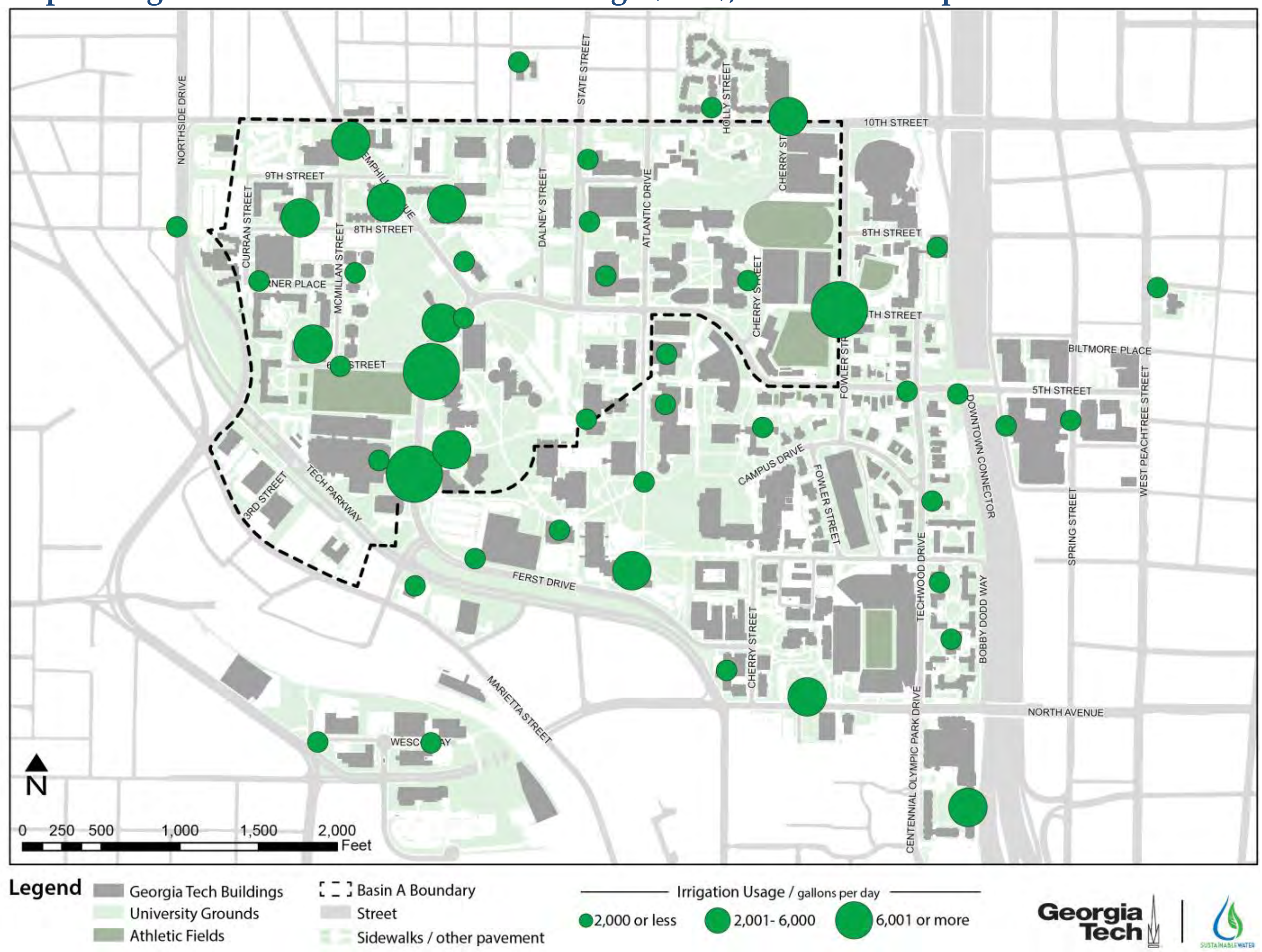
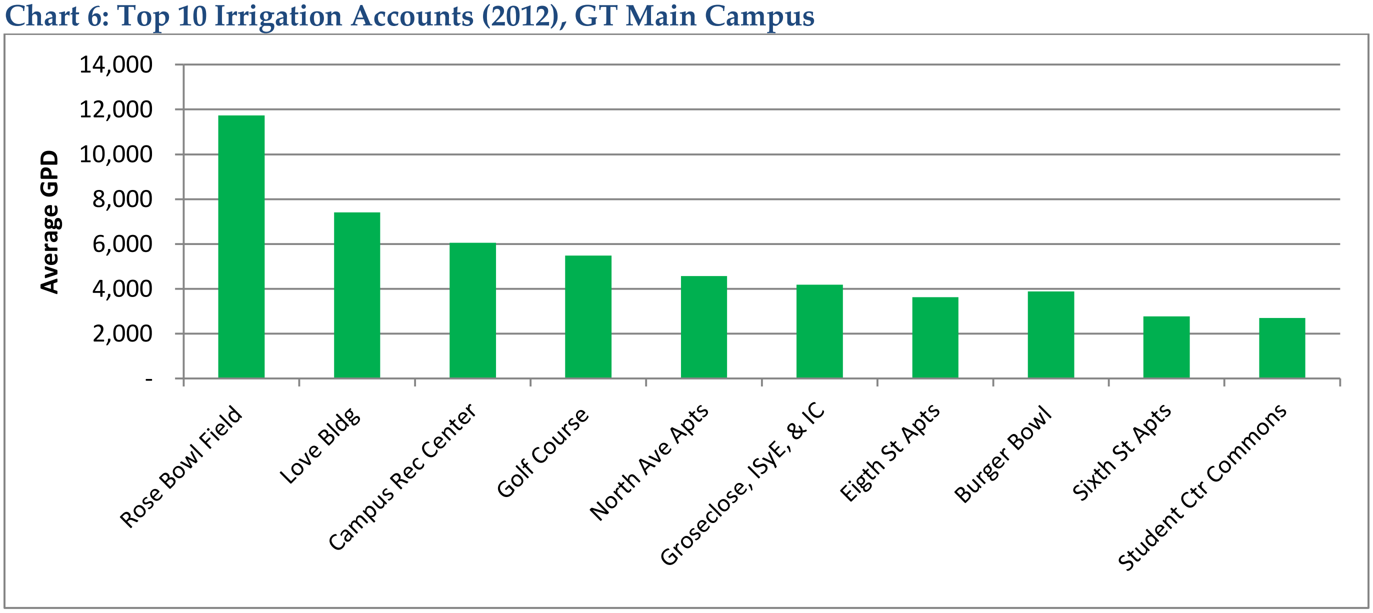


Chart 6: Top 10 Irrigation Accounts (2012), GT Main Campus

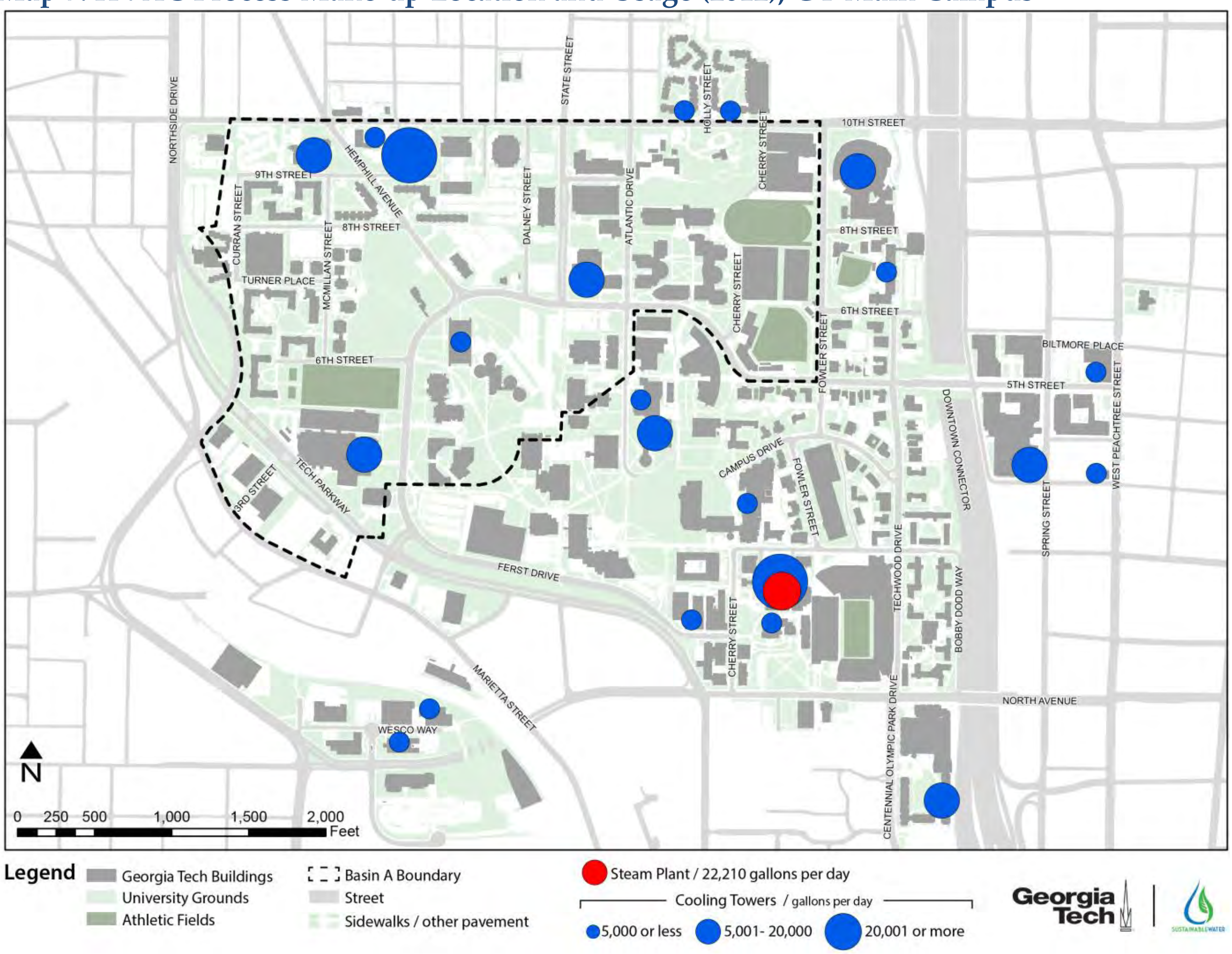


3.1.3. HVAC/Utility Water Make-up

HVAC/Utility process water is the largest single point source consumer of water on campus, comprising an estimated 37% of total consumption. At Georgia Tech, this category mainly consists of water used for large-scale heating and cooling. Water is used intensively in these processes to create steam heat or chilled water for basic air conditioning, humidification, sanitation and heating services. Georgia Tech has three central chiller plants, one of which is also a steam plant. A number of satellite cooling towers and boiler systems are used at individual buildings as well.

Table 3 outlines water use for HVAC functions on campus. The Institute sub-meters 23 locations where chilled HVAC/Utility use occurs. Map 7 shows the location of these utility systems on GT's main campus. Graduated blue points represent locations where make-up for chilled water systems is occurring, along with their respective consumption. The red node represents the location of steam use at the Holland Utility Plant. Cooling Towers north of 11th Street are not noted on this map.

Map 7: HVAC Process Make-up Location and Usage (2012), GT Main Campus



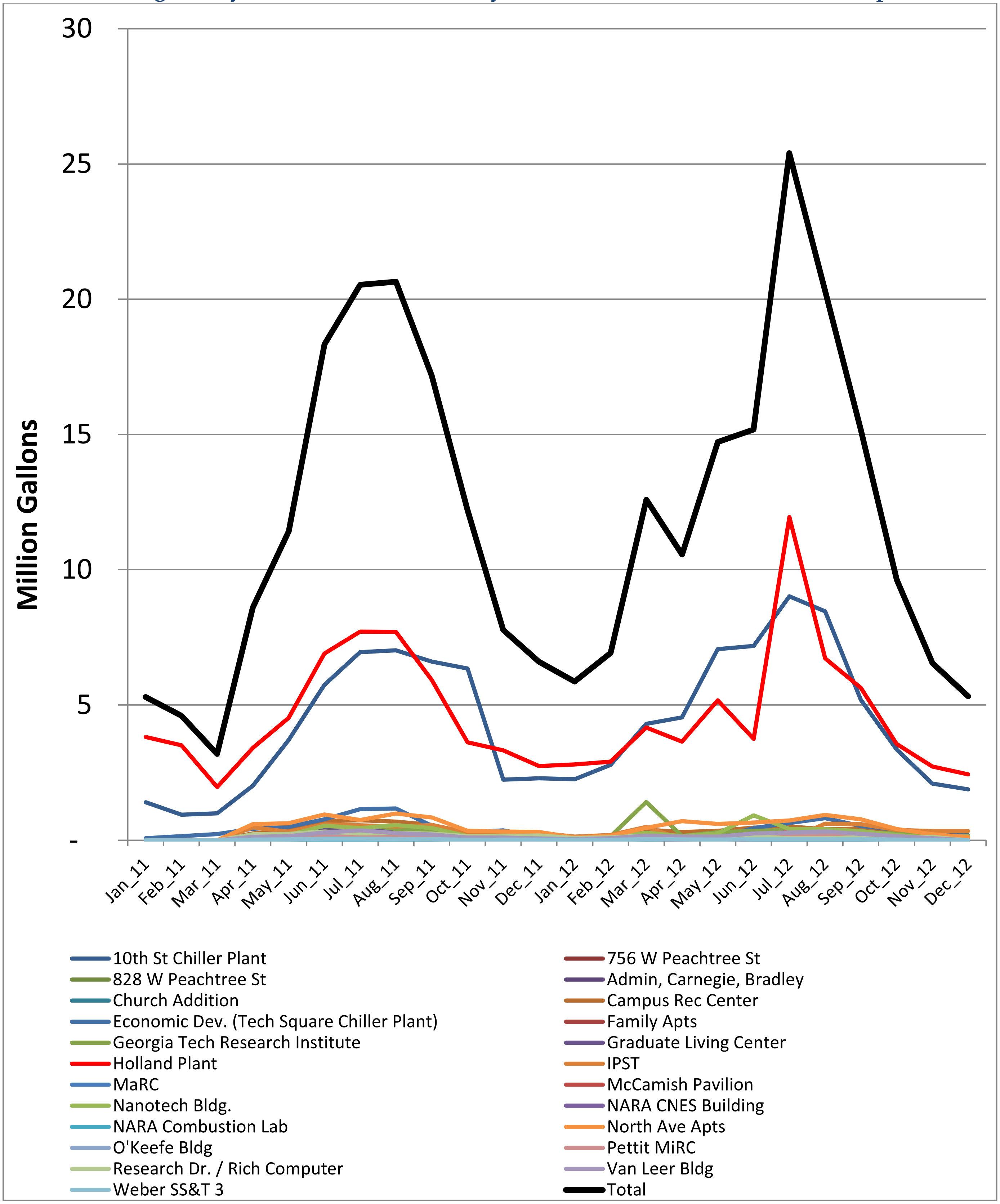
In 2012, over 148 M gallons were used for utility make-up at an average rate of 406,000 GPD. This is comprehensive of much of the chilled water system, but does not include make-up for satellite (building-level) boiler systems. It does, however, include make-up for the steam plant, which accounts for a majority of campus steam heat. Appendix C provides a detailed list and map of individual building boiler systems on campus. A majority of these systems require relatively small volumes of make-up.

As Table 3 demonstrates, the largest users of water in this category are the 10th Street Chiller Plant and the Holland Utility Plant. Together, they comprise nearly 77% of total HVAC/Utility water use metered on campus. Chart 7 shows average daily water use for HVAC functions on campus between 2011 and 2012. Similar to irrigation, HVAC make-up peaks in the summer as air conditioning demand grows. Total seasonal demand ranges from approximately 144,000 GPD in the winter to about 576,000 GPD in the summer. Water use in the spring and fall stays relatively consistent at 327,000 and 332,000 GPD, respectively. As Chart 7 demonstrates, only the two large utility plants (the Holland Utility Plant shown in green and the 10th Street Chiller Plant shown in pink) stand out in terms of usage.

Table 3: HVAC/Utility Water Use by Consumption (2012), GT Main Campus

Location	Bldg #	Type	2012 Usage (gal)	Months Reporting	2012 Average GPD
10th St Chiller Plant	133	Central Plant	58,121,300	12	161,448
Holland Utility Plant	26	Central Plant	55,449,300	12	154,026
North Ave Apartments	191	Satellite Tower	5,888,000	12	16,356
Georgia Tech Research Institute	141	Satellite Tower	3,957,100	11	11,991
Economic Development (Tech Square Chiller Plant)	173	Central Plant	3,816,200	12	10,601
Campus Recreation Center Domestic	160	Satellite Tower	3,463,300	12	9,620
Marcus Nanotechnology Building	181	Satellite Tower	3,385,000	12	9,403
Institute of Paper Science & Technology	129	Satellite Tower	3,231,900	12	8,978
Van Leer Building	85	Satellite Tower	1,879,300	11	5,695
Graduate Living Center	52	Satellite Tower	1,565,500	12	4,349
Family Apartments	180	Satellite Tower	1,283,100	12	3,564
O'Keefe Building	33	Satellite Tower	1,230,700	12	3,419
Research Dr. Master (Rich Computer)	51	Satellite Tower	1,173,980	11	3,558
Pettit Microelectronics Research Center	95	Satellite Tower	1,059,500	11	3,211
McCamish Pavilion	73	Satellite Tower	924,400	6	5,136
Manufacturing Research Center	126	Satellite Tower	641,670	11	1,944
Weber Space, Science & Technology Building 3	98	Other	327,930	12	911
NARA Combustion Lab	151	Other	252,700	11	766
756 W Peachtree St	826	Other	181,110	12	503
Church Addition	128	Other	152,210	12	423
828 W Peachtree St	178	Other	151,110	12	420
Carbon-Neutral Energy Solutions Lab	199	Other	81,500	3	906
Admin, Carnegie, Bradley Dormitories	35	Other	30,680	12	85
Total			***148,247,490***		***417,313***

Chart 7: Average Daily Water Use for HVAC by Month (2011 - 2012), GT Main Campus



10th Street Chiller Plant & Holland Utility Plant

The 10th Street Chiller plant is the largest user of water for HVAC/utility make-up on campus. Located in Basin A along the northern boundary of the campus, the 10th Street Chiller Plant currently has six chillers and six cooling towers, and provides chilled water for over 20 buildings in North Campus. In 2012, the 10th Street Chiller Plant used over 58 M gallons, averaging approximately 160,000 GPD. Chart 8 shows average daily make-up at the plant in 2011 and 2012 respectively. In 2012, make-up demand grew by approximately 12 M gallons or 26%. Georgia Tech Facilities Management attributes this to a number of meter replacements that occurred in early 2012.

The Holland Utility Plant is located in the southeastern section of campus, adjacent to Bobby Dodd Stadium. It is the second largest user of water on campus. In 2012, the Holland Plant was responsible for approximately 34% (47 M gallons) of the total HVAC/utility make-up on campus. The steam plant provides steam heat and hot water heat to a majority of buildings in the southern section of campus. It also provides chilled water for air conditioning to a majority of the south campus. Chart 9 illustrates the make-up demand curve for the cooling towers and boilers at the Holland Plant in 2012.

Chart 8: Average Daily Make-Up at Tenth Street Chiller Plant (2011, 2012)

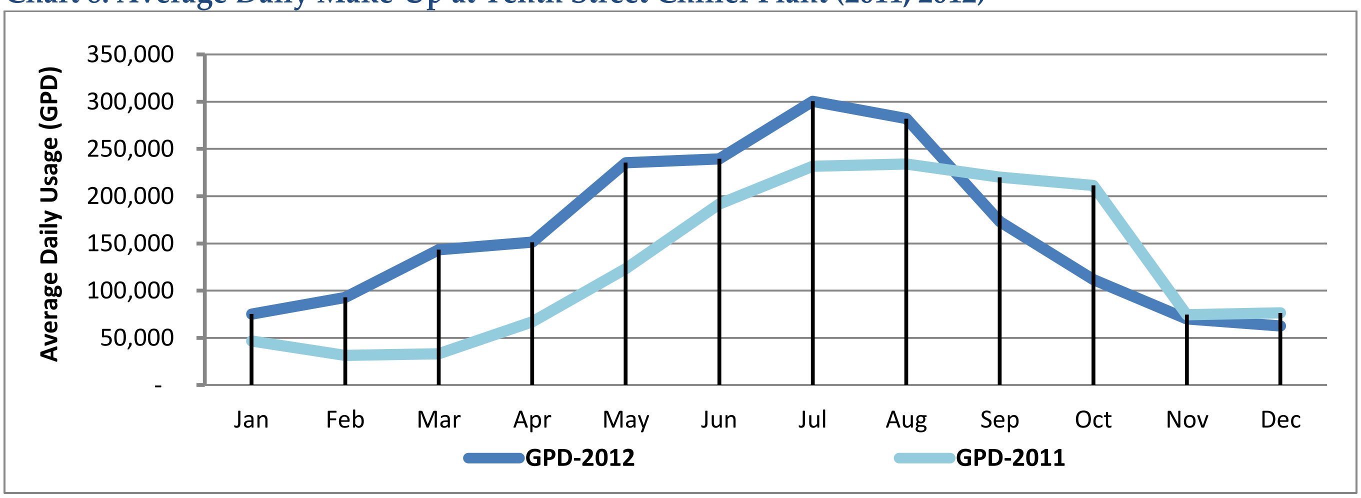
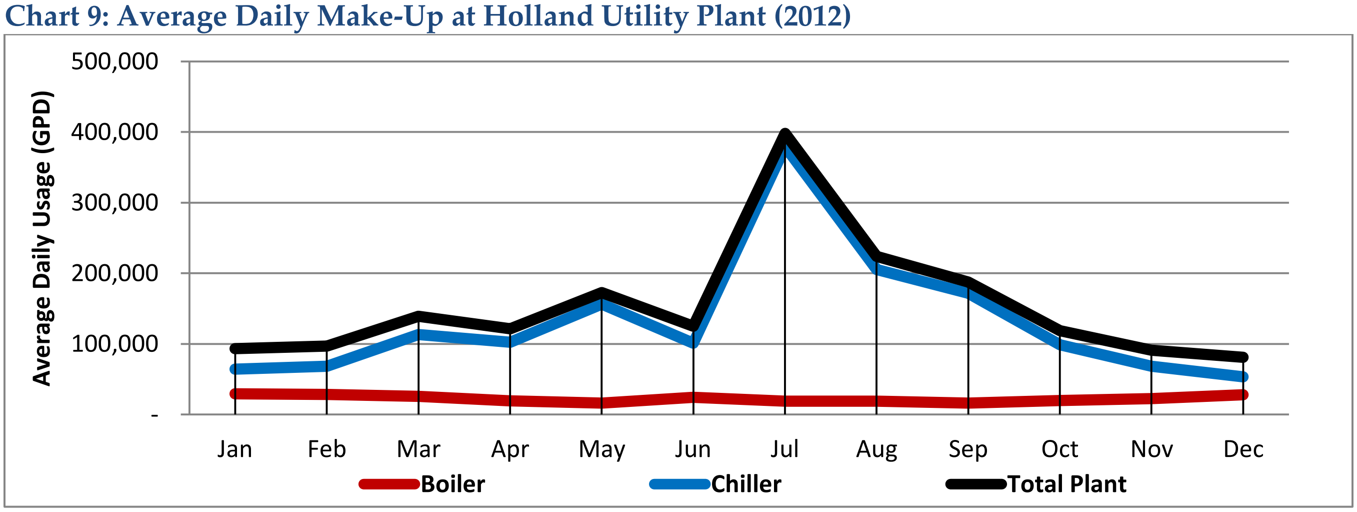


