Yale University
Water Management Plan

Update 2017

Office of Facilities

July 2017

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Table 1: Water Meter and Building Account Priorities

Acknowledgments

Introduction

In 2013, the Yale Water Management Plan 2013–2016 was released, detailing the importance of water management on campus; various approaches taken to date with campus metering, building, irrigation, and process systems; and methodology for analyzing water data and metrics. The plan also presented a suite of strategies identified toward a university-wide 5% water-use reduction goal.

In 2016, the Office of Sustainability released the Yale Sustainability Plan 2025, which presents a comprehensive approach to connect scholarship and operations at Yale under one sustainability vision. The plan sets a specific goal "to update the campus water management plan in alignment with local priorities."

This document provides an update to the Water Management Plan 2013–2016 and initial fulfillment of the Yale Sustainability Plan 2025. Moving forward, the University intends to incorporate water management progress and planning into the Campus Resilience Plan, High Performance Design Standards, Sustainability Progress Reports, and supporting documents. Collectively, these plans invite generative work and collaboration between the academic and operational sides of the University. The significance of operational commitments is expanded beyond Yale's campus with related applied research, teaching, and service.

Vision for Water Management

Yale University envisions a campus where water is actively and adaptively managed as a highly valuable resource.

Water is a critical utility for Yale, accounting for 6–8% of its annual utility budget. In addition to serving the daily domestic needs of more than 28,000 people, water is used for energy production, laboratory and critical research processes, dining services, and ground maintenance for a campus consisting of more than 19 million square feet and 1,000 acres.

Water also connects to the nine ambitions of the Yale Sustainability Plan 2025, particularly Health & Well-Being, Climate Action, Stewardship, and Built Environment.

Future efforts in water management planning shall be guided by a set of shared principles. Like the Sustainability Planning Principles, these principles capture the strength of near-term activities, provide direction for future development, and should be taken collectively to motivate and focus work:

Recognize water as a critical resource. Water is essential to Yale's daily operations. In addition to providing for domestic needs, water supports laboratory and critical research, and energy production on campus. Yale shall recognize the value of water beyond its utility costs to position the campus well for long-term resiliency.

Promote water metering, conservation technologies, and conservation research. Collecting water-use data and related activities offer and necessitate robust research and educational opportunities for students and faculty at and beyond Yale. Yale shall encourage university-wide participation and stewardship of water management strategies on campus, as well as applied research that informs regional and global efforts.

Prioritize adaptive management strategies. Strategies to inform and improve water management decisions and activities enable the most positive outcomes at Yale and across the region. Yale shall commit to collecting water-use data, sharing data broadly, and using an iterative decision-making process for ongoing water management on our campus and beyond.

Progress to Date

The following section describes the most current system and performance metrics on campus, reflecting changes since the Water Management Plan was initially released in 2013.

Metering

The campus metering system includes 269 revenue meters installed and maintained by the South Central Connecticut Regional Water Authority (RWA).

Included in this analysis are 219 meters tied to 144 electronically billed accounts, and 50 meters tied to 32 paper-billed accounts. The meters are read on a monthly or quarterly basis either automatically or manually. Yale receives water-use data as part of the billing statement from RWA. In addition to the 269 RWA meters, one meter is installed at the Central Campus chiller plant as a submeter of a revenue meter owned by others. Because the water use measured by this meter is substantial, it is recorded by Facilities on a regular basis.

For a more accurate and detailed analysis, we looked at meters on the building account level. Under the current billing system, meters are linked to building accounts rather than strictly to individual buildings. There are 197 building accounts included in this analysis.