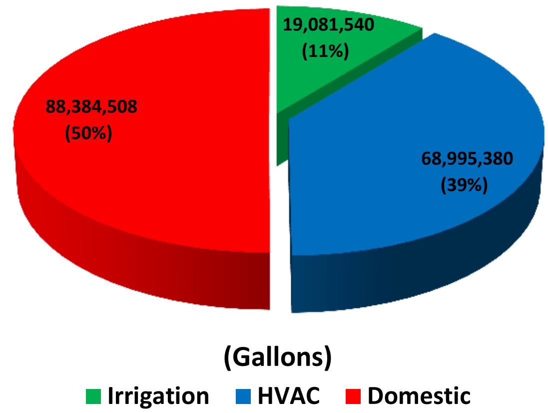
Chart 9: Average Daily Make-Up at Holland Utility Plant (2012)



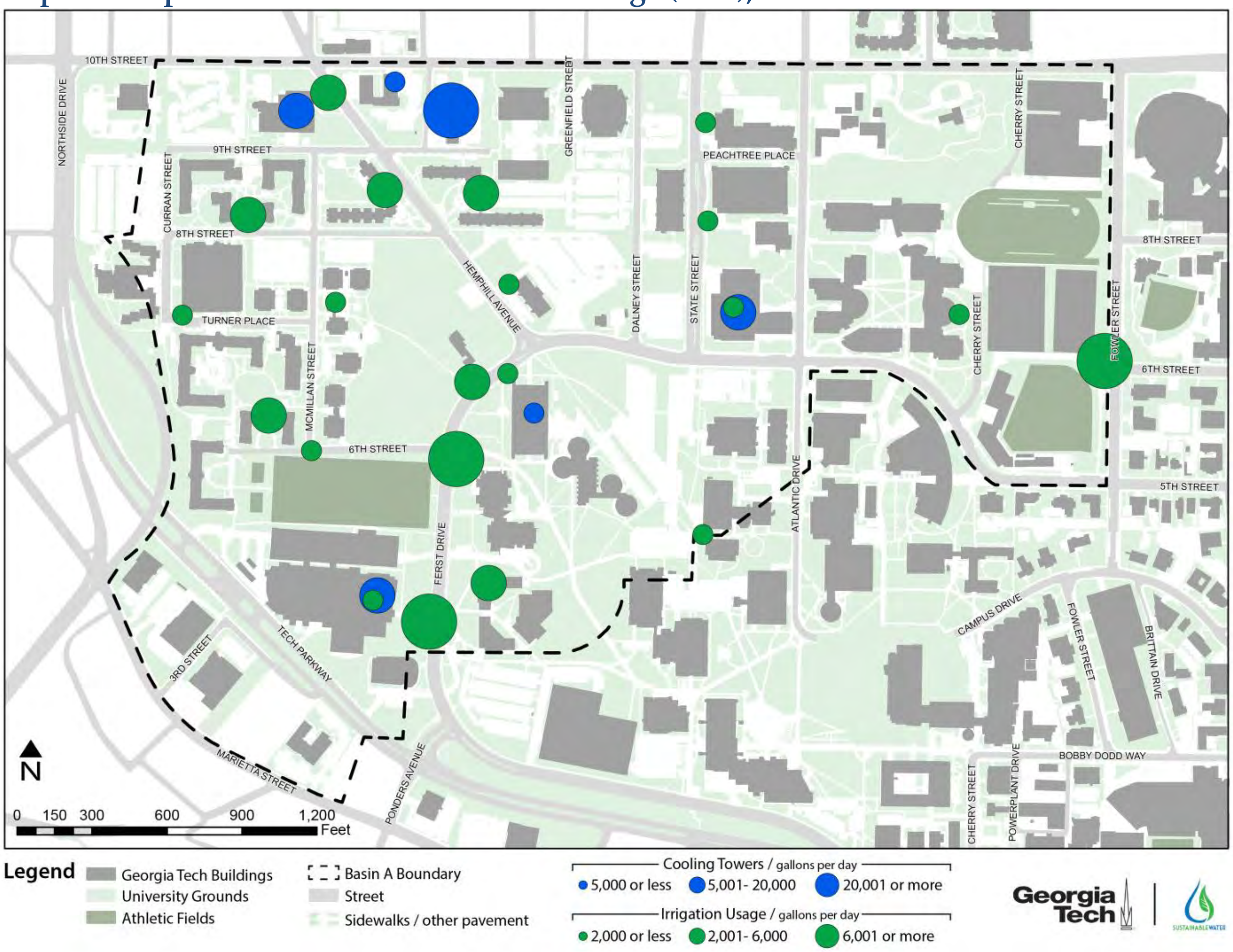
3.2. Water Use in Basin A

Basin A reported a combined total of 176,461,428 gallons of water in 2012. This represents 44% of the campus' overall water usage. Chart 10 breaks down the use by type in Basin A. Water use in Basin A largely mirrors total campus use; however, slightly greater volumes of irrigation and HVAC/utility water demand is present in this section of campus relative to the broader Institute. The 10th Street Chiller Plant represents approximately 33% of total water use in Basin A. The Campus Recreational Center has the largest municipal-supplied irrigation demand in Basin A.[11]

Chart 10: Total Usage by Category (2012), Basin A



Map 8: Non-potable Demand Location and Usage (2012), Basin A

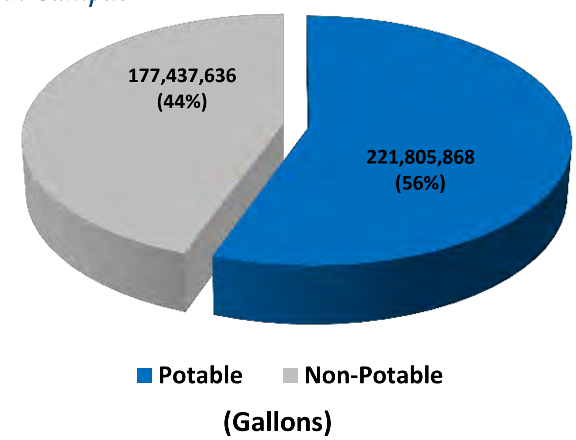


[11] Irrigation for the Burger Bowl is supplied by a campus well. It is unclear how much water is being used at this location.

3.3. Potable vs. Non-Potable Water Demand

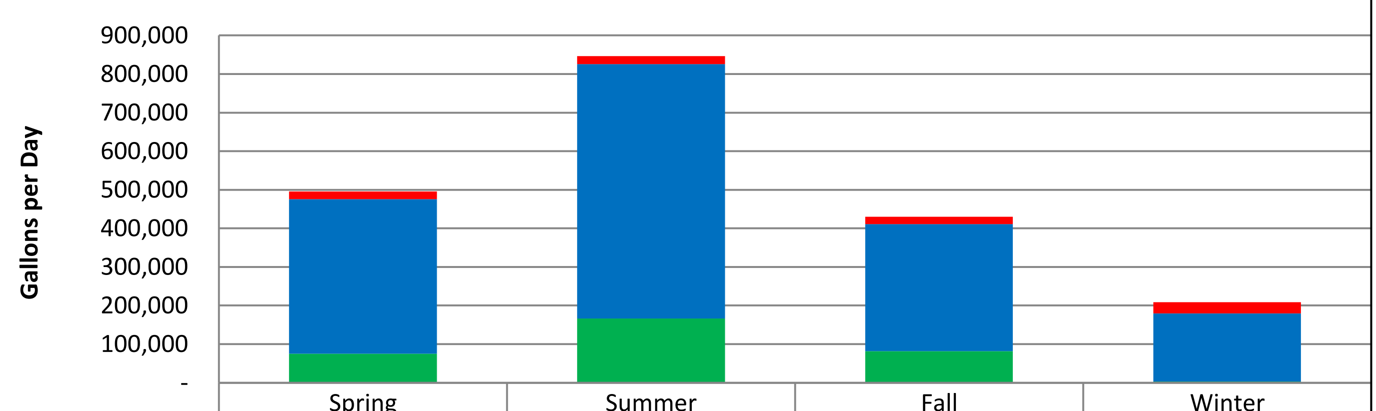
Georgia Tech currently uses potable water to meet nearly all of its water demand. However, not all campus uses require potable-quality water. A large percentage of everyday water use can be replaced by alternative sources of water, such as rainwater, gray-water, or reclaimed wastewater. Potable water is required for human consumption or whenever there exists a potential for prolonged human contact. All other water use could be supplemented with non-potable quality water. While acceptable non-potable water uses vary from state to state, some common uses are: irrigation, utility process water, fire protection, dust control, street cleaning, toilet-flushing and decorative fountains.

Chart 11: Potable vs. Non-potable Demand (2012), GT Main Campus



Sustainable Water attempts to quantify "easily accessible" sources of non-potable demand, which include the largest users and systems that can switch to an alternate source of water with relative ease. At Georgia Tech, Irrigation and HVAC/Utility uses comprise easily accessible non-potable water demand. In 2012, 177 M gallons, or 44% percent of demand, is considered non-potable. Chart 12 breaks down average daily non-potable water demand by season for the entire campus. Non-potable demand is highest in the summer months, reaching over 846,000 GPD on average. In contrast, winter months witness average daily demands of approximately 208,000 GPD. Average daily non-potable water demand for the year equates to approximately 485,000 GPD.

Chart 12: Average Daily Non-Potable Demand by Season (2012), GT Main Campus



	Spring	Summer	Fall	Winter
Steam	20,333	20,589	19,502	28,414
Cooling Makeup	400,439	659,525	329,039	177,164
Irrigation	74,963	166,473	81,720	2,676

3.3.1. Non-potable Demand in Basin A

Due to larger irrigation demands and the 10th Street Chiller Plant, the proportion of non-potable water demand is even greater in Basin A. However, no steam production occurs in Basin A. In 2012, approximately 88 M gallons was considered non-potable demand, accounting for 50% of use in Basin A (see Chart 13). This equates to an average 241,000 GPD of non-potable demand in Basin A. Chart 14 illustrates the seasonal non-potable water demand profile for Basin A. The highest level of demand occurs in the summer months, reaching approximately 439,000 GPD. In the winter, non-potable demand drops to approximately 93,000 GPD.

Chart 13: Potable vs. Non-potable Demand (2012), Basin A

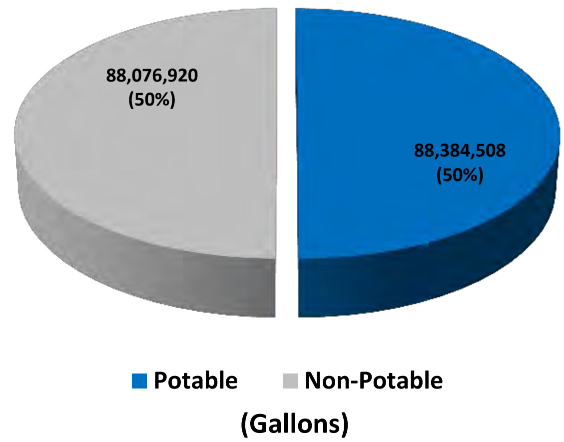
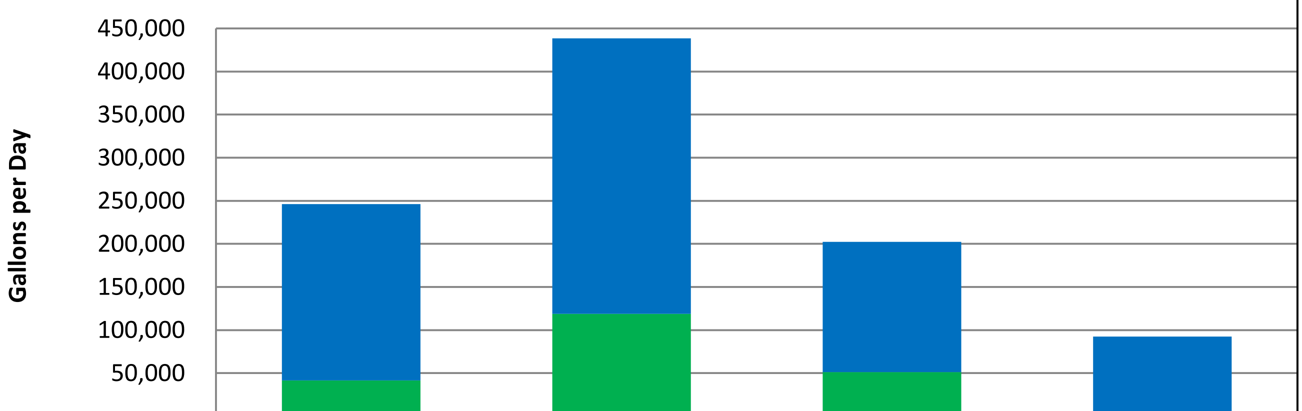


Chart 14: Average Daily Non-Potable Demand by Season (2012), Basin A



	Spring	Summer	Fall	Winter
Cooling Makeup	204,283	320,026	151,057	91,569
Irrigation	41,765	118,673	51,259	1,005

3.4. Future Water Demand

Georgia Tech is in the midst of a series of major campus improvements and expansions, many of which are occurring in Basin A. These include the addition of 11 new buildings, increased residence hall capacity, and the expansion of the 10th Street Chiller Plant, among others. Map 9 shows the location of future campus buildings (in gold) planned for Basin A in accordance with the EBB & Ferst Sector Plan. Appendix C provides a complete list of future and expanded building projects provided by the Institute.

Table 4 shows the projected future water demand for select campus improvements over the next 10 years. Future water demand is broken out over two five-year increments. Conservative estimates were made assuming water conservation initiatives would be deployed with each project. Detailed descriptions regarding the estimations for each project are provided below. In total, the five projects outlined in Table 4 are expected to increase water demand in Basin A by approximately 55M gallons per year after Phase II.

Table 4: Future Campus Water Demand Projections

Building Name	Phase I (1-5 yrs.) Additional Use (gal)	Phase II (6-10 yrs.) Additional Use (gal)	Total Build-Out Use (gal)
EBB I	2,365,000	n/a	2,365,000
EBB II	2,365,000	n/a	2,365,000
EBB III	n/a	2,365,000	2,365,000
800 Added Beds	2,120,000	2,120,000	4,240,000
10th St. Chiller Expansion P. 1	9,904,000	n/a	9,904,000
10th St. Chiller Expansion P. 2	16,900,000	n/a	16,900,000
10th St. Chiller Expansion P. 3	n/a	16,900,000	16,900,000
Total (gal/yr.)	***33,645,000***	***21,385,000***	***55,039,000***
Total (GPD)	***92,203***	***58,589***	***150,792***

This table is only inclusive of building projects in Basin A where there was adequate visibility to make semi-accurate water demand projections. In other instances, building projects, such as the parking deck planned in conjunction with the EBB II building, were left out because their water demand is not likely to affect Basin A's water footprint or wastewater production in any significant way. Map 9 outlines buildings or areas (in blue) associated with the future water demand projections made in this report.

Engineered BioSystems Building Complex

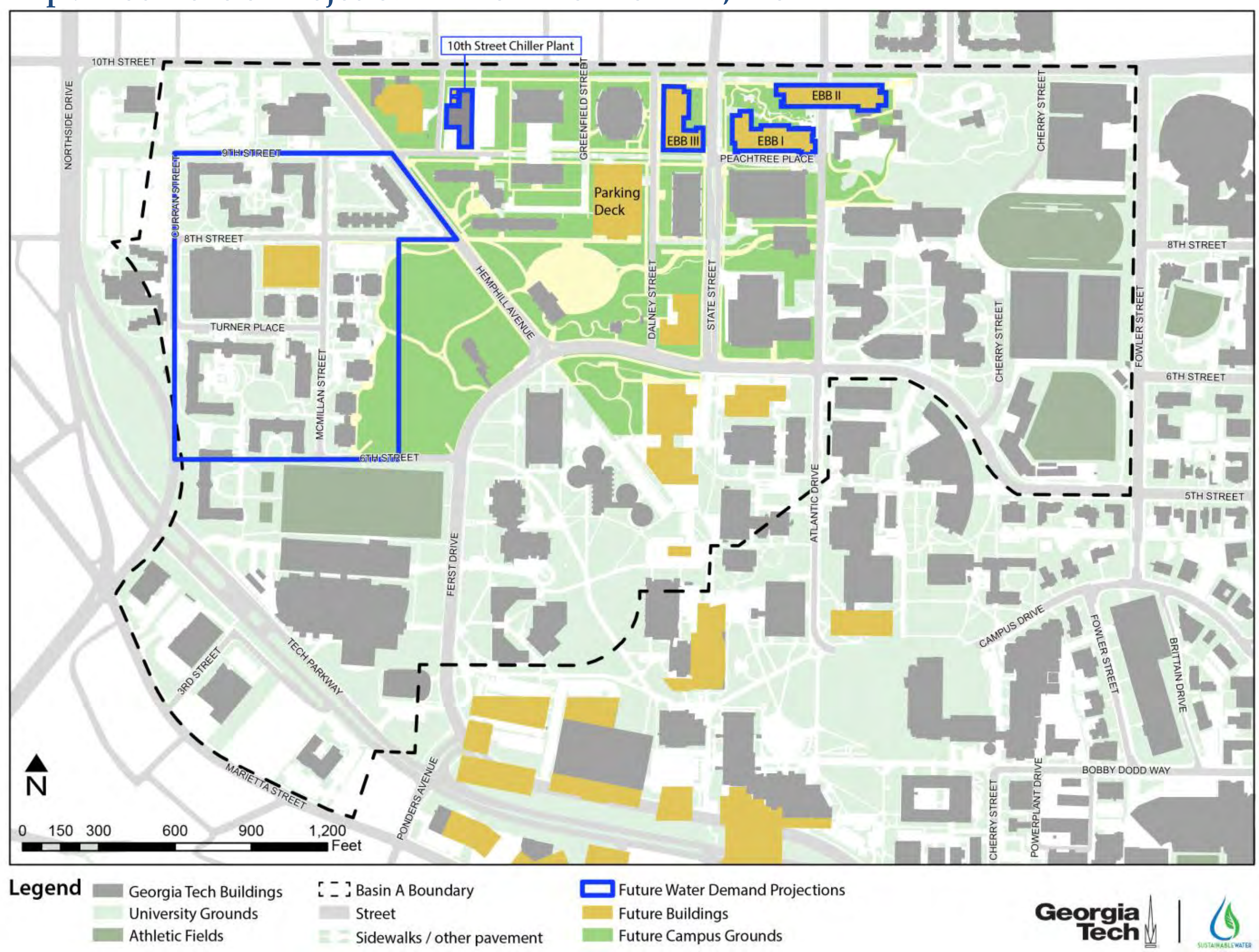
The EBB I building is currently under construction. Its construction will be followed by EBB Building II in the next 2-5 years and by EBB Building III within the next 10 years. To determine future water demand for this research/academic building complex, Sustainable Water analyzed water demand at the four buildings in the Ford Environmental Science and Technology (ES&T) complex, which is thought to have similar water usage patterns. In 2011 and 2012, the ES&T complex used approximately 10.8 gallons/ft^2/year. This ratio was then applied to the square footage for EBB I and projected to EBB II and EBB III. This yielded a total increase in demand of nearly 7.1 M gallons/year between these buildings.

Additional Residence Hall Capacity

The Institute plans to increase residence hall capacity by approximately 800 beds. The exact location of the proposed 800 beds has not been finalized, but it is assumed that it will likely occur in the area around Eighth Street Apartments. To determine the impact this will have on future water demand, Sustainable Water analyzed water use at Freeman, Montag, and Fitten residence halls, which were believed to demonstrate representative water usage patterns. On average, the 361 beds in these residence halls required approximately 5,300 gallons/bed/year. This ratio was applied across a two-phase build-out plan for the proposed additional residence hall capacity. Overall water demand is thus projected to increase by approximately 4,240,000 gallons/year, or approximately 11,600 GPD.

It is worth noting that this demand projection is based on residence halls that have deployed significant water conservation initiatives. In addition to low-flow retrofits, Fitten Hall utilizes an 8,000 gallon-capacity cistern to provide water for irrigation and toilet flushing on-site. While this minimizes potable water use, it does not diminish total water use and thus wastewater production. This cistern system is not currently metered to provide more accurate total water use projections.

Map 9: Locations of Projected Future Water Demand, Basin A



10th Street Chiller Expansion

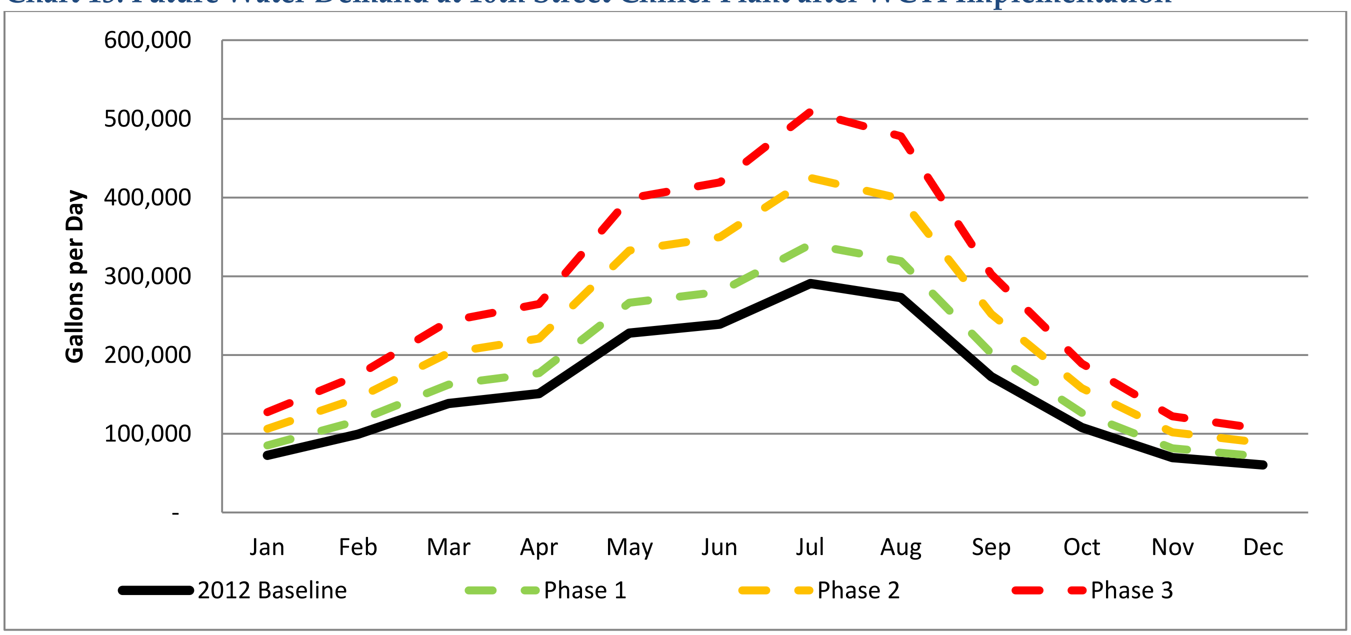
The largest increase in future water demand comes with the expansion of the 10th Street Chiller Plant (discussed in Section 2.1). There are plans for a 3-phase expansion to the plant, which coincides with the complete build-out of the EBB complex. Completion of Phase I will occur within the next year, as EBB Building I connects to its chilled water distribution network. Phase I expansion of the 10th Street

Chiller Plant also includes designs to move to a Water Conservation Technology International (WCTI) treatment program, which will eliminate cooling tower blow down and thus decrease make-up water demands by approximately 12% against 2012 baseline standards.

RMF Engineering originally predicted increased water demand at the plant using 2011 make-up water as a baseline. However, the significant increase in water use after installing calibrated water meters calls into question the accuracy of these predictions. Furthermore, final approval for transitioning to the WCTI Treatment Program occurred after the completion of the RMF report. As a result, future water demand projections were revised by using 2012 make-up as a baseline and incorporating the make-up demand changes associated with the new WCTI treatment program. Appendix C provides a table outlining revised make-up projections in detail.

Chart 15 shows future water demand projections over the three phases in gallons per day. If implemented, the Phase III expansion would effectively double the cooling capacity of the plant and increase make-up water demand by approximately 75% over 2012 levels. However, due to capacity limitations with the chilled water distribution network, it is unlikely that Phase III will come to fruition. Plans for Phases I and II seem more definitive. Phase I is projected to increase total demand from 58.1 M gallons to 68.0 M gallons annually – an increase of approximately 17% compared to current (2012) demand. Phase II is projected to increase total demand to 84.9 M gallons – an increase of approximately 46% compared to current demand.

Chart 15: Future Water Demand at 10th Street Chiller Plant after WCTI Implementation



3.5. Wastewater Flow Contributions

Factors affecting the quantity of wastewater flow from a given property relate to: 1) human water consumption, 2) evaporative losses due to irrigation or utility process water, and 3) line losses due to leaks. Since wastewater is unmetered at Georgia Tech, wastewater flow volumes are typically estimated based on water consumption. The City of Atlanta assumes a 1:1 ratio between water use and wastewater generation for billing purposes. However, a large proportion of the water consumed on campus is lost to evaporation and runoff. The City does honor a diverted wastewater credit for metered irrigation and HVAC/utility uses.

This study was careful not to overestimate wastewater flow contributions because those estimations correlate to the availability of recyclable water on-site. To determine wastewater production by building, most campus buildings were assigned an 85% wastewater flow rate. Any known irrigation use or HVAC uses associated with a given building was factored out before this flow rate was applied. Wastewater flows from cooling tower systems were considered to be 10% of make-up water demand.[12] Wastewater flows from boiler systems were considered to be 2% of make-up water demand.

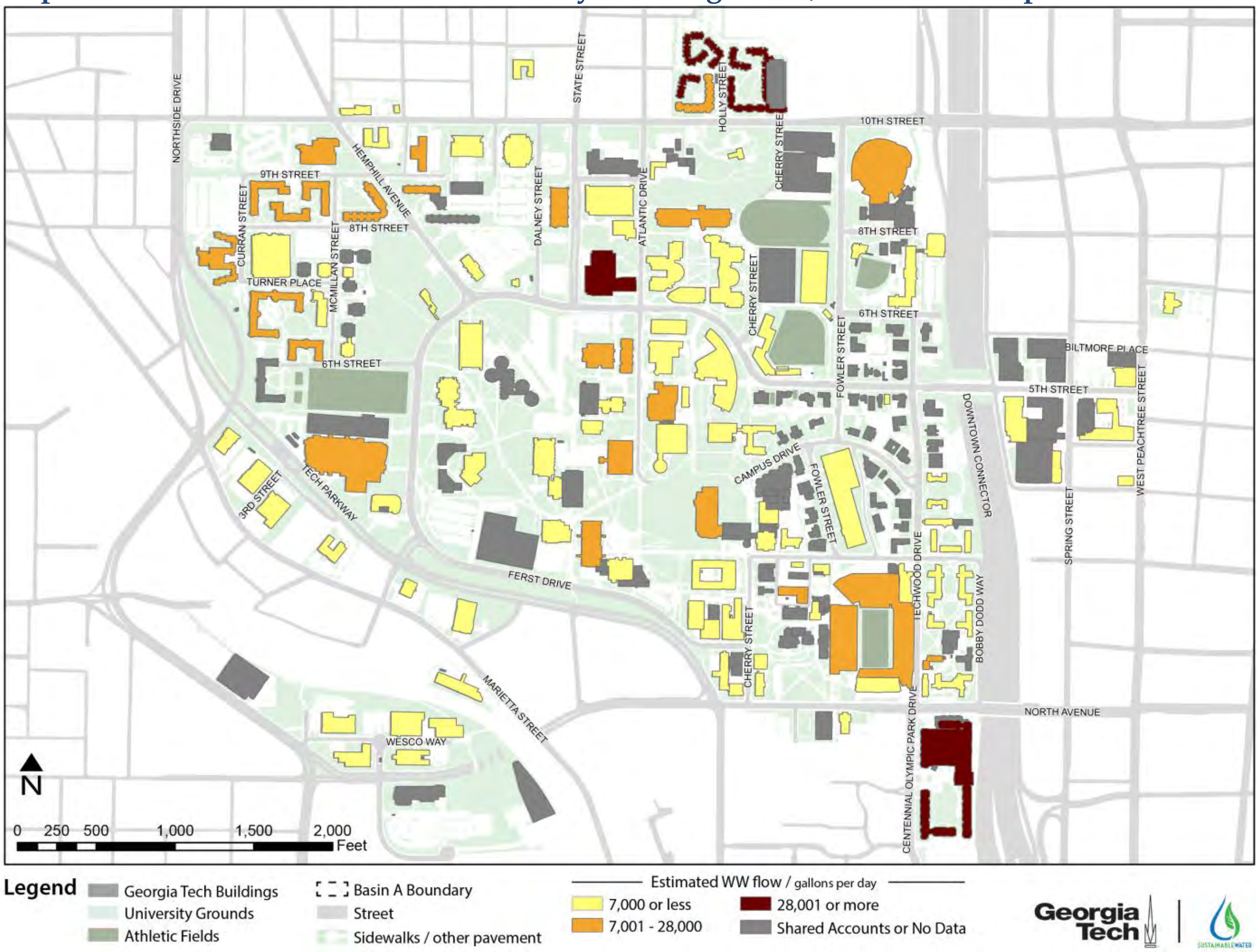
Conservative flow modeling demonstrated an approximate 50% return for all water consumed on campus. In total, Institute-owned buildings contributed approximately 212 M gallon of wastewater to the municipal collection system in 2012 – equating to approximately 580,000 GPD on average. The buildings with the largest wastewater flow returns in 2012 were North Ave Apartments (71,234 GPD), Nanotechnology Building (38,707 GPD), Family Housing Apartments (37,810 GPD), and 8th Street Apartments (27,314 GPD). A comprehensive list of all Georgia Tech buildings and their associated wastewater flows can be found in Appendix C.

Map 10 shows wastewater flow contributions by building for Georgia Tech's main campus in 2012. Buildings in dark brown produced the largest wastewater flow rates, while buildings in yellow produced the smallest flow rates. A number of buildings in gray had no wastewater production values, which is a result of one of three factors:

- **Shared Account Data** – multiple buildings had a shared or common water meter with an adjacent building; and, therefore all wastewater flow production is associated with just one building. Examples of this occurred at Center Street Apartments and the Manufacturing Related Disciplines Complex.
- **No Account Data** – some buildings, such as Greek Housing, are non-Institute owned buildings, and water usage is not tracked by the Institute.
- **No Water Use** – multiple buildings, such as the Burge Parking Deck and Student Center Parking Deck, had zero water use over the course of 2012.

[12] Average cooling tower blow-down (water returned to the sewer) varied between 10%-20% depending on the system and the season.

Map 10: Wastewater Flow Contributions by Building (2012), GT Main Campus



Once wastewater production by building was estimated, wastewater flow by line can be analyzed based on Georgia Tech's wastewater collection system. In accordance with the campus Stormwater Master Plan, wastewater is thought to primarily shed between Basin A and B. Much of Basin A feeds into an 18-inch collector and eventually into the Original Orme Street Sewer. Much of Basin B is believed to shed into the Orme Street Relief Sewer. Both sewer collectors exit the main campus at 10th Street approximately 350 feet apart.

Map 11 demonstrates the wastewater flow modeling at five measurement points on campus. Campus buildings (shown in pink and yellow) are divided between Basin A and B, and represent wastewater flows originating in North Campus and South Campus, respectively. Buildings in pink contribute to measurement points 1, 2 and 3. Buildings in yellow contribute to flow measurement points 4 and 5. Point 3, which includes wastewater production from Family Housing, modeled the overall highest wastewater flows on campus. Flows at measurement point 3 are inclusive of flows at points 1 and 2. Flows at measurement point 5 are inclusive of point 4.

This model underrepresents total available wastewater feedstock in the campus sewer collection network. A number of buildings in the southern section of campus, such as Greek Housing, have no data in this model. In addition, a number of non-Institute buildings south of North Avenue also contribute wastewater flows to measurement Points 4 and 5. Table 5 shows the detailed flow modeling results for each measurement point.

Wastewater flows at each measurement point were also analyzed from a seasonal perspective. A small spike in wastewater production is seen at each location in the fall. At point 3, this spike corresponded to a 26% increase in flow between summer and fall. Winter and summer saw comparative flow rates, while fall flows always exceeded spring flow rates in this model. A wastewater flow measurement study should be performed to validate wastewater flow volumes and seasonal flow variations.

Map 11: Wastewater Flow Modeling, GT Main Campus

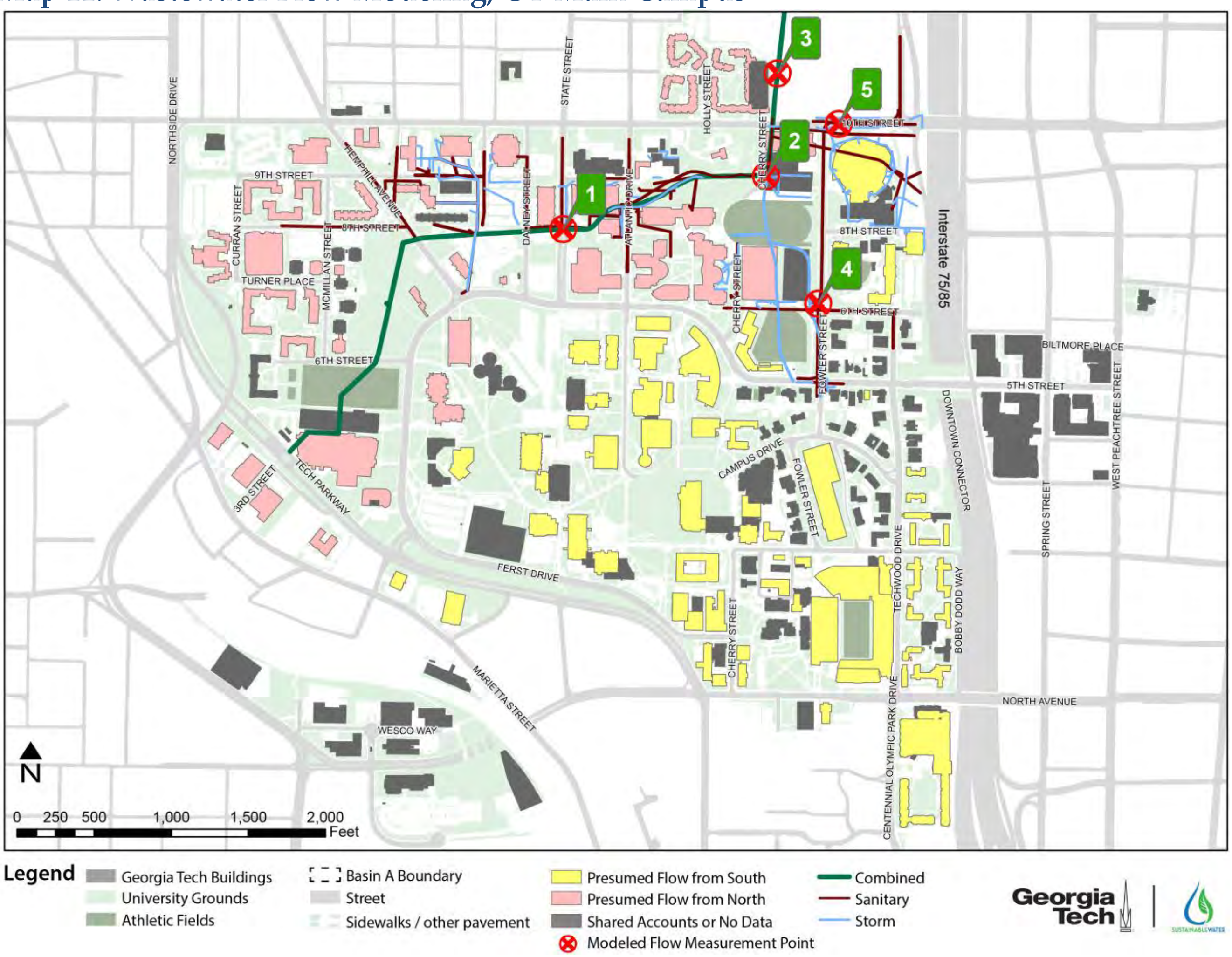


Table 5: Modeled Wastewater Flows at Select Locations on Campus

Flow Measurement Point	Total WW Flow (Gallons)	Average WW Flow (GPD)	Avg. Spring Flow (GPD)	Avg. Summer Flow (GPD)	Avg. Fall Flow (GPD)	Avg. Winter Flow (GPD)
1	73,990,034	205,570	188,087	194,725	252,810	187,093
2	95,482,767	265,272	254,074	249,097	324,636	233,717
3	112,548,568	312,677	293,021	298,810	378,373	280,940
4	88,373,162	246,453	255,194	203,619	282,741	244,429
5	91,310,624	258,306	259,279	217,150	297,417	248,209

3.5.1. Future Wastewater Flow – Basin A

As a result of anticipated increases in water demand, the wastewater flow through Basin A is expected to increase as well. Future water demand projections described in Section 3.4 were used to determine future wastewater flow production over the next 10 years. The conservative 85% wastewater flow rate is applied to the future buildings EBB I, EBB II, and EBB III and the 800 additional beds. The 10th Street Chiller Plant is assumed to have zero wastewater flow production as a result of the WCTI program. Table 6 shows the projected future wastewater flows for these projects in Basin A.

Table 6: Future Campus Wastewater Flow Contributions

Building Name	Phase I (0-5 yrs.) Add'l Wastewater (gal/yr.)	Phase II (5-10 yrs.) Add'l Wastewater (gal/yr.)	Total Build-Out Wastewater (gal/yr.)
EBB I	2,010,250	0	2,010,250
EBB II	2,010,250	0	2,010,250
EBB III	0	2,010,250	2,010,250
800 Added Beds	1,802,000	1,802,000	3,604,000
10th St. Expansion(s)	0	0	0
Total (gal/yr.)	***5,822,500***	***3,812,250***	***9,634,750***
Total (GPD)	***15,942***	***10,445,000***	***26,397***

The wastewater flow projections calculated here are very conservative in terms of quantifying additional wastewater feedstock availability. Wastewater produced from the additional residence hall capacity is likely underestimated as a result. However, if these values are applied to the flow modeling in Section 3.5, approximately 60% of this future flow will be seen at measurement point 1; and 100% of this flow will be seen at measurement point 2.

4.0 Water Quality and Utility Water Treatment Audit

Water quality is a critical issue for both treatment processes and end-users of water. Reclaimed water must be compatible with its end-users in order to have a successful reuse program that provides a level of operational reliability to the campus. Central Utility Plants are the largest point-source water consumer on campus that can use non-potable water supplies, which makes them a primary target for reclaimed water. However, utility systems are significant campus assets that require 100% uptime; and, therefore require proper management.

This section of the report looks at the water quality of various streams of water and the existing utility water treatment program implemented at the 10th Street Chiller Plant in order to ensure that wastewater can be safely and reliable reused at Georgia Tech. This section is broken into two subsections: 4.1: Water Quality and Characteristics and 4.2: Utility Water Treatment Program Assessment.

Overall, no evidence exists that suggests a water reclamation and reuse program would not be successfully administered at Georgia Tech. The utility water audit produced results that are conducive to water reclamation and reuse. The current water treatment program administered at utility plants consistently produces high-quality results. Equipment conditions appear to be appropriate for the age of the systems, and operator expertise is sophisticated enough to implement a successful treatment program utilizing reclaimed water.

4.1. Water Quality and Characteristics

Water quality is a critical issue for understanding overall treatability – whether that pertains to city water used as make-up in utility systems or wastewater streams used as feedstock in a reclamation process. Sustainable Water attempts to benchmark water quality characteristics for each source of water: drinking water from the City of Atlanta, raw groundwater characteristics from campus wells, and wastewater (blackwater). This is done in order to understand natural characteristics of regional water sources and develop a treatment process that is tailored specifically to any end-use applications at Georgia Tech.

4.1.1. Drinking Water and Well Water Characteristics

Water quality will vary from region to region depending on the source, natural geologic and environmental conditions, as well as human influences. The basic constituents of water are important to understand, as any elements naturally present will also prevail or be magnified in wastewater streams. At Georgia Tech, Garratt Callahan performs laboratory testing on potable water provided by the City of Atlanta, and, on occasion, groundwater quality at the request of the Institute. Currently, city water is used as process make-up in the utility plants. Table 7 examines the approximate constituents (in parts per million, or PPM) of numerous analytes pertinent to the Institute's chemical treatment program. Table 8 examines the approximate constituents of well water, which will be an alternate source of make-up water at the 10th Street Chiller Plant beginning in 2014.

Table 7: City of Atlanta Drinking Water Characteristics

#	Analyte (Test)	PPM
1	Total Hardness as $CaCO_3$	25
2	Calcium Hardness as $CaCO_3$	20
3	Magnesium Hardness as $CaCO_3$	5
4	'P' Alkalinity as $CaCO_3$	0
5	'M' Alkalinity as $CaCO_3$	20
6	Sulfate as SO_4	6
7	Chloride as Cl	10
8	Silica as SiO_2	5
9	Phosphate as PO_4	<1
10	Conductivity @ 25°C	100
11	Iron as Fe	<0.2

Table 8: Campus Well Water Characteristics

#	Analyte (Test)	Test Result	Unit	RDL
1	pH	7.71 at 2rc	s.u.	
2	Conductivity	430	µmhos/cm	
3	Phenolphthalein Alkalinity, as CaC03	ND	mg/L	5
4	Total Alkalinity, as CaC03	120	mg/L	5
5	Bromide, as Br	0.6	mg/L	0.1
6	Chloride, as Cl	28	mg/L	0.1
7	Nitrate, as N03	4.2	mg/L	0.1
8	Nitrite, as N02	0.1	mg/L	0.1
9	Orthophosphate, as P04	ND	mg/L	0.2
10	Sulfate, as S04	45	mg/L	0.1
11	Calcium Hardness, as CaC03	109	mg/L	0.5
12	Magnesium Hardness, as CaC03	50	mg/L	0.5
13	Total Hardness, as CaC03	159	mg/L	0.5
14	Molybdenum, Mo	0.01	mg/L	0.01
15	Potassium, K	8.0	mg/L	
16	Silica, as Si02	34	mg/L	0.1
17	Sodium, Na	18	mg/L	

4.1.2. Wastewater Characteristics

There was no existing wastewater sampling data for Georgia Tech's main campus. Subsequent work is planned to perform composite sampling in addition to wastewater flow monitoring at select locations. Once performed, sampling will provide detailed information with regard to wastewater quality, which is essential to help properly size a treatment facility and model end-use quality.

While no wastewater sampling has occurred near Georgia Tech's campus, Sustainable Water has performed wastewater sampling studies in other areas of the Metro Atlanta region. Characteristics of wastewater streams from similar land uses in DeKalb County were found to have medium to low levels of Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Ammonia, Nitrogen, and Phosphorus. If representative of Georgia Tech's waste stream, no major impediments to water reclamation are foreseen. Section 5.2 shows wastewater characteristics used for facility sizing in lieu of having specific wastewater characteristics for Georgia Tech.

4.2. Utility Water Treatment Program Assessment

Utility, or process water, refers to water used in manufacturing, industrial, or utility applications. These applications usually include rinsing, plating, coating, cooling, or heating. At Georgia Tech, process water is used for HVAC systems. This includes water use for boiler and cooling tower make-up. (Section 3.2.2 outlines campus water use for these applications.) At Georgia Tech, utility process water is the largest source of non-potable water demand on campus—equating to 84% of campus non-potable demand. In any water reuse program, utility plants will offer the greatest potential cost savings, as they require the least amount of infrastructure costs per gallon of water delivered.

Sustainable Water performed a Utility Water Treatment Program Assessment to ensure that reclaimed water could reliably be reused on site. This assessment looked at two major facets of utility water use, addressed in the following sections: 4.2.1: Utility Equipment and Conditions and 4.2.2: Treatment Program Administration. Comprehensively, this assessment sought to:

- Understand/inspect equipment uses and conditions;
- Review maintenance history and upkeep;
- Understand frequency and accuracy of existing treatment programs;
- Confirm the expertise of water treatment companies and operators;
- Analyze products dosages, consumption, and cost of programs;
- Review laboratory testing results; and
- Establish baseline metrics for corrosion, biological growth, and solids deposition for historical benchmarking.

4.2.1. Utility Equipment and Conditions

Over the years, Georgia Tech has increased its physical footprint, which results in a constant need to expand capacity at central chiller and steam plants. Incremental additions to air conditioning and heating capacity result in different generations of utility equipment, at various stages of useful life, reliability, and efficiency. Chillers, boilers, and cooling towers will vary in condition based on age, upkeep, use, and environment. A major objective of the feasibility study is to ensure that utility systems that may receive reclaimed water are operating effectively and in relatively good condition.

As the only chiller plant in Basin A, equipment conditions assessments were limited to the 10th street chiller plant. A tour of the 10th Street Chiller Plant was performed by Sustainable Water in February of 2013. During this walk through, chiller systems seemed to be operating normally. No outstanding equipment defects, hazards, or problems were noticed. Prior to this walkthrough, a list of operating chillers and their specifications was provided by Georgia Tech Facilities Management. Table 9 outlines this information.