Our evaluation of the current metering and billing system demonstrates that:

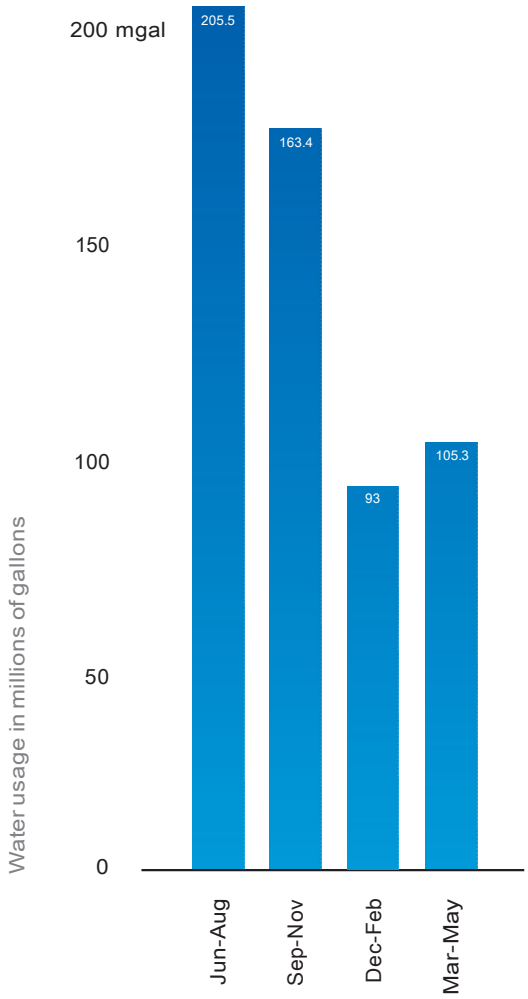
- Approximately 90% of meters are read and billed quarterly. Therefore, approximately 10% of meters are read and billed either monthly or quarterly depending on capacity.
- Approximately 7% of water use by volume is estimated on an annual basis rather than determined by actual meter readings. The percentage includes internal estimations of the Central Campus chiller plant as well as estimations based on billing data provided by RWA.
- There is a high number of meters and buildings on campus. However, 53 unique meters correlate to 27 building accounts and represent 80% of the annual water use. These meters may be considered the highest priority for maintenance, calibration, and obtaining actual values as opposed to estimated values. Priority buildings and their meters are listed in the Appendix.

Metrics

We used data from the four quarters of fiscal year (FY) 2016 for the analysis. Due to the format in which we receive RWA water meter billing data, we define the fiscal year as the quarter beginning on May 31 to the quarter ending on June 1 of the following year.

During FY2016, Yale used approximately 567 million gallons of potable water which are tracked on a quarterly basis.

Chart 1 Annual Total Water Use by Quarter

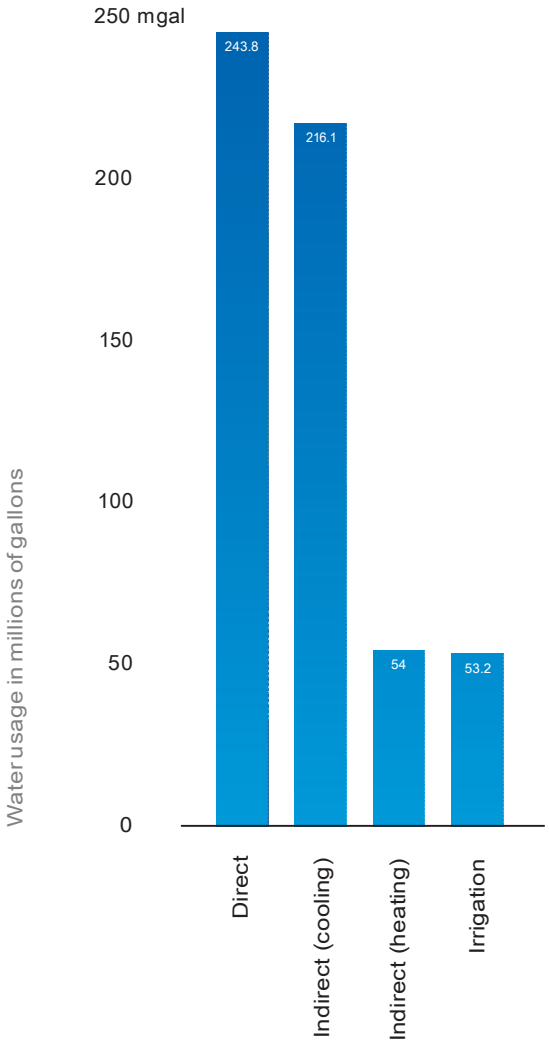


The 567 million gallons of potable water used at Yale during FY2016 may be apportioned to four major end-use categories:

- Direct: Potable water for domestic use, dining services, laboratory processes, critical research, as well as some building-level mechanical equipment.
- Indirect (Cooling): Potable water used for cooling tower makeup and chilled water makeup at the central plants.
- Indirect (Heating): Potable water used for steam condensate makeup, emissions control, and some direct humidification.
- Irrigation: Potable water used to irrigate grounds and athletic fields.

The consumption rate for each end-use category was developed by analyzing metered data and by benchmarking. Cooling and heating data were estimated by taking total power plant water use and making it proportional to past data.

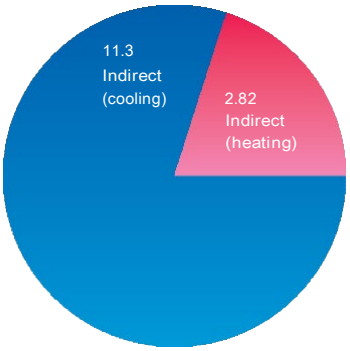
Chart 2 Annual Total Water Use by Major End Use



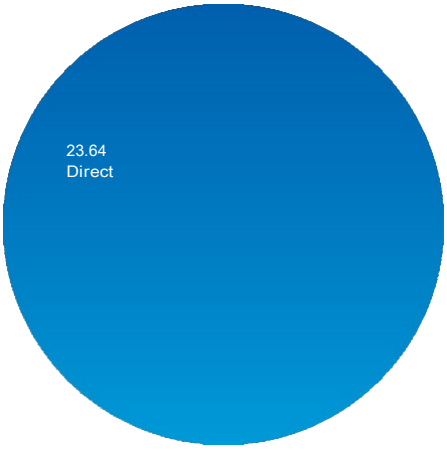
The potable water used at Yale during the representative year may be normalized based on campus gross square footage and campus users (Chart 3) to offer more context. Normalized metrics may be further used to benchmark Yale's performance compared with peer institutions if those data were validated and available.

Chart 3 Daily Total Water Use

Daily Total Indirect Water Use per Campus Gross Square Foot (GSF)



Daily Total Direct Water Use by Campus User



On average, the campus requires 14 gallons of potable water for heating and cooling a square foot of building space, with cooling representing 80% of the total. Consequentially, water use increases during the summer months.

On average, each person on campus uses 24 gallons of potable water for domestic needs. The University is opening Pauli Murray and Benjamin Franklin Colleges this academic year representing approximately 440,000 GSF of space. At full capacity, the two Residential Colleges will accommodate approximately 800 new undergraduate students on campus. Using these averaged values, water use may be projected to increase approximately 7 million gallons annually due to direct water use and 6 million gallons annually due to indirect water use.

Please note that for these charts, the following metrics were used:
Campus GSF: 19,127,321
Campus Users: 28,256
Days per Year: 365

The GSF is consistent with the calendar year (CY) 2015 GSF value reported to The Climate Registry for the operational boundary of university greenhouse gas emissions. While metered water use data is not available for all the square footage included, Yale intends to standardize on the operational boundary for consistent sustainability reporting. Moving forward, additional building accounts may be included in our water use analyses.

Progress

We updated the baseline year used in our first Water Management Plan from CY2012 to FY2013. We made the update for the following reasons:

- To align with the values provided in our annual progress report that compares years on the fiscal timeline.
- To include two significant meters that were omitted in the original baseline year.
- To provide a parallel timeframe for our new representative year used in this analysis.