Table 9: 10th Street Chiller Specifications

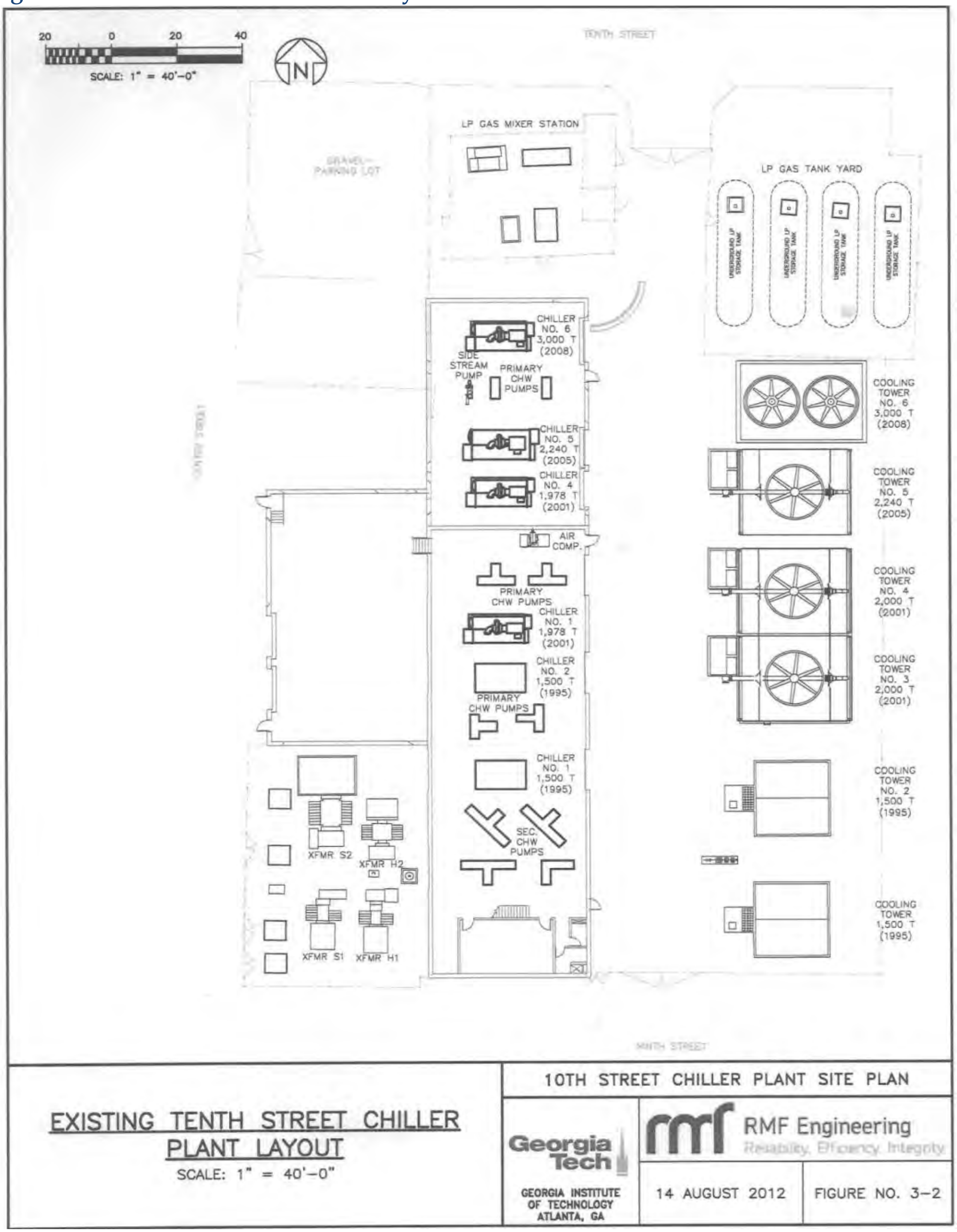
#	Manuf.	Chiller Type	Date Installed	Tonnage	Refrigerant Type	Condenser Type	Voltage
1	York	Centrifugal	1995	1,500	HFC-134a	Tower-open	4,160
2	York	Centrifugal	1995	1,500	HFC-134a	Tower-open	4,160
3	York	Centrifugal	2001	1,978	HFC-134a	Tower-open	4,160
4	York	Centrifugal	2001	1,978	HFC-134a	Tower-open	4,160
5	McQuay	Dual Centrifugal	2005	2,250	HFC-134a	Tower-open	4,160
6	York	Dual Centrifugal	2008	3,000	HFC-134a	Tower-open	4,160

The 10th Street Chiller Plant has six electric centrifugal or dual centrifugal chillers and six cooling towers. The chillers range in size from 1,500 to 3,000 tons of capacity and have a total available capacity of approximately 12,200 tons. The age and model of the chillers vary. Five of the six chillers were designed by York; one was designed by McQuay. The first chillers were installed in 1995 – making these units approximately 17 years old. The newest chiller, the largest unit, was installed in 2008. Overall, the average age of the chillers is approximately 11 years.

The 10th Street Chiller Plant currently serves 27 buildings in North Campus, but is also interconnected with Holland's chilled water distribution system (serving the southern part of campus) by a series of valves. The chilled water system relies on a series of primary and secondary pumps. Six primary (dedicated) pumps circulate water through the plant and four secondary pumps circulate water through the North Campus distribution system. Each primary pump can only operate with its paired chiller. The secondary pumps are rated at 400 horsepower and designed for 9,600 gallons per minute.

The cooling towers are a combination of cross-flow as well as field-erected cross- and counter-flow types. Each tower and pump is designed to serve a single chiller. Each tower has its own chemical management system. The current layout of the 10th Street Chiller Plant and its configuration of cooling towers can be seen in Figure 8. Design parameters of the chillers are provided in Appendix D.

Figure 8: Current 10th Street Chiller Layout



Georgia Tech Facilities Management is responsible for the overall operation and maintenance of campus utility systems. The utility water treatment program is outsourced to Garratt Callahan – which has a regional headquarters in Atlanta. Garratt Callahan's technicians are typically on site once a week to check water quality parameters and the general administration of the treatment program.

Utility Water Audit Forms were provided by Sustainable Water to gather pertinent information about the 10th Street Chiller Plant. Forms were completed by Garratt Callahan technicians upon request from Georgia Tech Facilities Management. Completed audit forms can be found in Appendix D of this report. The audit requests various historical data and literature to help assess the treatment program and equipment conditions. Data requests pertinent to equipment condition were as follows:

- Inspection reports from the past five years,
- Boiler and chiller video inspection results from the past five years
- Five-year historical corrosion coupon data, and
- Non-destructive integrity assessments (i.e., ultrasonic testing and EDDY Current Testing) from the past five years.

Garratt Callahan provided field reports and operator logs for January 2011 through December 2012. During this time period, operators kept meticulous logs indicating equipment defects and system operations. On numerous occasions, field reports identify minor equipment problems – such as needed piping repairs, leaks, or faulty control systems. Once noted, repairs are made by Georgia Tech Facilities Management. Beyond normal wear and tear, field reports did not indicate any major flaws or equipment problems.

Outside of the provided field reports, Georgia Tech has limited supplemental information pertaining to equipment conditions. To our knowledge, no chiller video inspections or non-destructive integrity assessments have been performed at the 10th Street Chiller Plant within the last five years. Moving forward, it is recommended that EDDY Current testing be performed on each chiller as a part of routine maintenance.

In October 2012, RMF Engineering released a draft report of its findings related to the 10th Street Chiller Plant. The report did not cite any major problems or concerns with existing equipment or performance. Consequently, RMF assumes that existing equipment will be able to maintain its current capacity over the next 10 years as new chillers accommodate future cooling requirements for the additional 1.1 million gross-square feet of building space planned for North Campus.

4.2.2. Treatment Program Administration

Water quality plays a major role in the efficiency and lifespan of utility equipment. To protect expensive utility equipment, a water treatment program is always administered, regardless of the water source (drinking water, well water, or reclaimed water), to ensure the highest level of compatibility with the utility process. A proper water treatment program will safeguard utility systems from unnecessary water consumption, along with providing corrosion, mineral deposition, scaling, and microbiological control within the system. In addition to this, the efficacy of a utility water treatment program ultimately plays a significant role in the heat-transfer efficiency and lifespan of utility systems. When properly administered, water treatment ensures safe and reliable operations.

Sustainable Water reviewed treatment products, chemical treatment dosages, historical chemical usage, program costs, operator test logs, field reports, chemical feed automation, control equipment, laboratory analyses, and corrosion monitoring data to better understand GT's existing treatment program. A reclaimed water program may cause a slight change in influent water characteristics at utility systems, which may require subsequent adjustments to the treatment program administered. At the start of the feasibility process, Sustainable Water requested various historical data and literature to help review the treatment programs at the large area-wide utility plants. This data request included:

- Treatment program design specifications,
- Any laboratory testing from past years,
- Operator log sheets/test logs from past years,
- Chemical treatment supplier service reports from the past two years, and
- Five-year historical corrosion coupon data.

The Utility Water Audit form (provided in Appendix D) captured most of the detail pertaining to the administration of the treatment program. Overall, operator testing at the 10th Street Chiller Plant is thought to be consistent and comprehensive – showing extensive operator expertise. Systems are currently treated via a conventional inhibitor and dual alternating biocide treatment program. Table 10 summarizes the chemical treatment controls used in the cooling towers, the chilled water closed loop and the hot water closed loop. Product Material Safety Data Sheets (MSDS) are provided in Appendix D.

The conventional treatment program applied at the 10th Street Chiller Plant is appropriate and achieving excellent results in terms of efficiency. Cooling Towers are operating at about 10 cycles of concentration. Georgia Tech Facilities Management cycles chillers to spread load between units as far as possible. Systems cycle between idle and duty depending on load. Tower blow down occurs via conductivity control. Cycles are limited by hardness, and to a certain extent, suspended solids in the tower sump. There is no acid or caustic feed to these systems as make-up water quality does not dictate that this would be necessary. The systems could gain some improvement through the use of traced chemical inhibitor which will dose chemical inhibitor based on demand and use.

Field reports show that products and chemical dosages have been maintained consistently by Garratt Callahan, and historical use demonstrates reliable and consistent chemical consumption in accordance with program targets. This indicates reliable operator control and automation and quick, responsive action. For corrosion monitoring, the 10th Street Chiller Plant utilizes an on-line CorTrac corrater unit installed by Garratt Callahan. The unit measures mild steel and copper corrosion. Results of the corrater were not provided, but there is no indication from field reports of outstanding corrosion issues with any of the condensers or evaporator units.

Table 10: Chemical Treatment Controls at 10th Street Chiller Plant

Location	Product	Feed Point	Generic Type	Active Ingredient	Desired Concentration	Control Test
Cooling Towers	GC-222-L	Chemical Bypass	Corrosion Inhibitor	Sodium Hydroxide	150 PPM based on makeup	Molybdate
	GC-3338	Chemical Bypass	Biocide 1	Halogenated Complex, Sodium Hydroxide	60 ppm twice per week	Halogen
	GC-312	Chemical Bypass	Biocide 2	Glutaraldehyde	120 ppm once per week	None
Chilled Water Closed Loop	GC-16	Bypass Feeder	Corrosion Inhibitor	Sodium Silicate	3lb./1,000 gal.	Si
	GC-2018	Bypass Feeder	Biocide	Sodium Tolyltriazole	0.2lb./1,000 gal.	Azole
Hot Water Closed Loop	GC-12L	Bypass Feeder	Closed System Corrosion Inhibitor	Sodium Nitrite; Sodium Tolyltriazole; Sodium Hydroxide	20 lb./1,000 gal. (as required)	Nitrite

Charts 16 and 17 track inhibitor feed and thermal conductivity on a weekly basis throughout 2012. These are important control parameters that are constantly analyzed by Garratt Callahan. The following descriptions outline these controls tests as they relate to the 10th Street Chiller Plant:

- Molybdate is a control test for the corrosion inhibitor applied by Garratt Callahan. Molybdenum itself is a corrosion inhibitor and scale control product. Molybdate target concentrations are between 0.5 and 1 ppm.
- Thermal Conductivity, also known as conductance, is a material's ability to conduct heat. With regard to cooling water systems, it demonstrates scale control and reliability of automation (automatic blow down). Conductivity levels typically indicate mineral levels in water and are used to help optimize water conservation and minimize risk of scaling deposition and corrosion. Target conductivity results are between 750 and 1,000 ℧.

Variation in concentration levels is expected as influent water quality can change daily. Operator logs and testing demonstrate that the current treatment program is operating with timely corrective actions when treatment residuals are out of specification. Field service reports and laboratory analyses provide additional validation of proper program implementation.

Overall, review of available data shows consistent control over corrosion, deposition, and biological growth. Not all data requests were fulfilled during the Utility Program Audit, but disclosed data does indicate adequate program control and expertise. It is Sustainable Water's opinion that Garratt Callahan delivers cost-effective water treatment program results, well within industry standards. Garratt Callahan expressed comfort using reclaimed water as a make-up source for the 10th Street

Chiller Plant, and has demonstrated significant expertise utilizing reclaimed water in the past. The level of sophistication and expertise present between Georgia Tech Facilities management and Garratt Callahan will be more than adequate to implement a reclaimed water program, which can be as reliable, efficient, and safe as utilizing city-supplied water. Specific changes to chemical controls and/or equipment currently used in the utility water treatment program will be explored during the engineering and design phase of a water treatment program once specific effluent water quality is better understood.

Chart 16: Cooling Tower Molybdate Level vs. Time, 10th Street Chiller Plant (2012)

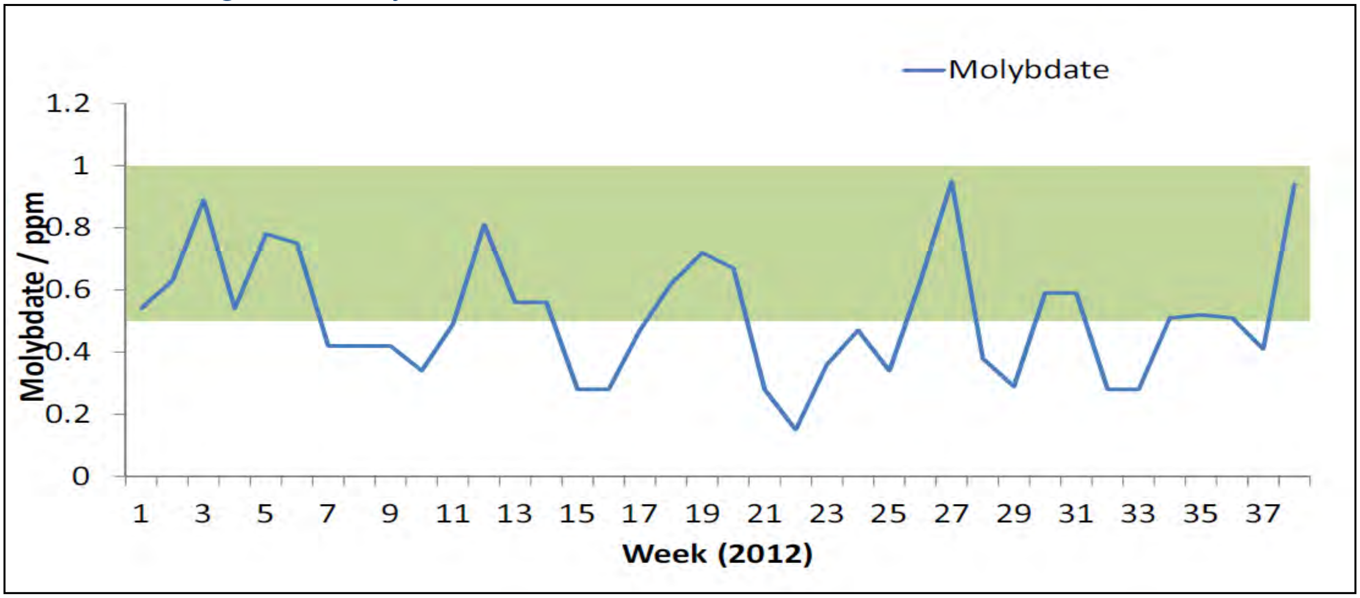
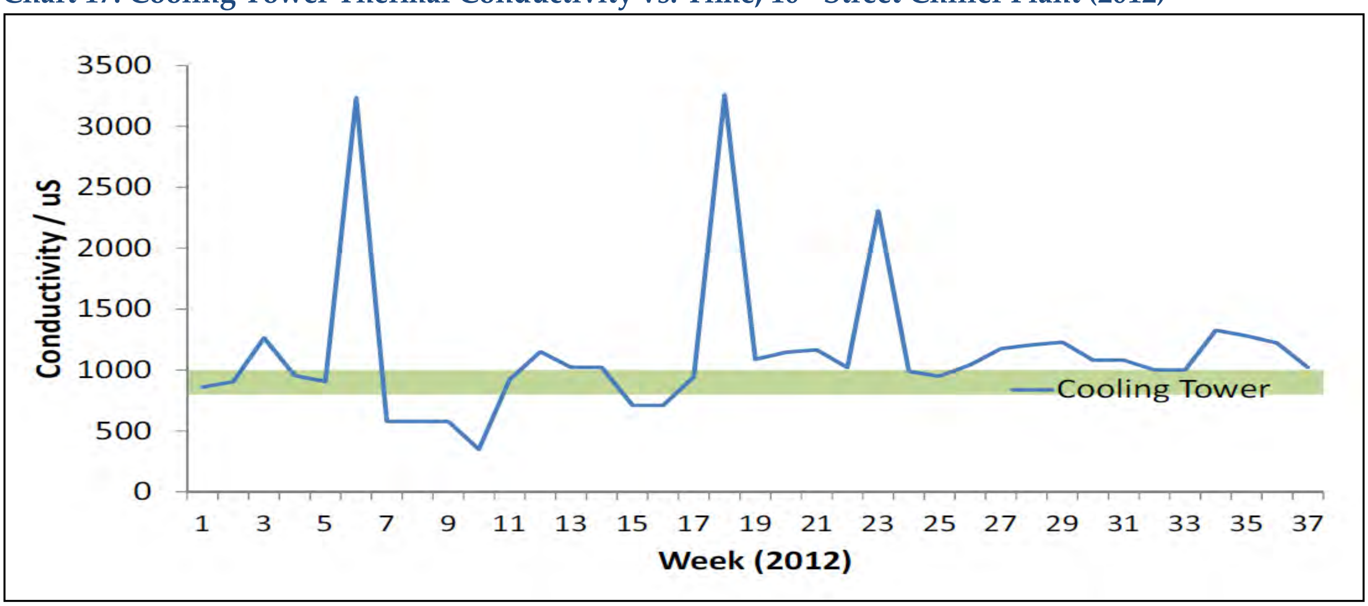


Chart 17: Cooling Tower Thermal Conductivity vs. Time, 10th Street Chiller Plant (2012)



5.0 Integrating Water Reclamation and Reuse at Georgia Tech

This section reviews regulatory, siting, and facility sizing considerations specific to Georgia Tech. Section 5.1 provides a brief overview of the federal, local and regulatory environment specific to decentralized water treatment and reclamation. Section 5.2 analyzes physical footprint requirements for various ecological treatment technologies. Section 5.3 reviews siting considerations and challenges uncovered during the feasibility process.

5.1. Regulatory Environment

5.1.1. Federal Regulations

The U.S. Environmental Protection Agency (EPA) sets minimum environmental regulatory standards relating to water quality, treatment, and discharge. Most of these standards are laid out in the Clean Water Act. State governments have the option of exceeding these standards, but must conform to their minimum criteria. The EPA does not have specific regulations pertaining to water reclamation and reuse, but it does produce guidelines for states to voluntarily follow.[13] Many states choose to accept and implement these policies. Many water reuse regulations within the state of Georgia have been influenced by these guidelines. Appendix E of this report provides the EPA's Guidelines for Water Reuse.

Although the EPA does not produce formal water reuse regulations, it clearly endorses water reuse as a best management approach to conserving water resources and reducing pollution. The introduction to the 2012 Guidelines for Water Reuse notes the following:

> As urban areas continue to grow, pressure on local water supplies will continue to increase. Already, groundwater aquifers used by over half of the world population are being over-drafted. As a result, it is no longer advisable to use water once and dispose of it; it is important to identify ways to reuse water. Reuse will continue to increase as the world's population becomes increasingly urbanized and concentrated near coastlines, where local freshwater supplies are limited or are available only with large capital expenditure.

In addition, the EPA cites water reuse and reclamation as beneficial in terms of economic savings, environmental protection, energy production, sustainability and infrastructure capacity.

> The ability to reuse water, regardless of whether the intent is to augment water supplies or manage nutrients in treated effluent, has positive benefits that are also the key motivators for implementing reuse programs. These benefits include improved agricultural production; reduced energy consumption associated with production, treatment, and distribution of water; and significant environmental benefits, such as reduced nutrient loads to receiving waters due to reuse of the treated wastewater.

The Clean Water Act (CWA) governs state water reuse regulations by setting basic requirements in regard to wastewater treatment and discharge. As such, the EPA developed the National Pollutant Discharge Elimination System (NPDES) in 1972 to regulate point source water pollution. Wastewater

[13] The EPA Guidelines for Water Reuse, 2012 are provided in Appendix E.

treatment facilities are required to meet federal discharge standards as laid out in this permit system. States are responsible for the enforcement of regulations associated with NPDES and the CWA, as well as the development of their own water reuse regulations if so inclined. The following sections summarize the regulatory environment pertaining to water reclamation and reuse for the state of Georgia and the City of Atlanta.

5.1.2. Georgia Water Reclamation & Reuse Regulations

The State of Georgia recognizes that water reclamation and reuse is a viable water management tool, which helps reduce demand on available surface and ground waters, delays or eliminates the need to expand potable water supply and treatment facilities, and eases pressure on these water supplies by helping conserve potable water reserves.[14] Because of these benefits, Georgia informally incentivizes water reuse through a number of policies and endorsements. Water reuse is mentioned as a viable and sustainable water management tool in multiple state-published water supply planning and water conservation documents. To promote the use of water reclamation and reuse, the Georgia Department of Natural Resources, Environmental Protection Division (EPD) released the Guidelines for Water Reclamation and Urban Water Reuse in 2002.

Currently, there are approximately 75 permitted reuse facilities in the state of Georgia. The Georgia EPD, Watershed Protection Branch specifies the requirements for wastewater treatment and water reclamation and reuse. The state officially reviews each permit application and issues necessary permits. The Georgia Guidelines for Water Reclamation and Urban Water Reuse, provided in Appendix D, outline the specifications and regulatory requirements for a water reclamation permit. The following regulatory topics are found in these guidelines:

1) Wastewater treatment,
2) Monitoring requirements,
3) System requirements and reliability,
4) Operation requirements,
5) Reclaimed water storage and disposal,
6) Access control and warning signs, and
7) Distribution systems

A majority of the guidelines focus on treatment process, monitoring, and operational requirements for permitting reclaimed water facilities. They outline standards regarding detailed treatment design (biological oxidation, filtration, disinfection, etc.), clean water distribution and plumbing, reclaimed water quality, excess water disposal, and operations and maintenance.[15] For the most part, these regulations are similar to other states' water reclamation and reuse standards. The most significant differences are related to permitting time-frames, effluent standards for water reclamation facilities, and allowable uses of reclaimed water.