In 2013, Yale made a goal to reduce potable water use on campus 5% below 2013 levels by June 2016. While Yale did not meet its 5% reduction goal in water consumption, the University did reduce water consumption by 0.5% from its baseline value. Yale used 570.2 million gallons of potable water in FY2013 and 567.3 million gallons of potable water in FY2016.

A key initiative towards the water reduction goal involved replacing existing showerheads within residential and athletic facilities with high-performance, low-flow showerheads. Water use data shows the impact of this initiative. Potable water use decreased by 12% at Yale's twelve Residential Colleges (Chart 4) and 13% at Payne Whitney Gym (Chart 5) between FY2013 and FY2016.

Chart 4 Annual Total Water Use at the Residential Colleges

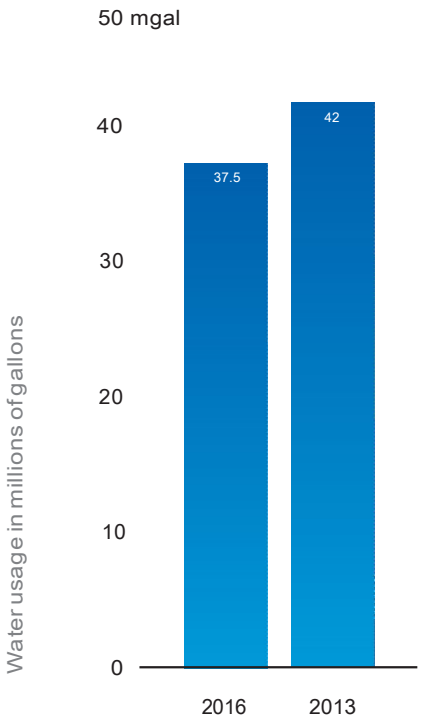
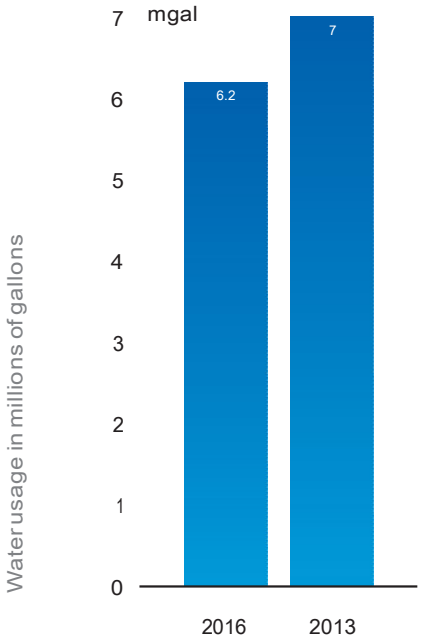
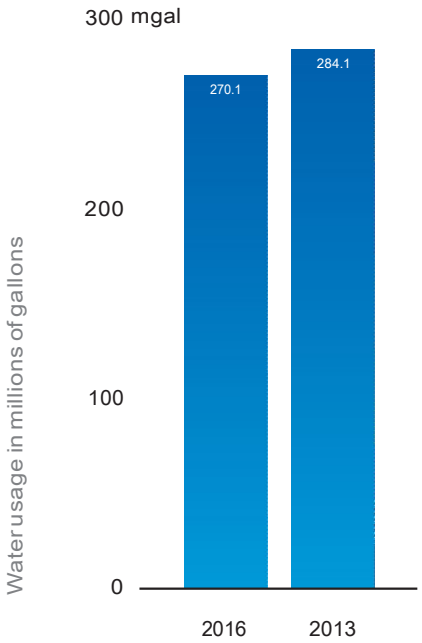


Chart 5 Annual Total Water Use at Payne Whitney Gym



Another initiative involved various strategies to minimize cooling tower water demand during peak cooling months. Water use data shows that the overall annual total water use at power plants decreased by 5% between FY2013 and FY2016 (Chart 6).

Chart 6 Annual Total Water Use at Power Plants



While data demonstrates the success of these initiatives, it is assumed that these reductions were counterbalanced by general campus growth and maintenance issues.

Moving Forward

The following section describes strategies toward the University's immediate water conservation goals and longer-term vision for active and adaptive water stewardship. These strategies build on the progress and analyses made since the Water Management Plan 2013–2016 and provide a coherent and flexible framework for future activities.

Strategy 1 Maintain commitment to water metering and analysis

Maintain current metering infrastructure and quarterly data collection processes, while preparing to convert to Advanced Metering Infrastructure (AMI) in partnership with RWA. Analyze and publish data at the campus level on an annual basis.

For the past three years, we have continued to log and monitor water-use data as it is provided on our quarterly and monthly bills from RWA. We have also reported this water use annually. We have found that the time and resources needed to collect, validate, analyze, and share water-use data from RWA and Yale's internal submeters on a more frequent basis are too high. In addition, inconsistent data quality does not allow actionable conclusions to be drawn about water-use trends across campus.

We are hoping to significantly improve our metering and analysis capabilities moving forward in conjunction with RWA's AMI project. Yale has been selected as a participant in the "pilot testing program," which is the first phase of AMI deployment that began in January 2017. 10 meters on priority buildings have been upgraded to advanced meters, allowing hourly data to be viewed using a web-based interface. Yale agreed to provide technical support to install the devices and to give administrative feedback to RWA. Ultimately, this water-use data will be highly valuable because it will be available through a directly accessible web portal in real time, offering an unprecedented opportunity to learn about campus and building water dynamics, and to inform proactive and innovative operations.

Water-use data will continue to be reported annually in Sustainability Progress Reports.

Strategy 2 Align design standards and planning documents

Update existing design standards and planning documents to reflect the most current requirements for water metering, water efficiency, and reclaimed water strategies.

Yale has piloted a number of water conservation and metering systems over the past several years, particularly within LEED-certified buildings, and has reviewed the performance of many of these pilots to intentionally inform future direction on campus.

Future projects, including those designated as Comprehensive, Small Scope, and Limited Scope, will be executed in accordance with design standards and planning documents updated with water management goals. Sections of Division 15 of Yale Design Standards for Capital Projects were updated in spring 2016 and will continue to be updated to reflect requirements for water-efficient plumbing fixtures and water metering as they evolve. Guidelines in support of building-level reclaimed water and irrigation systems will also be developed.

Yale intends to incorporate all lessons learned to date, standards, and guidelines in the update and adoption of High Performance Design Standards by 2019 in accordance with the Yale Sustainability Plan 2025.

Strategy 3 Implement water conservation projects and activities

Implement projects and activities to reduce annual potable water use on campus 5% below FY2013 levels by June 2020.

Three years ago, Yale committed to an assertive water conservation goal within the Sustainability Strategic Plan 2013–2016 and the corresponding Water Management Plan 2013–2016. While this goal was not achieved, several successful projects were implemented, including:

- Retrofit of all existing showerheads in the residential colleges and Payne Whitney Gym. Following pilot of various showerheads, a high-performance 1.5 gpm model was selected and installed over a period of three months.
- Decommissioning of underutilized washing equipment serving critical research areas at the Medical Campus; implementation of a "warm water wash" cycle within critical research areas that saves steam and quench water.
- Pilot of high-performance irrigation systems and moisture monitoring at select irrigation locations to inform future use; investigation and resolution of underground irrigation leaks.
- Active monitoring and scheduling of academic spaces during the summer months to reduce chilled water demand during peak cooling months and avoid use of potable water as cooling tower makeup.

In addition, Yale Facilities has completed feasibility studies and preliminary permitting reviews to develop a campus-level reclaimed water system to

supply nonpotable water to the Sterling power plant. A system of this scale could provide approximately 100M gallons of nonpotable water annually, while offering new teaching and research opportunities associated with urban water infrastructure.