[14] Source: Georgia Guidelines for Water Reclamation and Urban Water Reuse. GA Department of Natural Resources, Environmental Protection Division, Watershed Protection Branch, 2002.
[15] ibid

The guidelines released in 2002 are heavily tilted toward irrigation uses of reclaimed water. However, the guidelines do recognize a number of “expanded” allowable uses. Expanded uses of reclaimed water include: “fire protection, aesthetic purposes (landscape impoundments and fountains), industrial uses[16] and some agricultural irrigation.” As of 2002, the use of reclaimed water inside of a dwelling was prohibited, but recent revisions to the plumbing code have approved the use of reclaimed water within dwellings where residents do not have access to the plumbing. This greatly expands the use of reclaimed water in hotels, apartment buildings, and dormitories.

The Georgia EPD, Watershed Protection Branch issues water reclamation permits that allow permittees to provide reclaimed water to approved designated users. Generally, the permit holder must establish reasonable policies, regulations and resolutions, ordinances, or written agreements concerning the use of reclaimed water and compliance with state requirements. The permittee is responsible for ensuring that reclaimed water meets the requirements set forth by state regulations at the point and time of delivery. An industrial pre-treatment permit may also be required based on the return of solids or any discharge to the municipal sewer system. This permit is issued by the local water and sewer authority.

The state’s largest concern is water quality. Georgia’s Guidelines for Water Reclamation and Urban Water Reuse outline strict reclaimed water quality standards to ensure human health and safety. Demonstrating a treatment process’s ability to meet these requirements is a significant portion of the permitting application. Table 11 shows Georgia reclaimed water quality standards in conjunction with typical wastewater influent. In Georgia, there are five parameters by which reclaimed water is judged: biological oxygen demand, turbidity, total suspended solids, fecal coliform, and pH.

Table 11: Georgia Reclaimed Water Quality Standards

Parameter (Analyte)	Typical Influent WW Quality	GA Reuse Effluent Requirements
Biological Oxygen Demand (BOD)	190 mg/L	<5 mg/L
Turbidity	100 NTU	<3 NTU
Total Suspended Solids (TSS)	220 mg/L	<5 mg/L
Fecal Coliform	10^4 - 10^6	<23 per 100 mL monthly geo. mean, 100 per 100 mL maximum daily
pH	-	6-9

Another area of focus for the state is project awareness and overall system reliability, redundancy and safety. Guidelines thus outline requirements for public awareness campaigns and general public support, which usually take place before project approval. Once operating, extensive effluent water quality testing is required. Georgia guidelines also specify special plumbing and water distribution procedures to ensure safety in regard to cross-contamination and backflow prevention. Some of these rules include designating purple colored distribution piping, practicing maximum separation between reclaimed water and potable water lines, coloring reclaimed water, labeling reclaimed water end-uses

[16] Utility process water is commonly referred to as “industrial uses” in most state water reclamation and reuse regulations. According to preliminary meetings held with the EPD, there are a few instances in Georgia of reclaimed water being used for cooling purposes.

with proper signage, and providing education programs for operators and end-users of reclaimed water.

In the spring of 2011, Sustainable Water and McKim & Creed Engineering Consultants held a preliminary meeting with the Georgia EPD, Watershed Protection Branch to confirm the guidelines discussed above. Curtis Boswell, the former contact for the Water Reuse Program, was among those attending on behalf of EPD. This meeting focused on the general application of decentralized water reuse in urban environments and specific aspects of the permitting process. An additional goal of this meeting was to familiarize the state permitting agency with hydroponic treatment technology and its general application as a sewer mining facility. The intent of this meeting was to identify any potential design issues with ecological treatment technology before the permitting process begins.

Regulators found no general problems with the technology or its application within the Institute setting. The general assertion was that as long as state requirements are met, issues with the local water authority may become the largest contingency factor. The overall permitting process is projected to take 2 to 6 months, depending on project specifics. However, expedited permitting is possible for a set fee. Preliminary Design Development Reports (DDR) showcasing specific aspects of ecological treatment technologies were submitted to the EPD. However, no formal comments were received because state protocol reserves specific feedback for full permit applications that have paid all permitting fees. This advanced submittal was meant to help further familiarize the state with the technology.

5.1.3. Local Regulations

Although the treatment permit is officially issued by the state, local municipal governments must approve a reuse system from a zoning and building code perspective. Allowable land uses, fire code, building design, and setback requirements are all part of the local approval process. State universities, however, may be exempt from many of these regulations. In addition, the local water and sewer authority will need to approve the system, as it interacts with public infrastructure or requires billing and/or rate adjustments. In some instances, an industrial pre-treatment permit may be required if the system discharges anything into the municipal sewer system. Additionally, state permit issuers will look for feedback from the local water and sewer authority to ensure that any proposed reuse system will not negatively interfere with county-owned infrastructure or resources.

The City of Atlanta's municipal code was reviewed for any regulatory statutes associated with on-site water treatment, water reuse, sewerage disposal, sewer connections, and permitting requirements. Code requirements exist for private water systems and sewerage disposal; however, the City currently has no regulations specific to blackwater reuse. The municipal code does require plan approval processes by the City, and outlines protocol with regard to easements, municipal infrastructure connections, and the application process for wastewater discharge permits. No local restrictions were uncovered that may prohibit a decentralized water treatment/reuse facility on campus.[17]

[17] Source: City of Atlanta Municipal Code. http://library.municode.com/index.aspx?clientId=10637

Currently, the City of Atlanta does not clearly define a credit program that recognizes the recycling of blackwater. However, the City does recognize wastewater credits in some instances dealing with meter failures, underground leaks, and vandalism that may cause a surge in usage for an account. Georgia Tech and Sustainable Water plan to have meetings with the Department of Watershed Management at the close of this study to discuss the potential for a wastewater credit for recycled water.

5.2. Preliminary Facility Sizing

Wastewater characteristics can play a significant role in the cost, treatment techniques used, and size of a water reclamation facility. High-strength wastewater, depending on its attributes, may cause longer reactor contact-time, or retention, compared to low-strength wastewater. Additionally, the existence of unforeseen contaminants may require added treatment steps. In contrast, low-strength wastewater may require lower hydraulic retention, smaller reactor volumes, and thus lower operational costs.

In lieu of having wastewater sampling results specific to Georgia Tech's wastewater streams, sampling results from a contributing wastewater line to Atlanta's RM Clayton Treatment Facility were used. This wastewater sampling point is actually found in DeKalb County and monitored by the DeKalb Department of Watershed Management. Wastewater quality data and end-use water quality requirements were submitted to Living Machine for testing and modeling in the Tidal-Flow Wetland treatment process. Table 12 outlines the influent characteristics and effluent requirements used when performing preliminary process-sizing for a tidal wetland facility at Georgia Tech. This information allows Living Machine to determine approximate facility sizing, retention time, and disinfection requirements. Effluent requirements were determined based on the end-uses of water.

Table 12: Influent Characteristics and Effluent Requirements

Influent Characteristics	Maximum	Average	SW Specified Effluent Requirements	GA Reuse Limits
COD	716 mg/L	463 mg/L	< 20 mg/L	No limit
BOD	266 mg/L	180 mg/L	< 5 mg/L	< 5 mg/L
Phosphorus	6.2 mg/L	5.2 mg/L	< 1 mg/L	No limit
TKN	65 mg/L	48 mg/L	< 7 mg/L	No limit
TSS	350 mg/L	280 mg/L	< 5 mg/L	< 5 mg/L
Ammonia-Nitrogen (NH_4-N)	30 mg/L	23 mg/L	< 1 mg/L	No limit
pH	No data	6.9	7.0-7.5	6-9
Turbidity	No data	No data	< 3 mg/L	< 3 mg/L
Fecal Coliform	No data	No data	< 23 col/100ml	< 23 col/100ml
E. Coli	No data	No data	< 3 col/100ml	No limit
Coliphage	No data	No data	< 5 col/100ml	No limit
Clostridium Perfringens	No data	No data	< 5 col/100ml	No limit
Temperature	80 F	60 F	n/a	n/a

Overall, reclaimed water modeling results, using the above feedstock characterization, were positive. Influent quality found at the DeKalb County sampling location is considered to be typical domestic-strength wastewater. Assuming a similar wastewater quality at Georgia Tech, standalone Tidal Flow Wetlands should have no problem producing reclaimed water quality that meets standards specified by the State of Georgia. However, trends in historical sampling data suggest an increase in BOD, COD, and TSS concentrations in wastewater over time. A primary cause may be a new focus in water conservation initiatives and green building techniques that render wastewater less diluted compared to a decade ago. If this trend continues, design may need to account for increased wastewater retention time in the future. This would be explored in further detail in Engineering and Design.

Based on process-sizing results, a 100,000 GPD Tidal-Flow Wetland would comprise approximately 7,200 square feet. Table 13 shows the estimated footprint of Tidal Flow Wetland (TFW) systems serving a predetermined capacity and using the above assumptions for influent characteristics. Table 13 also shows the estimated size of a hydroponic, reactor-based system that has a higher overall capacity for treatment. These sizes may be further refined in the Engineering & Design phase of the project. Both hydroponic and tidal wetland systems are extremely scalable – accommodating many different overall capacities. Hydroponic treatment systems allow for a significant reduction in footprint relative to the overall capacity. However, Tidal Flow Wetlands typically require far less energy – minimizing operational costs and associated carbon footprint.

Table 13: Minimum System Footprint Based on Capacity

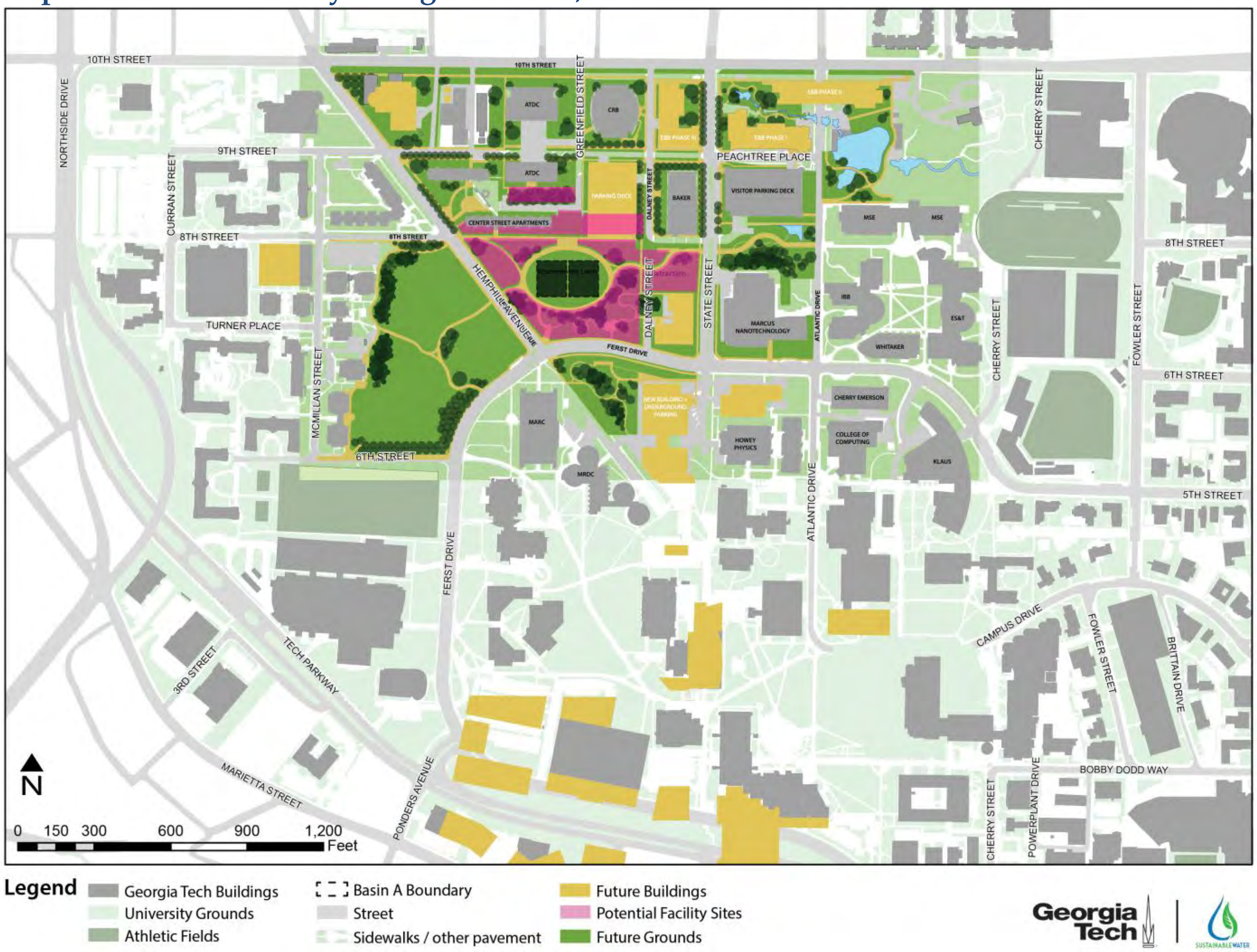
System Type	System Capacity	Estimated Footprint
Living Machine Tidal Flow Wetland	100,000 GPD	7,200 ft^2
Living Machine Tidal Flow Wetland	150,000 GPD	10,800 ft^2
Living Machine Tidal Flow Wetland	200,000 GPD	14,200 ft^2
Hydroponic System (Reactor-Based System utilizing MBBR Clarifiers)	250,000 GPD	2,100 ft^2

5.3. Facility Siting

A number of factors are considered when siting a water reclamation facility. Existing land use, future land use, available feedstock locations, point of use locations for clean water, topography, buried infrastructure, and the level of disruption to the Institute's core mission should all be considered. Operational concerns such as service access and overall energy demands should be balanced against these considerations as well. Sustainable Water worked with Georgia Tech's Capital Planning and Space Management (CPSM) group to narrow down potential siting locations. Siting was explored relative to future campus improvements proposed in conjunction with the EBB Sector Plan and Stormwater Master Plan.

At the start, Georgia Tech considered an ecology-based treatment system a perfect complement to the Eco-Commons concept proposed for Basin A. CPSM proposed siting locations in multiple areas around the future "Eco-Commons lawn" to allow for maximum visibility for the system. In total, the Institute provided nearly 230,000 square feet of available space for potential siting. Map 12 shows these siting areas in conjunction with the future campus build-out under the EBB and Ferst Sector Plan.

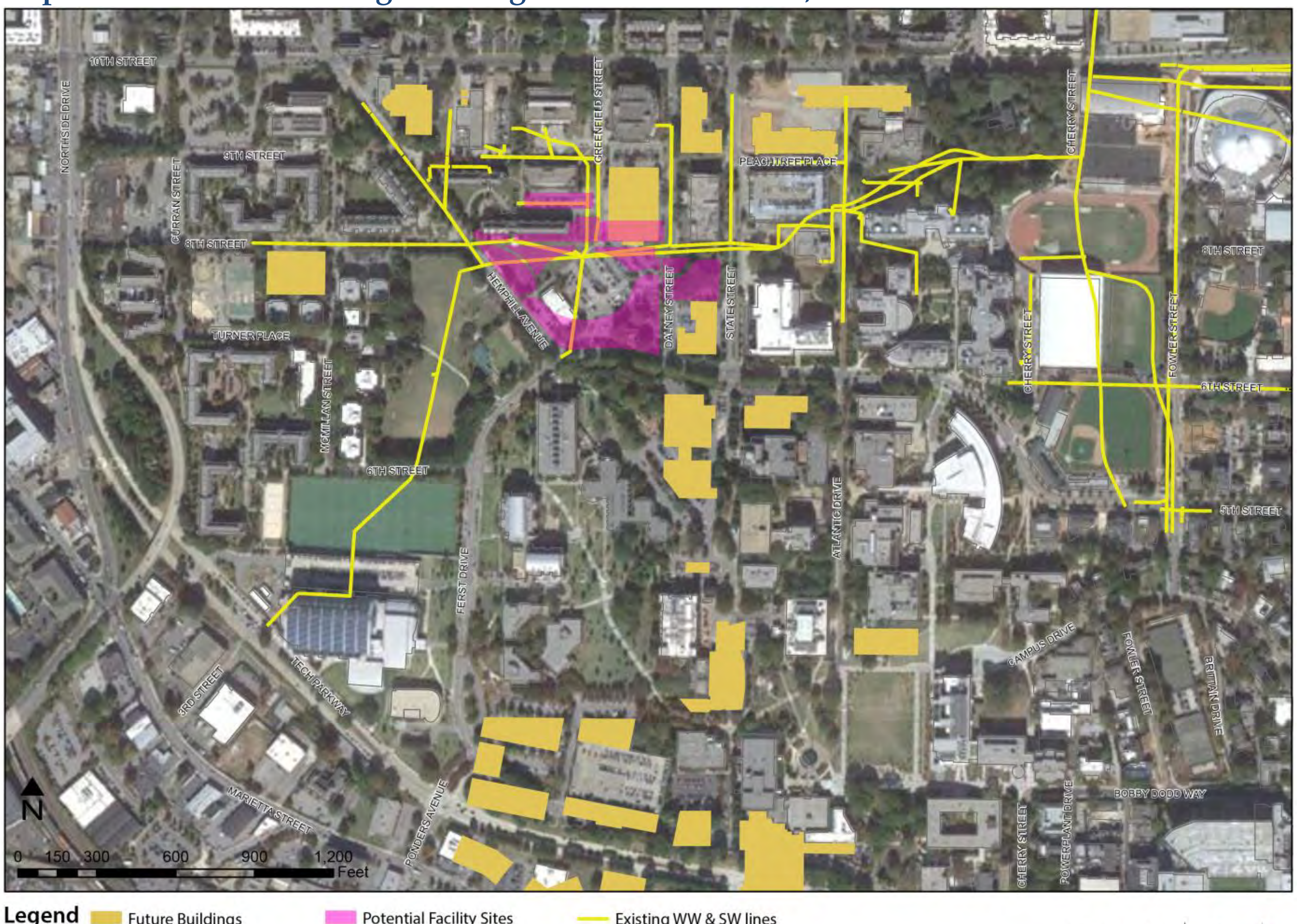
Map 12: Potential Facility Siting Locations, Basin A



During the facility siting process Sustainable Water attempted to rationalize current and future uses in order to streamline the implementation process. Map 13 shows an existing satellite view of campus in relation to the proposed siting areas described above. It also shows the location of future buildings and existing wastewater and stormwater infrastructure in Basin A. As Map 13 demonstrates, much of the proposed Eco-Commons lawn area is currently a parking lot. However, open green space exists in front of the Center Street Apartments, adjacent to the Georgia Tech Police Department, adjacent to the Alpha Phi Omega House, and to the south of the Baker Building. The Police building and the Alpha Phi Omega House will be removed as a part of the Sector Plan.

Careful site selection and overall footprint requirements were of utmost importance. Urban campuses typically have very little free land available for development and highly value that which they do have. One location proposed along 10th Street, adjacent to the chiller plant, was quickly ruled out due to setback requirements associated with the road. Other locations were less attractive because they would require the Institute to give up functional uses – such as existing parking lot space or existing buildings – before development plans have been finalized for the Eco-Commons.

Map 13: Future and Existing Buildings and Infrastructure, Basin A



As Map 13 indicates, a portion of the proposed siting area has underground utilities running through it. Wastewater and stormwater infrastructure run through the northern portion of the site. This provides an opportunity for wastewater feedstock, but may limit development in this section of the siting area. The 18-inch sanitary collector and combined (mostly stormwater) main is buried approximately 11 feet deep in front of Center Street Apartments. Tidal Flow Wetlands would require excavation to approximately 10 foot depth and hydroponic systems typically require excavation to 15 feet below grade, which may require siting in a manner that avoids these utilities. Figure 9 shows the existing site of what is proposed as the Eco-Commons lawn area shown in Map 14.

Figure 9: Existing Area proposed for Eco-Commons Lawn

A) Looking west across Center Street Apartment's lawn; B) looking northwest toward Center Street Apartments; C) looking south toward Alpha Phi Omega House; D) looking east toward the Centennial Research and Baker Buildings.

Wastewater Extraction

A wastewater extraction point located along the 18-inch sanitary collector provides the closest available feedstock location to the proposed Eco-Commons lawn area. An extraction point at State Street (approximately 400 feet west of the Eco-Commons lawn) should provide sufficient feedstock for a 150,000 GPD facility. However, flow rates one block to the west on Atlantic Drive – along the same 18-inch sanitary collector – should have larger flows, with added discharge from the Marcus Nanotechnology Building. Street-scaping improvements along Atlantic Drive are currently underway as a part of the EBB I build-out. However, installing a wastewater extraction point can be minimally invasive to the above street if performed correctly.

Based on the available wastewater feedstock in the 18-inch sanitary line, any facilities above 150,000 GPD in capacity would likely require an additional or more robust wastewater extraction point. Sustainable Water recommends leaving a minimum 33% wastewater flow rate in order to properly convey solids through the municipal system. While flow rates predicted through modeling are believed to be conservative, Sustainable Water recommends validating wastewater flows through subsequent flow measurement studies.

Figure 10: Optional Extraction Location at State Street

The most attractive alternate extraction point is along the Orme Street Relief Sewer, the 11-foot diameter tunnel that conveys a majority of wastewater flow from the southern section of campus. Any location between 6th and 10th Street on Fowler Street would likely provide adequate wastewater feedstock. Extraction in proximity to 10th Street and Fowler Street would provide approximately 260,000 GPD of flow from Institute-owned buildings alone. Additional wastewater flow from South Campus and non-Institute owned buildings, such as Greek housing, make the wastewater flows in this pipe extremely attractive. With a large diameter conveyance tunnel, the depth of these flows would determine overall feasibility of utilizing this tunnel as an extraction location.

End-Use Locations

Figure 11: 10th Street Chiller Plant

In Basin A, the 10th Street Chiller Plant becomes the logical end-use destination for reclaimed water. It currently uses 160,000 GPD on average, with projected demand exceeding 230,000 GPD in the next five years. The 10th Street Chiller Plant is approximately 550 linear feet from the northern section of the proposed siting area.

A significant number of buried utilities are located to the north of the proposed siting area around the 10th Street Chiller Plant. Appendix E provides a drawing, which details the numerous natural gas lines, power lines, communication lines, chilled water pipes, stormwater pipes and sewer pipes buried between Hemphill and Greenfield Streets on 9th Street. This level of underground utility congestion may present challenges with siting reclaimed water distribution lines north of the Eco-Commons lawn. Campus utility drawings indicate that Hemphill Avenue has far less utility congestion, suggesting a slightly more remote, but less complicated route for reclaimed water distribution.

Satellite cooling towers at the Marcus Nanotechnology Building, the Campus Recreational Center and the Institute for Paper Science Technology (IPST) building present supplemental opportunities to displace HVAC/Utility water in Basin A. The IPST cooling tower is located only 650 linear feet from the 10th Street Chiller Plant. Each of these towers consumed approximately 10,000 GPD on average between 2011 and 2012. However, a majority of their water use occurs in the summer months where extensive peak demands already occur at the 10th Street Chiller Plant. Designing reclaimed water facilities to accommodate these high summer peak demands will result in significant facility underutilization rates outside of these brief demand periods.

Large irrigation accounts also present economically attractive end-use locations for reclaimed water. However, like satellite cooling towers, a majority of irrigation use historically occurs concurrent to peak utility demands. This presents design challenges associated with extensive peak capacity requirements. Nevertheless, if Georgia Tech has irrigation demand in winter months that is currently not being performed, larger irrigation systems may be a viable location for reclaimed water. Sustainable Water received no indication that Georgia Tech was under deploying irrigation in winter however.

The Holland Utility Plant – 154,000 GPD on average – is the second largest single consumer of water on campus, and a logical location to use reclaimed water. The Holland Utility Plant is approximately 4,500 linear feet from the proposed Eco-Commons Area. Despite its distance, distribution costs would be far cheaper than installing an additional reclaimed water facility in the south part of campus. Locating a reclaimed water distribution pipe, using directional boring, could be minimally invasive to the Institute's operations.

Figure 12: Holland Utility Plant

5.4. Educational Alignment

Sustainable Water attempted to involve faculty members in meetings and presentations in order to facilitate input with regard to any educational value provided from an ecology-based blackwater treatment facility. A faculty charrette was specifically held to determine this value. The charrette explored curriculum development, community outreach, and research initiatives as it pertained to a potential facility. The suggestions, enthusiasm, and level of interest uncovered in this charrette suggest there is substantial research and educational value to the Institute.

Dr. Steven Van Ginkel, a faculty member in the School of Civil and Environmental Engineering, proposed multiple uses for a blackwater treatment facility as it related to his research. He suggested that nutrients removed in the treatment process could be used to grow fish and produce in an aquaponics facility as part of the ArkFab Green Phoenix Initiative. In his words:

> "The nutrients in the blackwater can go to the algae…we are planning on growing larvae, worms, duckweed, azolla, and algae off of food waste from the dining halls which will feed the fish. I think both aquaponics and algae will make great educational facilities for people to see."

Research by Dr. Van Ginkel is moving forward. Soon he will be in charge of testing algae growth in six mini-ponds located on top of the ES&T building – one of five Department of Energy test centers for biodiesel production.

In addition to ideas proposed by Dr. Van Ginkel, the charrette uncovered an interest in designing a research-related facility that is flexible in accommodating future research topics that are currently not envisioned by the faculty. Some of this future research could be centered on water quality and water chemistry. Dr. Michael Chang, Deputy Director of the Brook Byers Institute, stated:

> "If the project is designed and built in such a way that maximizes accessibility and flexibility, this will preserve future opportunity. For example, we discussed being able to access influent and effluent before and after every stage, and also being able to have access within the stage itself (e.g if someone wanted to study sludge in situ) or to all media above and below the surface. Access, access, access."

Dr. Chang also advocated general meeting space in the facility that can double as an interdisciplinary collaboration and event venue for general education purposes. Other ideas emerged about including "inspirational" space useful for hosting design studios where participants can be challenged to "think more sustainably." Collectively, all of these applications can create a true immersion learning experience on campus. Furthermore, the presence of a blackwater reuse facility may increase grant funding opportunities as the Institute is now able to perform new research in a variety of disciplines.

Figure 13: Students conducting research in a Living Machine Treatment System

6.0 Recommendations

6.1. Reuse Program Recommendations

With immediate cost savings available for reclaiming campus wastewater, Sustainable Water recommends designing a water reclamation facility that serves both current and future needs. An expandable system will allow the Institute to begin reclaiming water today and provide additional capacity at a later date. In Phase I, the Institute can deploy a more passive treatment system that requires no building or structure, and can be flexibly integrated into the existing landscape seen today. As Georgia Tech finalizes development plans for the Eco-Commons Plan and begins implementation, the system can be expanded with a hydroponic system to increase overall capacity.

Sustainable Water modeled various capacities using the monthly make-up demand at the 10th Street Chiller Plant and Holland Utility Plant in order to determine the most appropriate size of a reclaimed water facility. The goal is to determine the optimum level of potable water displacement requiring the lowest water distribution costs, without deploying an underutilized asset in terms of capacity. However, capacity is limited by the extractable level of wastewater from feedstock locations.

Table 14 shows the volume of potable water that can be displaced at the 10th Street Chiller Plant under select capacities. The estimated gallons replaced and the facility utilization rate is a function of the make-up demand curve associated with the Phase I expansion of 10th Street Chiller Plant utilizing a zero blow-down Water Conservation Technology International (WCTI) Treatment Program. As the table demonstrates, the volume of water displaced increases with capacity, while the facility utilization rate decreases. Typically, anything below a 50% utilization rate is considered oversized. In Georgia's climate, make-up water displacement should ideally be above 70% to maximize cost savings.

Table 14: Facility Utilization Using Water Demand Forecasts for 10th Street Chiller Plant

Facility Daily Capacity (GPD)	Facility Annual Capacity (M gallons)	Estimated Annual Gallons Replaced	% of Total HVAC Water Demand Displaced	Facility Utilization based on Demand	Estimated Additional Annual Gallons Replaced w/ Well	% of Total HVAC Water Demand Displaced w/ Well & Rec.Water
50,000	18.25	18,250,000	27%	100%	22,196,306	59%
100,000	36.50	34,595,220	51%	95%	16,395,678	75%
150,000	**54.75**	**46,582,296**	**68%**	**85%**	**11,618,285**	**86%**
200,000	73.00	55,424,535	81%	76%	8,759,176	94%
250,000	91.25	61,644,581	91%	68%	5,808,858	99%

As Table 14 demonstrates, a 250,000 GPD reclaimed water facility displaces 99% of the make-up demand at the 10th Street Chiller Plant. In order to assess a broader impact on campus-wide non-potable water demand, larger facilities were analyzed relative to the make-up demand at the Holland Utility Plant. As a result, facilities capable of displacing demand at both utility plants were analyzed at 300,000– 500,000 GPD. Table 15 shows the capacity modeling results of these larger facilities. The estimated gallons replaced and the facility utilization rate is a function of the combined make-up demand curve of the 10th Street Chiller Plant and the Holland Utility Plant, accounting for the Phase II expansion of 10th Street Chiller Plant, both utilizing a zero blow-down WCTI Treatment Program.

Table 15: Facility Utilization using Water Demand Forecasts for 10th Street Chiller & Holland Plants

Facility Daily Capacity (GPD)	Facility Annual Capacity (M gallons)	Estimated Annual Gallons Replaced	% of Total HVAC Water Demand Displaced	Facility Utilization based on Demand	Estimated Additional Annual Gallons Replaced w/ Well	% of Total HVAC Water Demand Displaced w/ Well & Rec. Water
300,000	109.50	95,422,807	71%	87%	12,659,759	80%
350,000	127.75	104,716,566	78%	82%	10,943,407	86%
400,000	**146.00**	**112,366,566**	**83%**	**77%**	**9,168,588**	**90%**
450,000	164.25	119,103,973	88%	73%	5,825,178	93%
500,000	182.50	123,565,151	92%	68%	4,464,000	95%

Based on available wastewater feedstock and the modeling summaries above, Sustainable Water recommends designing a Phase I facility around the Eco-Commons lawn that processes 150,000 GPD to satisfy demand at the nearby 10th Street Chiller Plant. If larger volumes of feedstock are available after further wastewater flow measurement studies, both the 200,000 and 250,000 GPD facilities would provide larger cost savings for a Phase I facility.

As the EBB II building comes on-line in the next five years, Sustainable Water recommends building a Phase II hydroponic expansion to the system as a lamination to the parking deck proposed for the northeast side of the Eco-Commons lawn. Hydroponic systems require a greenhouse-type structure to house the reactor units. A greenhouse-type lamination may minimize construction costs for both structures, and help mask the parking deck. The hydroponic systems should be sized to a minimum of 250,000 GPD in order to bring overall capacity up to 400,000 GPD. This overall capacity (in conjunction with the 10th Street Well) would satisfy approximately 90% of future demand at both central utility plants.

Overall, the proposed system provides tangible synergies with the Eco-Commons theme in Basin A. Although Sustainable Water recommends a phased implementation of the system in order to capture immediate cost savings, the broader project could be implemented in one initial stage. Details regarding each of the proposed phases are discussed in further detail below.

6.1.1. Phase I

A Tidal Flow Wetland associated with Phase I would require approximately 11,000 square feet and can be integrated into the existing landscape around the proposed Eco-Commons lawn. If implemented, a 150,000 GPD TFW would displace nearly 70% of demand at the 10th Street Chiller Plant after its Phase I expansion. With the addition of the 10th Street Well, providing up to 72,000 GPD, 86% of future demand would be satisfied – equating to over 58 M gallons in reduced potable water use annually.

Chart 18 demonstrates the future make-up water profile at the 10th Street Chiller Plant utilizing back-up well supply and a 150,000 GPD reclaimed water system. Reclaimed water would become the first source of water supply, as it is the most sustainable source of water and provides the most value to the Institute. Only 4 months out of the year (May through August) will require make-up purchased from the City of Atlanta. The 10th Street Well would only require full-time use during these same months, which would minimize groundwater withdrawal under the WCTI Treatment Program by approximately 14.6 M gallons annually.

Map 14 shows the recommended location and footprint of the proposed 150,000 GPD TFW system in conjunction with the EBB and Ferst Sector Plan. The west side of the Eco-Commons lawn became a logical location for three reasons:

- Available open green space currently exists in front of Center Street Apartments, which allows immediate implementation of Phase I. This area is relatively flat and will stay "open" through the EBB build-out.

Chart 18: Proposed Phase I Make-up Water Source Profile at 10th Street Chiller Plant

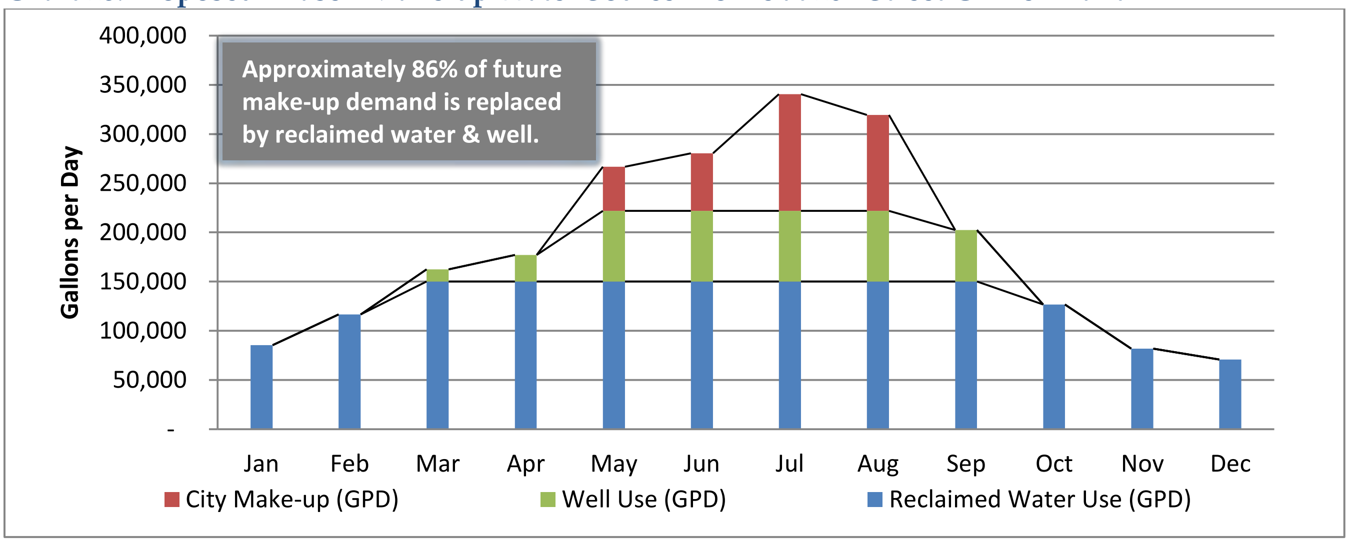


Figure 14: Phase I Facility Adjacent to Eco-Commons Lawn

- Hemphill Avenue provides the easiest route for distributing reclaimed water to the 10th Street Chiller Plant – avoiding the utility congestion to the east of the chiller plant.
- Hemphill Avenue provides a high level of visibility to both pedestrians and commuters – symbolizing the eco-commons goal of sustainable urban design.

Figures 14 and 15 are renderings of the recommended Phase I facility. As demonstrated, the tidal wetland bio-cells can be separated to allow walking paths through the system. Separated bio-cells also allow the system to straddle underground utilities to minimize disruption to existing infrastructure. Retaining walls can be designed higher off the ground to limit access to the system or even flush with grade. Georgia Tech will have input with regard to the overall design, which includes layout, building material, signage, and even plant selection.

Tidal Flow Wetland facilities can be flexibly integrated into the existing landscape. Alternative siting locations are shown in Map 15, but multiple other siting locations are feasible for this area. More desirable or cost effective locations may be identified in a detailed design phase.

Map 14: Proposed Siting of Phase I Tidal Wetland

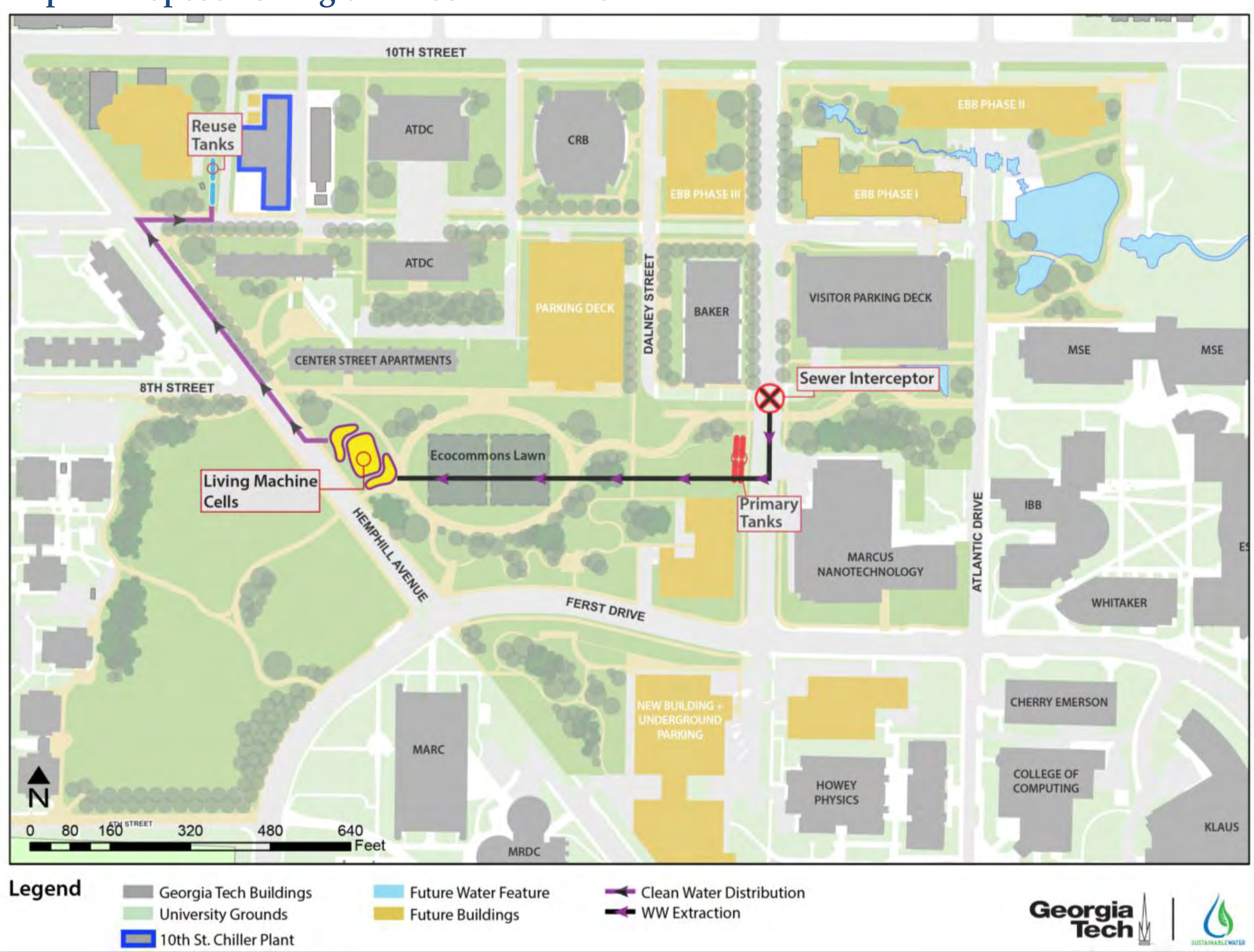
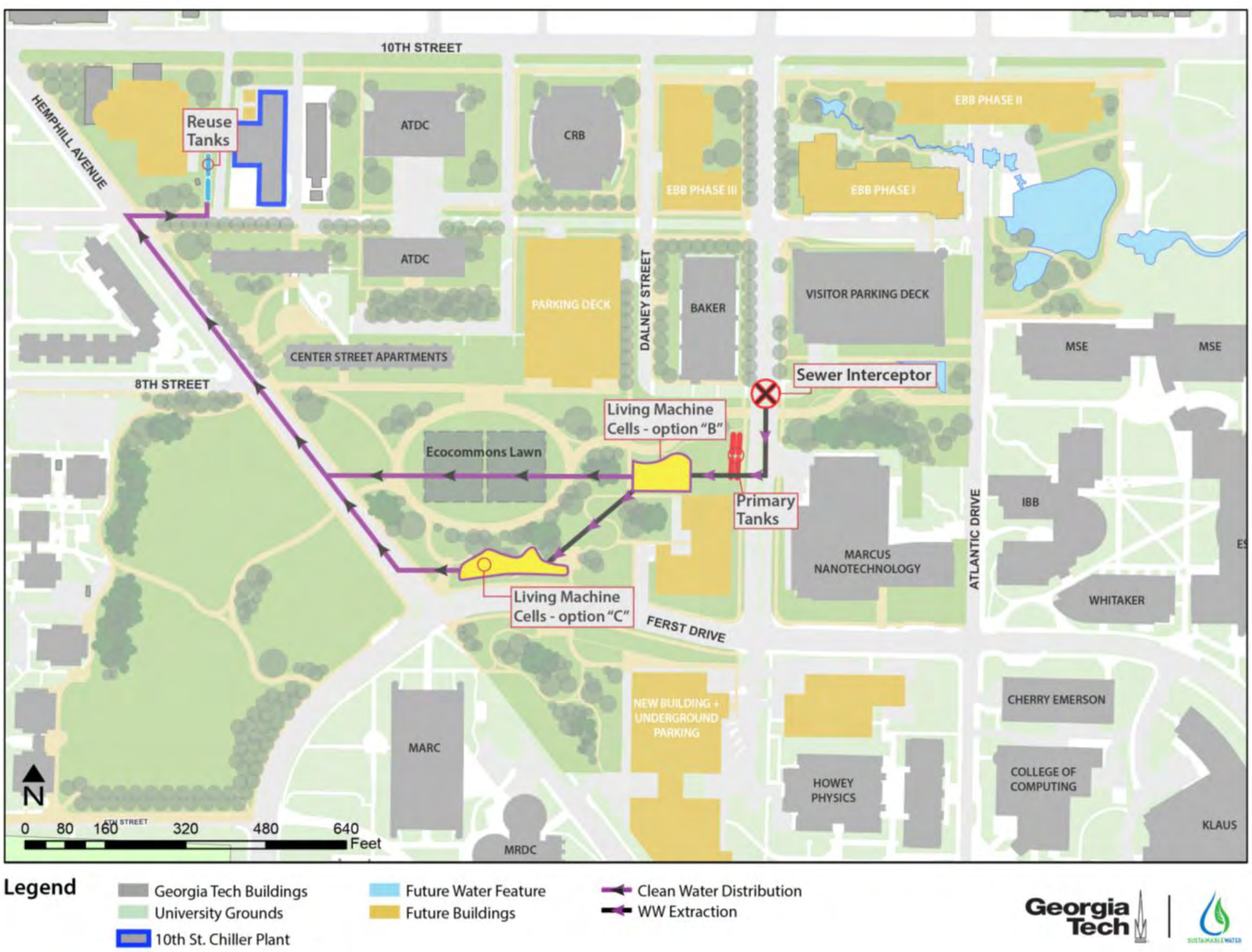


Figure 15: Conceptual Rendering of Phase I Tidal Flow Wetland System

Map 15: Alternative Siting Areas for Phase I Tidal Wetland



6.1.2. Phase II

Figure 16: Conceptual Rendering of Greenhouse Lamination for Phase II

A proposed Phase II facility should be designed to accommodate an additional 250,000 GPD of capacity, at only 2,100 additional square feet. The proposed facility would utilize hydroponic reactors housed in a greenhouse-type structure in order to minimize the total footprint of the system. The structure can also house mechanical elements, and provide additional research or academic space at the request of the Institute. The location of the Phase II facility is recommended as a lamination to the parking deck – proposed as a part of the EBB Sector Plan. Figure 16 shows a concept drawing of the phase II lamination to the proposed parking deck. The timing of the second phase build-out can coincide with the build-out of EBB II, which is thought to occur within the next five years.

With 250,000 GPD of additional capacity, the Phase II facility can replace non-potable demand at the Holland Utility Plant. A 400,000 GPD facility, used in conjunction with the 10th Street Well, would displace 90% of demand at both the 10th Street Chiller Plant (after its Phase II expansion) as well as the Holland Utility Plant. The expanded system would reclaim approximately 112 M gallons annually based on the combined water demand curve of the central utility plants.

Chart 19 demonstrates the future make-up water profile for both utility plants utilizing back-up well supply and a 400,000 GPD reclaimed water system. Again, as the most sustainable and valuable source of water, reclaimed water would become the first source of water supply for both plants. Only about two months out of the year (July and August) will require make-up purchased from the City of Atlanta. The 10th Street Well would only be required for approximately 4.5 months – which minimizes groundwater withdrawal from the 10th Street Well by approximately 17.1 M gallons annually.

Chart 20 demonstrates the distribution of reclaimed water between the two utility plants and the respective end uses of reclaimed water. During the winter months, reclaimed water can be provided as make-up for the cooling towers at each utility plant as well as the boilers at Holland. As demand grows during the spring and summer, the Holland Plant would default back to City make-up as the reclamation system reaches capacity. This reclaimed water distribution profile will help reduce energy use by the system by eliminating water distribution to the most distant user first.

The additional 250,000 GPD of capacity will require an alternate extraction point to supply adequate feedstock to the facility. The recommended extraction point is along the Orme Street Relief Sewer in proximity to 10th Street. A second extraction location will not only provide adequate feedstock for the facility to run at capacity, but provide a redundant source of wastewater feedstock in case one is compromised. Although one extraction location will require the lowest project cost, it is unclear at this point whether or not the Orme Street Relief Sewer provides adequate flow level to accommodate a 400,000 GPD reclamation facility. Whether a single or dual extraction point is required or recommended would be determined after exact flow measurements are determined.