Moving forward, in alignment with Yale Sustainability Plan 2025, Yale will continue to seek opportunities within buildings and the central power plants. Concerted efforts toward more effective identification and resolution of maintenance issues will be made. Opportunities that increase the resiliency of systems and are focused on both water and energy savings, addressing the campus-level energy / water nexus, will be prioritized.

Strategy 4 Adapt management plan goals

Identify progressive water conservation goals by 2020 in alignment with municipal, regional, and state priorities.

The Water Management Plan is presented to support an adaptive and iterative process to promote water conservation at Yale. In the initial plan, we intended to garner a more robust water-use data set to complement a portfolio of projects implemented for water conservation. However, inconsistent data quality has prevented a comprehensive assessment of all the projects completed between 2013 and 2016. We are hoping that AMI data at the building level will allow a more precise evaluation of specific water conservation activities.

Yale will set the next water conservation goal by 2020 in explicit alignment with municipal, regional, and state priorities. Currently, several significant and related plans are being developed, including:

- New Haven Climate & Sustainability Framework
- CT State Water Management Council Plan
- RWA Strategic Plan

Yale intends to identify ways to contribute to the forthcoming priorities of these plans, which will likely include specific goals related to stormwater reduction, water quality, and drought response. As an example, while water supply is relatively abundant across our region, the Connecticut Interagency Drought Workgroup tracked persistent dry weather and issued the first ever Drought Watch in October 2016. It is critical that the University develop strategies to conserve water in response to regional conservation needs as they arise.

More broadly, the University intends to address water management priorities as a critical component of the Campus Resilience Plan as part of the Yale Sustainability Plan 2025. This document will comprehensively address campus issues with and preparation for climate change adaptation, including extreme weather events.

Conclusion

Yale is continuing its commitment to reduce its potable water usage by 5% from 2013 levels by the end of 2020 and making efforts for more robust and actionable water-use data. Yale recognizes the value of water beyond its utility costs and the necessity of active and adaptive water management for long-term resilience.

Appendix

Table 1 Water Meter and Building Account Priorities

Location	Meter name	Meter number	FY2016, gallons	%
Sterling Power Plant	305 ConGRESS RMt bx Lt SIDE 309 ConGRESS AvEnuE 184 LIbERtY St–YpI (*0.66)	31909803 70030356 8702700	154,588,644	27.25
Central Power Plant	18 AShMun St. 18 AShMun StREEt MnSAChEM RMt pSt tREE (*0.6) RMt Lt Ft 205 pRoSpECt Sage Bowers Sci Hill SW Sn 18 AShMun St.	31904141 1633286 30780133 12702042 31952679	51,415,276	9.06
West Campus Power Plant	400 Morgan Lane Fire Pit 1 (*0.07) 0 Heffernan Rd York Cooling Tow 0 Heffernan B-45 Water Pit 4 (*0.96) 0 Heffernan Rd Water Pit 3 (*0.07)	54890340 1587444 1568651 7704335	40,423,005	7.13
Hunter Building	Hunter Bldg.–15 York	8702604	34,504,492	6.08
10 Amistad Building	10 Amistad St	59293682	27,353,612	4.82
Central Chiller Power Plant	CCCp		23,691,217	4.18
Anlyan Center	350 ConGRESS AvE. 300 CEDAR St.	7701653 1577905	23,098,921	4.07
Outdoor Tennis Center	CEntRAL AvEnuE Wh AthLt FLD RMt pSt	12700045 7707394	11,233,464	1.98
Yale Bowl	150 Yale Ave SoCCER FIELD 150 Yale Ave Yale Bowl 150 Yale Ave Yale Bowl	8805702503 1633237 6703756 5702503	10,360,548	1.83
Morse College	MoRSE CoLLEGE toWER pkWY MoRSE CoLLEGE toWER pkWY MoRSE CoLLEGE toWER pkWY	8702677 10702113 10702116	6,763,416	1.19
Boyer Center for Molecular Medicine	295 ConGRESS AvE	6702526	6,591,376	1.16
Payne Whitney Gym	Payne Whitney Gym 68 Lake PL 70 toWER pkY	14703098 31952680	6,177,096	1.09
344 Winchester	344 Winchester 344 Winchester	11701534 31931549	5,458,418	0.96

Location	Meter name	Meter number	FY2016, gallons	%
Yale Health Center	55 Lock St 55 Lock St	9708524 8700516	5,318,280	0.94
Hall of Graduate Studies	RMtbx InSIDE WALL tWR	1577988	5,304,442	0.94
Silliman College	354 Temple St / Silliman 344 tEMpLE RM 327RMtWnDFR 505 College St Yale Block#622	7701522 9702497 6708213 6702517	5,155,964	0.91
Dewitt Cuyler Track Complex	DERbY AvE	10704214	4,157,010	0.73
Yale Golf Course	200 ConRAD DR. 200 ConRAD DR.	56221770 1588076	4,069,142	0.72
Hopper College	CALhoun CoLLEGE 189 ELM St RMt Rt bSMt DoR 434 CoLLEGE	8705900 12702185	4,041,968	0.71
Ezra Stiles College	StILES CoLLEGE bRoADWAY 19 Tower Pkway RMt RtFRt on bRDWY SID RMt RtFRt	10702123 8703269	3,682,030	0.65
Becton Lab	bECtIn LAb pRoSpECt St	10704175	3,510,738	0.62
WestCampusB24researchbuilding	0 Heffernan Rd—West Campus (*0.66)	1578216	3,505,128	0.62
Timothy Dwight College	tIMothY DWIGht CoL 116 GRovE Timothy Dwight Col 65 Wall	1554430 1588568	3,337,950	0.59
Branford College	hIGht St bFD CLG-RnW bRAnFoRD CoLLEGE 98 hIGh St (*0.5)	1554448 1554449	3,296,810	0.58
Kline Biology Tower	MnSAChEM RMt pSt tREE (*0.4)	30780133	3,267,264	0.58
Davenport College	pIERSon CoLLEGE 221 pARk St (*0.5) 240 YRkDvnptRMtLtFtDRSt (*0.5)	1554437 10700001	3,233,604	0.57
Pierson College	pIERSon CoLLEGE 221 pARk St (*0.5) 240 YRkDvnptRMtLtFtDRSt (*0.5)	1554437 10700001	3,233,604	0.57