Chart 19: Phase II Make-up Water Source Profile, 10th Street Chiller and Holland Plants

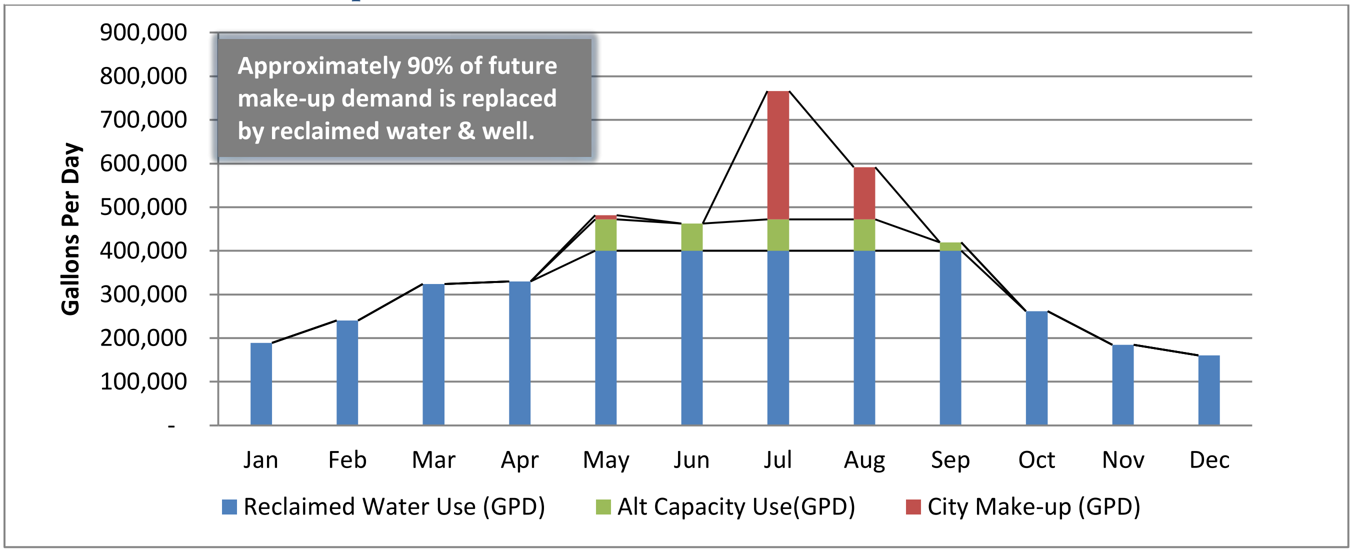
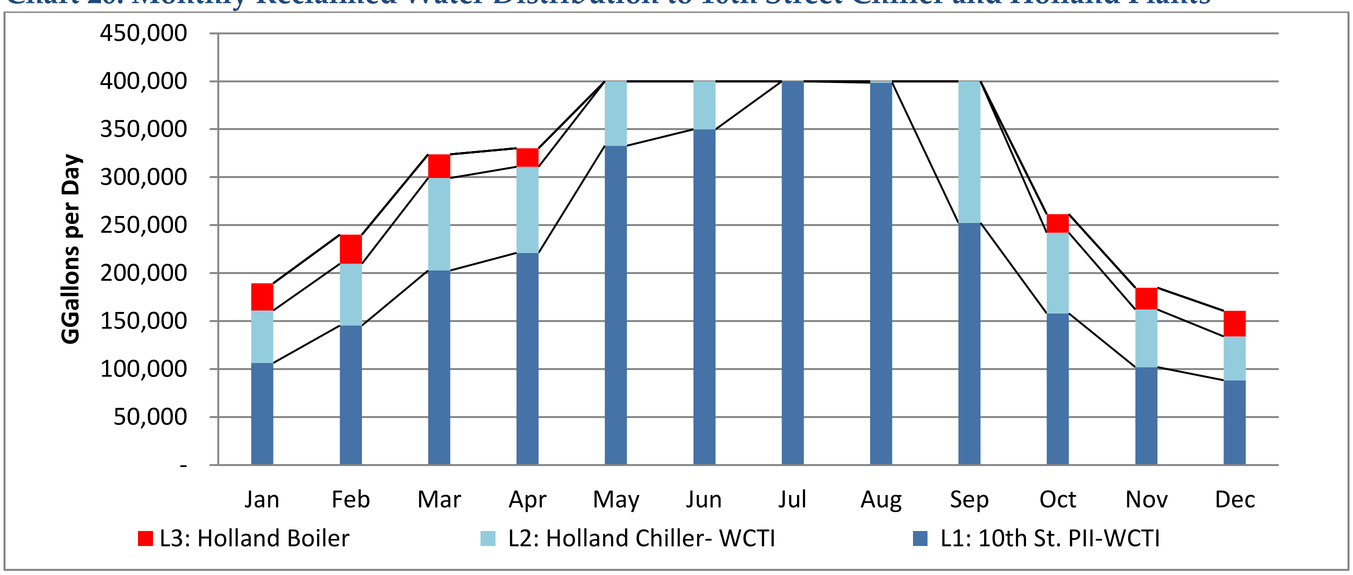


Chart 20: Monthly Reclaimed Water Distribution to 10th Street Chiller and Holland Plants



Map 16 shows the site plan associated with Phase II, which includes the proposed extraction route for wastewater feedstock and clean water distribution. The proposed piping route for wastewater feedstock is along 10th Street, which is scheduled for street-scaping improvements in the near future. Laying pipe during these improvements would likely offer cost savings for trenching or boring pipe. The proposed route for clean water distribution was provided by CPSM.

The hydroponic system itself only requires approximately 2,100 ft^2 of building space. However, doubling this square-footage is recommended to allow for classroom and research space. Figures 17-20 show various conceptual views of the proposed two-phase build-out. These renderings depict a 5,000 square feet lamination, as it is believed this is more in line with the mission of the Institute. This facility maximizes space by incorporating a second level above a machine/equipment room, which allows for additional classroom or research space. The general floor plan is much more open as well, accommodating a higher level of student/faculty access. Appendix F provides a proposed floor plan for the hydroponic system at Georgia Tech.

Figure 17: Conceptual Rendering inside Hydroponic Facility

Figure 18: Conceptual Rendering of Complete Phase II Build-out along Hemphill Avenue

Map 16: Proposed Siting for Phase II Hydroponic System

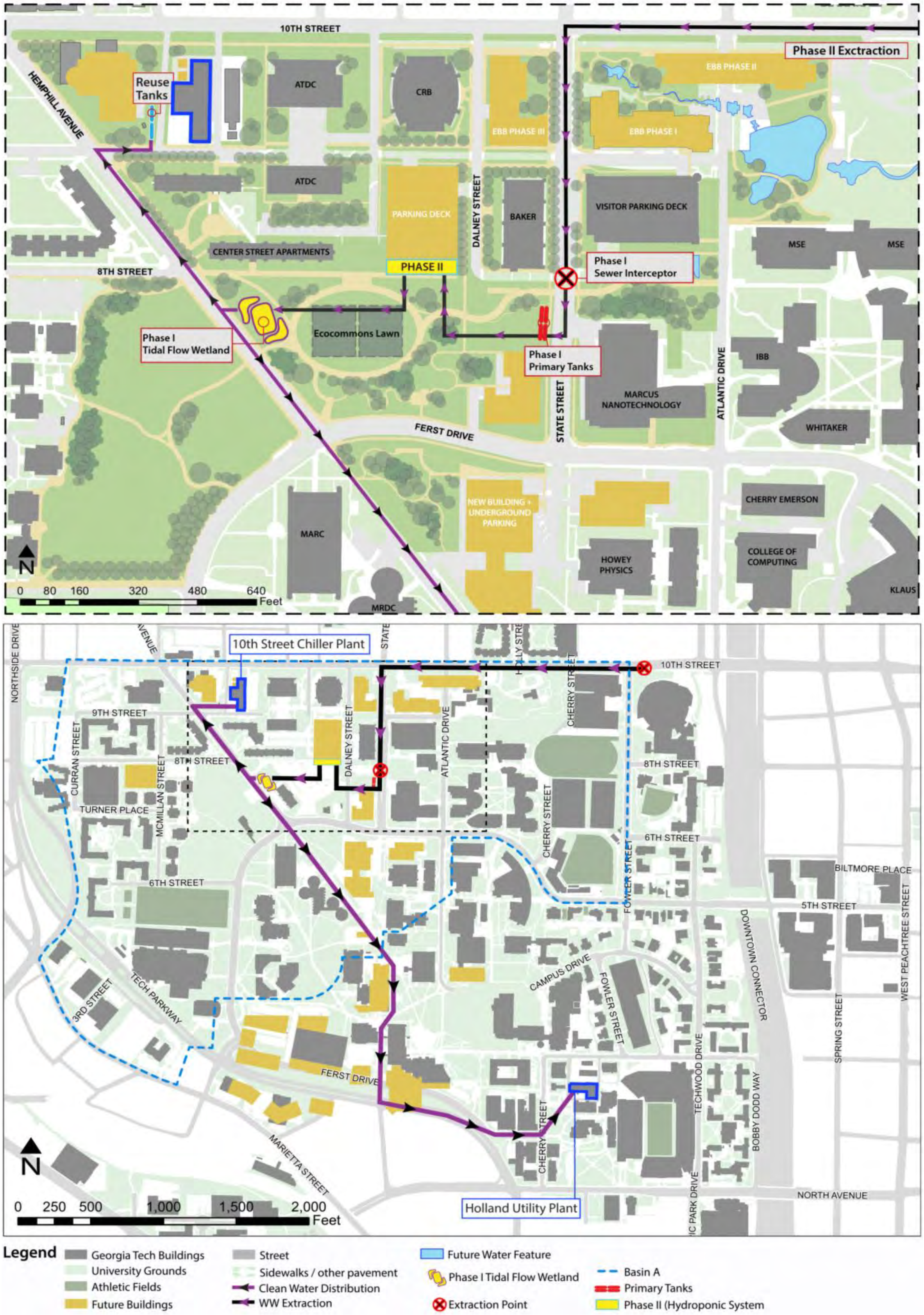


Figure 20: Conceptual Rendering of Inside Hydroponic Treatment System

Figure 19: Conceptual Rendering Looking Toward Eco-Commons from Hydroponic System

6.2. Economics & Cost Savings

With one of the highest unit costs for water and sewer in the country, the City of Atlanta produces an ideal economic environment to recycle wastewater. In 2012, nearly 45% (approximately 177 M gallons) of all water use at Georgia Tech can be classified as non-potable demand (NPD). The cost of this water alone is approximately $1.5 M annually at the City's highest tiered water rate. The equivalent volume of wastewater production costs the Institute approximately $5.1 M at the City's highest sewer rate. As water rates continually rise, water conservation initiatives will become an increasingly important aspect of the Institute's environmental and economic sustainability platform.

This section of the report provides detailed economic and lifecycle saving analysis for the facility recommendations produced in this report. Section 6.2.1 outlines the Water Purchase Agreement offered by Sustainable Water. Sections 6.2.2 and 6.2.3 provide detailed costs and forecasted savings for the Phase I and II water reclamation systems proposed for Georgia Tech.

6.2.1. Water Purchase Agreement

Sustainable Water offers to build a turn-key water reclamation system at Georgia Tech through a Water Purchase Agreement (WPA). A WPA is a financial arrangement in which Sustainable Water constructs, owns, operates, and maintains the water reclamation and reuse system, and the host (Georgia Tech) agrees to site the system on its property and purchase reclaimed water from the provider for a predetermined period. This financial arrangement allows Georgia Tech to receive stable, lower cost water, while Sustainable Water operates the system on behalf of the host/customer. Under this financial arrangement, Georgia Tech buys the services and benefits produced by the reclamation system rather than the system itself. Sustainable Water is responsible for all operations and maintenance, which eliminates performance and operating risk.

A WPA requires no upfront capital from the Institute and offers immediate and long-term cost savings over current municipal water and sewer rates. WPA contracts can be highly flexible depending on the financial, operational, or ownership structure preferred by the Institute. The goal of the WPA is to accommodate clients based on their financial preferences, accelerate and simplify project implementation, and minimize risk for the client. Typically, a WPA is accomplished through a Design-Build-Own-Operate (DBOO) contract or Design-Build-Own-Operate-Transfer (DBOOT) contract.

The DBOO is a contract to provide a turn-key water reclamation system from design through commissioning, as well as the operational services for the system itself. Complete project financing is provided by Sustainable Water or a third-party, and the host typically pays a monthly water service fee. This fee is paid for a fixed period of time, such as 20 years. At the completion of this time period, the facility can be purchased or transferred to the host customer. A buyout arrangement can be made for the facility at certain points in the contract as well. Based on the economic conditions at Georgia Tech, Sustainable Water recommends waiving the reclaimed water fee and re-capturing operational expenses through a sewer rebate obtained from the City of Atlanta.

6.2.2. Water Costs and Savings under a Water Purchase Agreement

Sustainable Water analyzes lifecycle costs and potential savings through detailed economic modeling of the recommendations produced in this report. This modeling looks at displacing bulk volumes of non-potable water demand with reclaimed water. A number of assumptions are made to determine immediate and long-term savings. Universally, the following assumptions are made:

- Current municipal water rate: $8.24 per 1,000 gallons;
- Current municipal sewer rate: $20.98 per 1,000 gallons;
- Zero annual growth rate of municipal water and sewer rates between 2012 and 2015;
- Municipal water & sewer rates grow conservatively at 3% annually after 2015; and
- A water purchase agreement term of 20 Years.

Phase I Savings

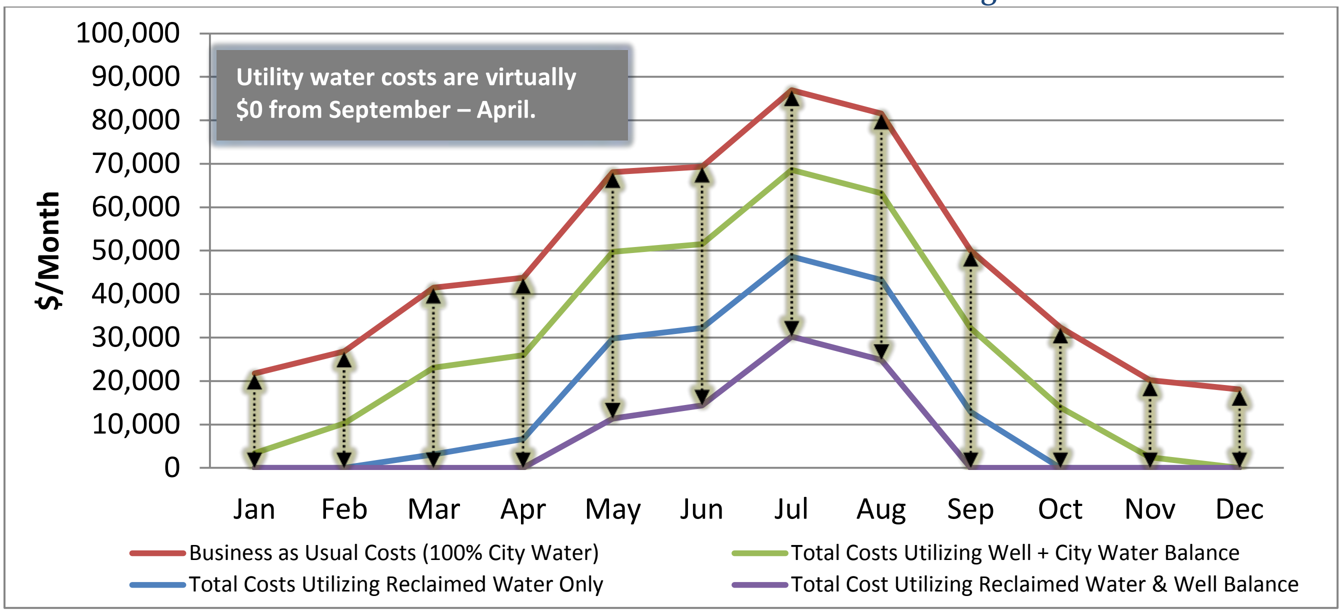
As stated in Section 6.1, Sustainable Water recommends an initial installation of a Tidal Wetland Flow (TFW) facility that reclaims 150,000 gallons of water per day. This passive treatment system allows the Institute to begin reclaiming water in the near-term, utilizing existing green space and developable land without interfering with future campus build-out plans. Near-term implementation of a reclaimed water system enables the Institute to secure extensive cost savings available today.

When analyzing available savings for the Phase I facility, Sustainable Water assumed a WPA financial arrangement because this provides the lowest overall risk to the Institute. In addition to the universal assumptions presented above, the following assumptions are made for Phase I:

- The TFW facility has an overall daily capacity of 150,000 GPD. The factility will only displace make-up water demand at the 10th Street Chiller Plant. Revised make-up water projections for the Phase I expansion to the 10th Street Chiller Plant were used to accommodate future water demands. These make-up volume projections were adjusted (decreased by 12%) to accommodate the transition to a WCTI treatment program that will eliminate blow down from the cooling towers, and thus reduce make-up.
- An existing well, the 10th Street Well, will be used in conjunction with the WCTI treatment program to help displace city potable water use at the 10th Street Chiller Plant. The well is assumed to yield 50 gallons per minute (72,000 GPD). Despite having some tangible costs, the unit cost of well water is considered $0 in the modeling platform.
- The highest tiered water and sewer rate ($8.24/1,000 gallons for water and $20.98/1,000 gallons for sewer) is used to determine business-as-usual costs and potential savings since a large majority of water and sewer costs are billed at this rate.
- A sewer rebate will be obtained for eliminating wastewater flows to the City of Atlanta. As mentioned, the extent of this rebate will require discussion with the City. Reclaimed water will be provided at a unit cost of $0.00 per 1,000 gallons. All operational expenses will be recovered through a sewer rebate.

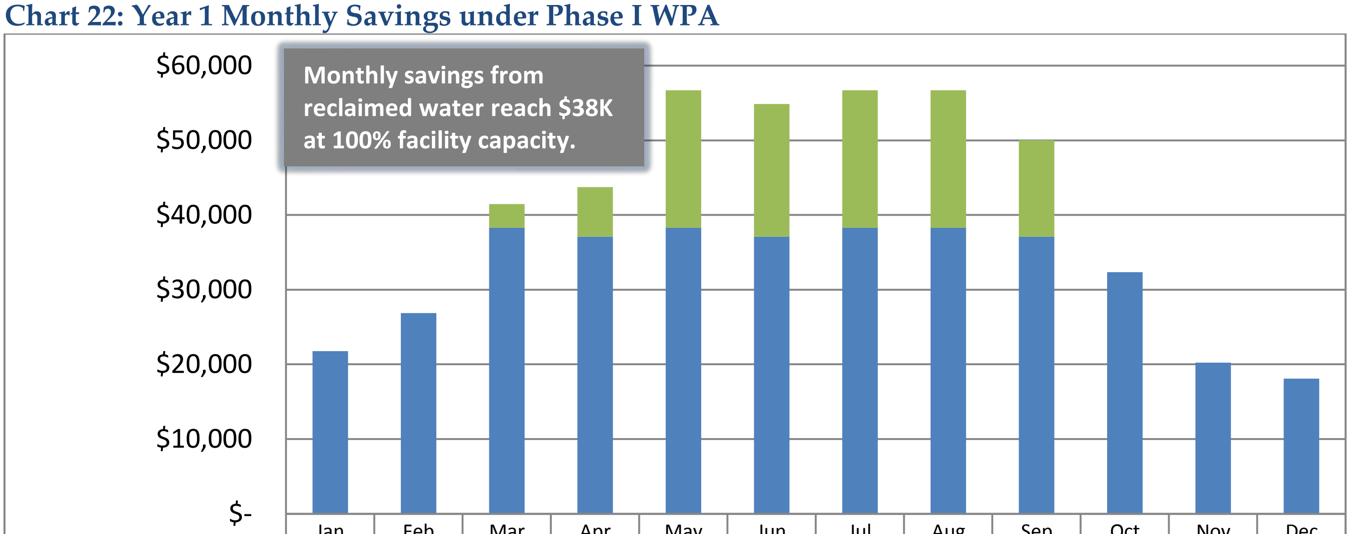
Utilizing the above assumptions, Chart 21 shows total projected water costs by month for the 10th Street Chiller Plant under business-as-usual conditions compared to costs with the proposed reclaimed water system. The delta (yellow line) between the cost curves indicates available savings. Chart 22 breaks downs the immediate projected savings by month. As this graph demonstrates, monthly cost savings increase dramatically as the facility approaches 100% capacity in the summer months.

Chart 21: Business-as-Usual Water Costs vs. Phase I Reclaimed Water Program Costs



Charts 23 and 24 show total annual and cumulative savings from the well and reclaimed water system. Since Sustainable Water reclaims revenue through a sewer rebate, the sewer credit does not directly affect Institute water savings. However, the extent of the sewer credit provided by the City of Atlanta may determine the overall economic feasibility of the project. Sustainable Water anticipates obtaining a near 100% credit. As demonstrated in these charts, reclaimed water savings exceed $380,000 year one and produce nearly $9.75 M in cumulative (20-year) savings.

Chart 22: Year 1 Monthly Savings under Phase I WPA



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Well Savings	$-	$-	$3,153	$6,671	$18,392	$17,798	$18,392	$18,392	$12,937	$-	$-	$-
Reclaimed Water Savings	$21,776	$26,871	$38,316	$37,080	$38,316	$37,080	$38,316	$38,316	$37,080	$32,350	$20,229	$18,107

Chart 23: Annual Savings over 20 Years under Phase I WPA

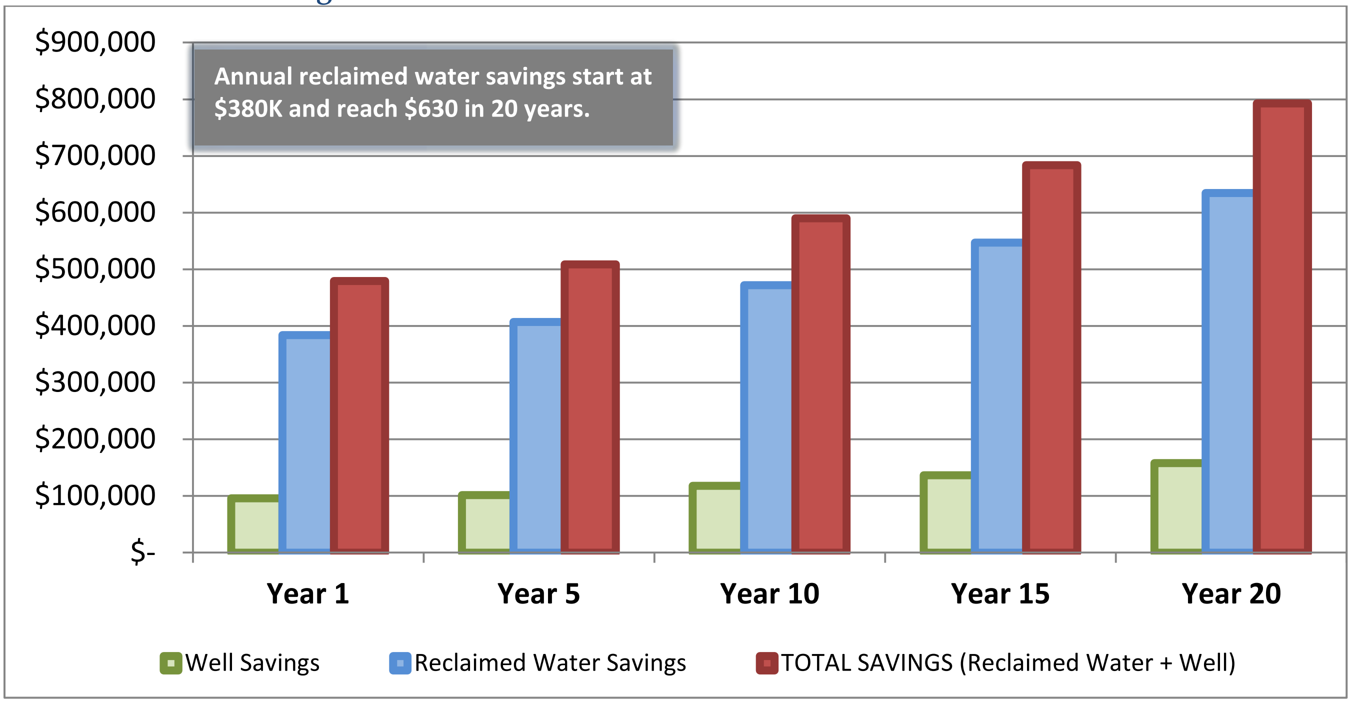
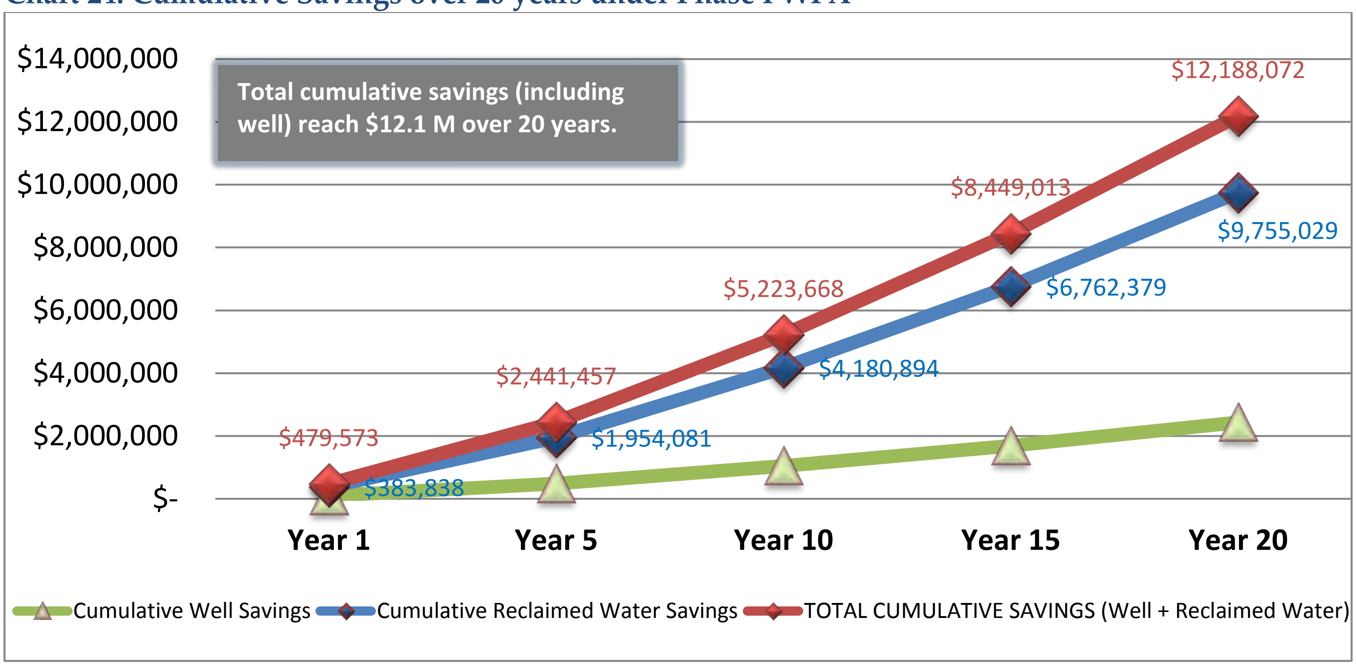


Chart 24: Cumulative Savings over 20 years under Phase I WPA



Phase II Savings

Sustainable Water recommends a 250,000 GPD capacity hydroponic system for Phase II. Using a basic design, this will add approximately 165% throughput capacity to the system with only a 20% increase in physical footprint. When analyzing available savings for the Phase II facility, Sustainable Water used the following assumptions in addition to universal assumptions presented above:

- The facility has an overall daily capacity of 400,000 GPD. The facility will displace make-up water demand at the Holland Utility Plant in addition to the 10th Street Chiller Plant. Revised make-up water projections for the Phase II expansion to the 10th Street Chiller Plant were used to accommodate future water demands in line with the construction of this Phase II facility. Make-up volumes for 10th Street Phase II and Holland were adjusted (decreased by 12%) to accommodate the transition to a WCTI treatment program that will eliminate blow down from the cooling towers, and thus reduce make-up.
- The well utilized in Phase I will continue offsetting potable water demand at the 10th Street Chiller Plant. As stated previously, the well is assumed to yield 50 gallons per minute (72,000 GPD). Despite having some tangible costs, the unit cost of well water is considered $0 in the modeling platform.
- The highest tiered water and sewer rate ($8.24/1,000 gallons for water and $20.98/1,000 gallons for sewer) is used to determine business-as-usual costs and savings since a large majority of water and sewer costs are billed at this rate.
- A sewer rebate will be obtained for eliminating wastewater flows to the City of Atlanta. The extent of this rebate will require discussion with the City. Reclaimed water will be provided at a unit cost of $0.00 per 1,000 gallons. All operational expenses are recovered through a sewer rebate.

Chart 25 shows total projected water costs by month for the 10th Street Chiller Plant and Holland Utility Plant under business-as-usual conditions compared to costs associated with the proposed reclaimed water system. The delta (yellow line) between the cost curves indicates savings. Chart 26 breaks down the immediate projected savings by month. As this graph demonstrates, monthly cost savings increase dramatically as the facility approaches to 100% capacity in the summer months.

Charts 27 and 28 show total annual and cumulative savings between the 10th Street Well and reclaimed water system. Since Sustainable Water reclaims revenue through the sewer rebate, the sewer credit does not affect the Institute’s water savings. However, the extent of the sewer credit provided by the City of Atlanta may determine the overall economic feasibility of the project. As demonstrated in these charts, reclaimed water savings in Phase II exceed $920,000 in year one and produce nearly $23.4 M in cumulative (20-year) savings.

Chart 25: Business-as-Usual Water Costs vs. Phase II Reclaimed Water Costs

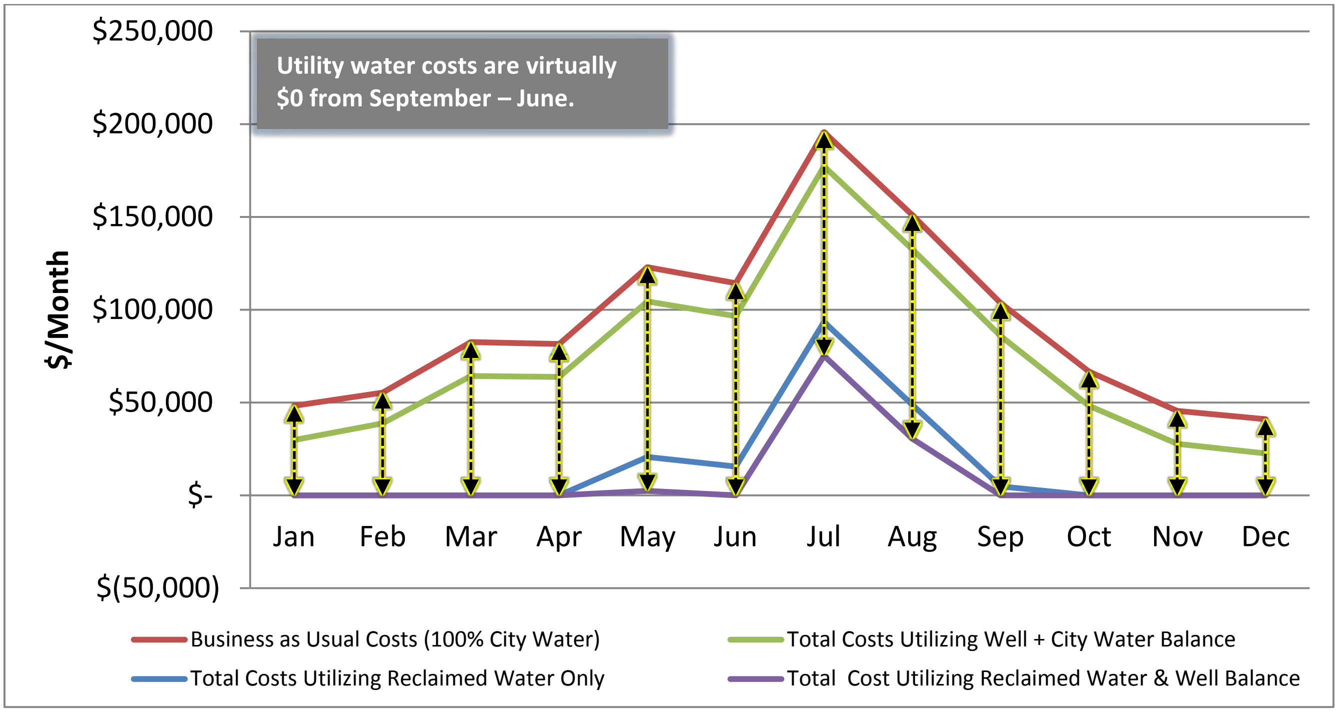


Chart 26: Year 1 Monthly Savings after Phase II Installation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Well Savings	$-	$-	$-	$-	$18,392	$15,534	$18,392	$18,392	$4,840	$-	$-	$-
Reclaimed Water Savings	$48,346	$55,423	$82,719	$81,617	$102,176	$98,880	$102,176	$102,176	$98,880	$66,770	$45,665	$41,073

Chart 27: Annual Savings over 20 Years after Phase II Installation

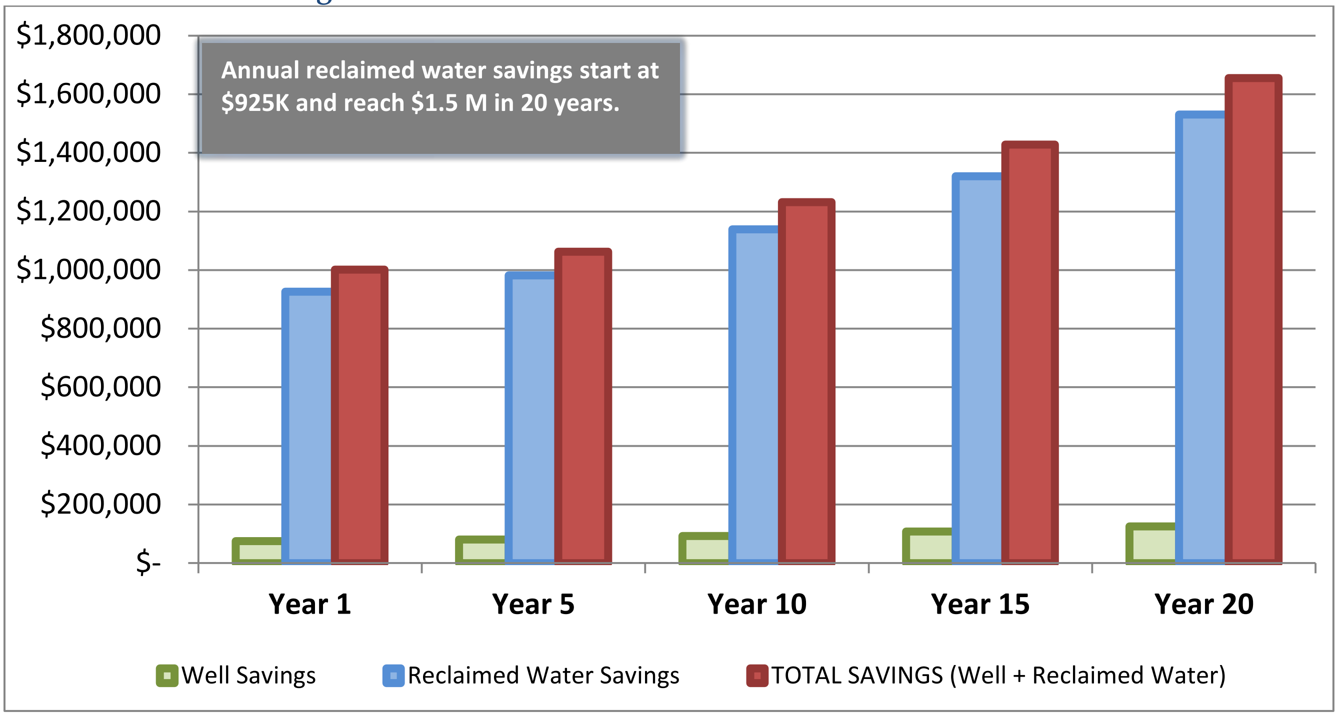
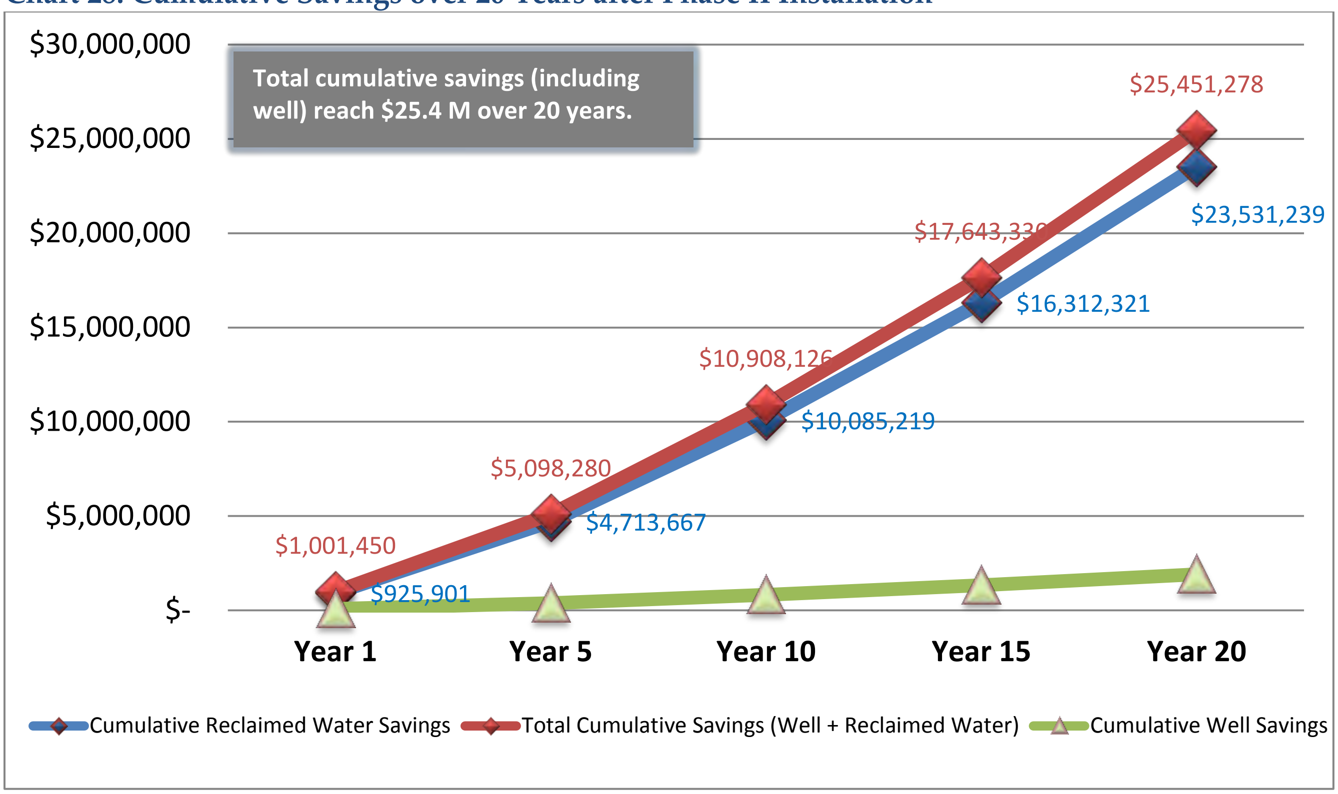


Chart 28: Cumulative Savings over 20 Years after Phase II Installation



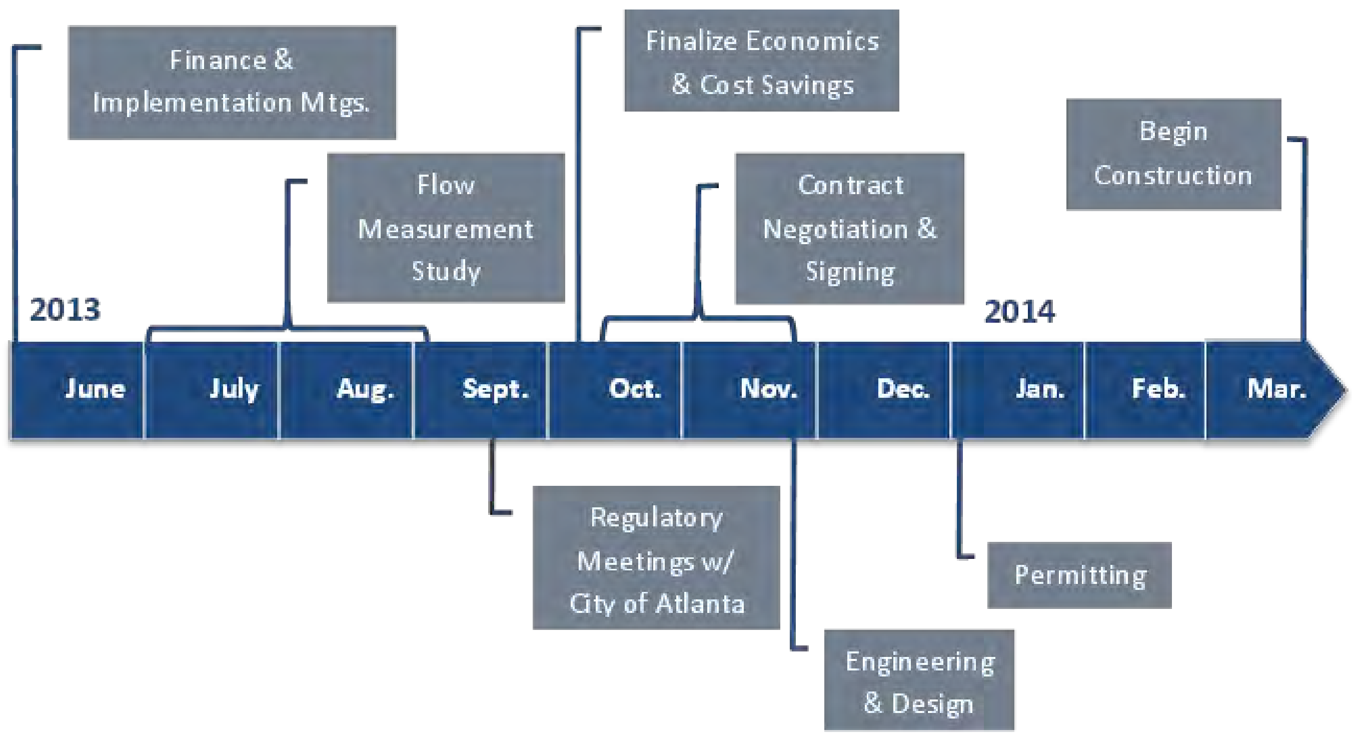
6.3. Project Timeline

Based on the level of cost savings available at Georgia Tech, Sustainable Water recommends moving toward a design and engineering phase to begin project implementation. Before beginning detailed design, Sustainable Water recommends moving forward with a number of tasks:

1. Perform a detailed flow-measurement study to validate available feedstock for a reclaimed water facility;
2. Evaluate and validate economic models for various financing scenarios; and
3. Present this project to the City of Atlanta Department of Watershed Management to gain project approval and confirm economic payback.

Figure 20 provides a proposed timeline outlining milestones for project implementation. If expedited, the project could begin construction as early as April, 2014.

Figure 21: Proposed Project Timeline



7.0 Appendix Documents (Provided in Digital Format)

Appendix A

1. Feasibility Scope of Work
2. Map – Georgia Tech Campus Map & Focus Area

Appendix B

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4. Campus Topography and Wastewater Infrastructure, GT Main Campus
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6. 2010 Georgia Water Conservation Implementation Plan
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9. Undergraduate Living Center Water Bill
10. Baker Building Water Bill
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12. Detailed Cistern Summary, GT Main Campus

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2. Water Usage by Category & Potable vs Non-Potable Demand, GT Main Campus and Basin A
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8. Map – HVAC Usage by Location, GT Main Campus
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10. Gas Consuming Boilers Campus Inventory, GT Main Campus
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15. Non-potable Demand by Season, GT Main Campus and Basin A
16. Future Water Demand, Wastewater, and WCTI Make-up Projections, Basin A
17. Map – Future Demand by Location, Basin A
18. Map - Wastewater Flow by Location, GT Main Campus
19. Extraction Points Summary (Wastewater Flow Modeling), GT Main Campus
20. Map – Extraction Points and Wastewater Flow Model, GT Main Campus

Appendix D

1. Garratt Callahan 10^{th} Street Water Laboratory Report
2. 10^{th} Street Well Water Analysis
3. Garratt Callahan Field Service Reports
4. Central Chiller Plant Specifications
5. RMF 10^{th} Street Chiller Plant Expansion Plan
6. SW Utility Water Audit Form – 10^{th} Street Chiller Plant

Appendix E

1. 2012 EPA Guidelines for Water Reuse
2. 2002 Georgia Guidelines for Water Reclamation and Urban Water Reuse
3. Georgia Guidelines for Reclaimed Water Systems for Buildings
4. Map – Potential Facility Siting Locations, Basin A
5. Map – Future and Existing Conditions, Basin A
6. Map – Buried Utilities and Proposed Siting, Basin A
7. Campus Umap & Survey Drawings

Appendix F

1. Phase I Site Plan Layout (Living Machine)
2. Phase I Facility Adjacent to Eco-Commons Lawn
3. Map – Proposed Siting of Phase I Tidal Flow Wetlands
4. Conceptual Rendering of Phase I Tidal Flow Wetlands System
5. Map – Alternative Siting Areas for Phase I tidal Flow Wetlands
6. Hydroponic Floor Plan (1st Story)
7. Hydroponic Floor Plan (2nd Story)
8. Conceptual Rendering of Greenhouse Lamination for Phase II
9. Conceptual Rendering of Complete Phase II Build-out along Hemphill Avenue
11. Map – Proposed Siting for Phase II Hydroponic System
12. Conceptual Rendering looking toward Eco-Commons from Hydroponic System