Acknowledgments

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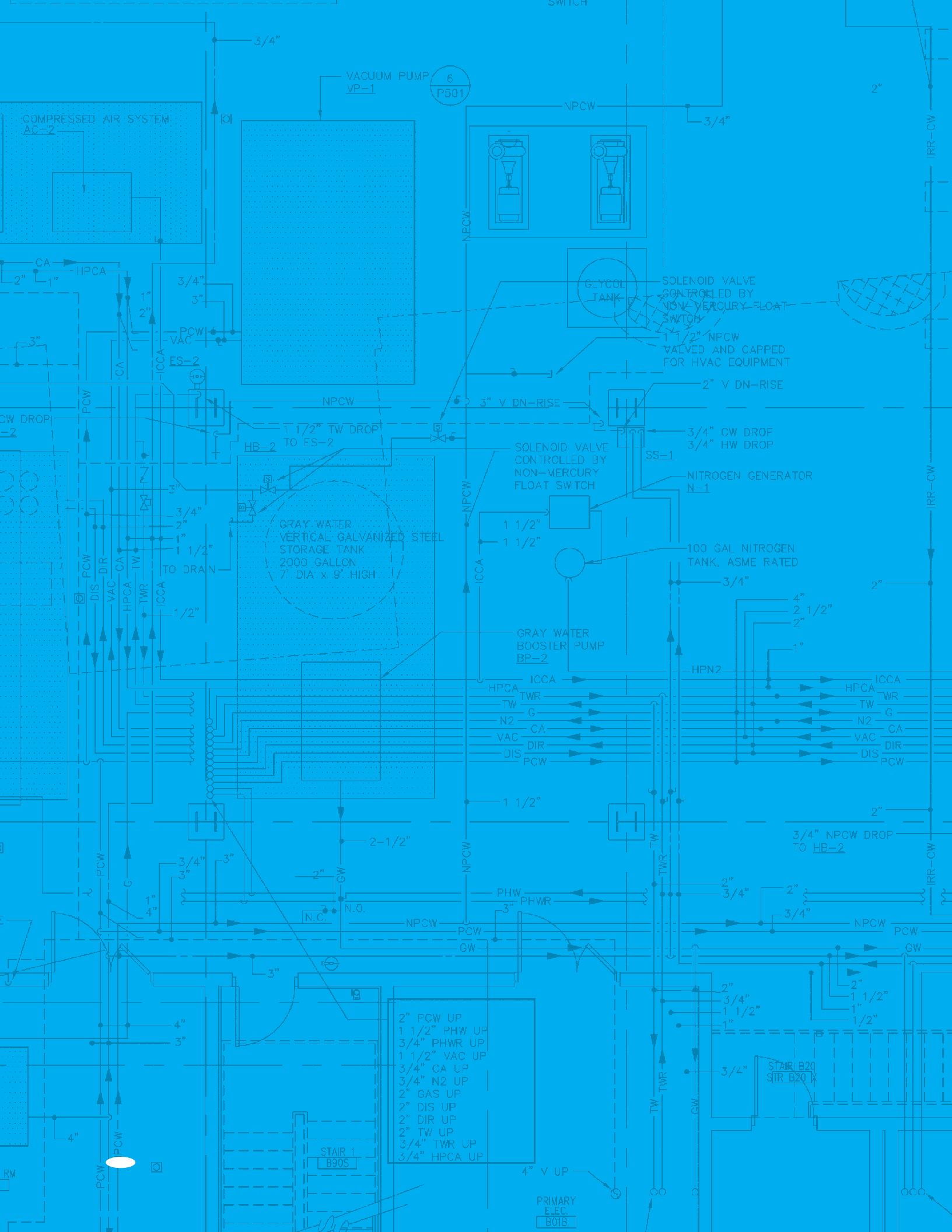
SWITCH
3/4"
VACUUM PUMP VP-1
6 P501
COMPRESSED AIR SYSTEM AC-2
NPCW
3/4"
2"
IRR-CW
CA
HPCA
2"
1"
3/4"
3"
1"
2"
PCW
VAC
ES-2
3"
CA
ICCA
GLYCOL TANK
SOLENOID VALVE CONTROLLED BY NON-MERCURY FLOAT SWITCH
1 1/2" NPCW VALVED AND CAPPED FOR HVAC EQUIPMENT
2" V DN-RISE
NPCW
3" V DN-RISE
1 1/2" TW DROP TO ES-2
HB-2
3/4" CW DROP
3/4" HW DROP
SS-1
SOLENOID VALVE CONTROLLED BY NON-MERCURY FLOAT SWITCH
NITROGEN GENERATOR N-1
3"
3/4"
2"
1"
1 1/2"
TO DRAIN
GRAY WATER VERTICAL GALVANIZED STEEL STORAGE TANK 2000 GALLON 7' DIA x 9' HIGH
1 1/2"
1 1/2"
100 GAL NITROGEN TANK, ASME RATED
3/4"
2"
4"
2 1/2"
2"
1"
1/2"
GRAY WATER BOOSTER PUMP BP-2
HPN2
ICCA
HPCA
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2" TW UP
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STAIR 1
B90S
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PRIMARY ELEC.
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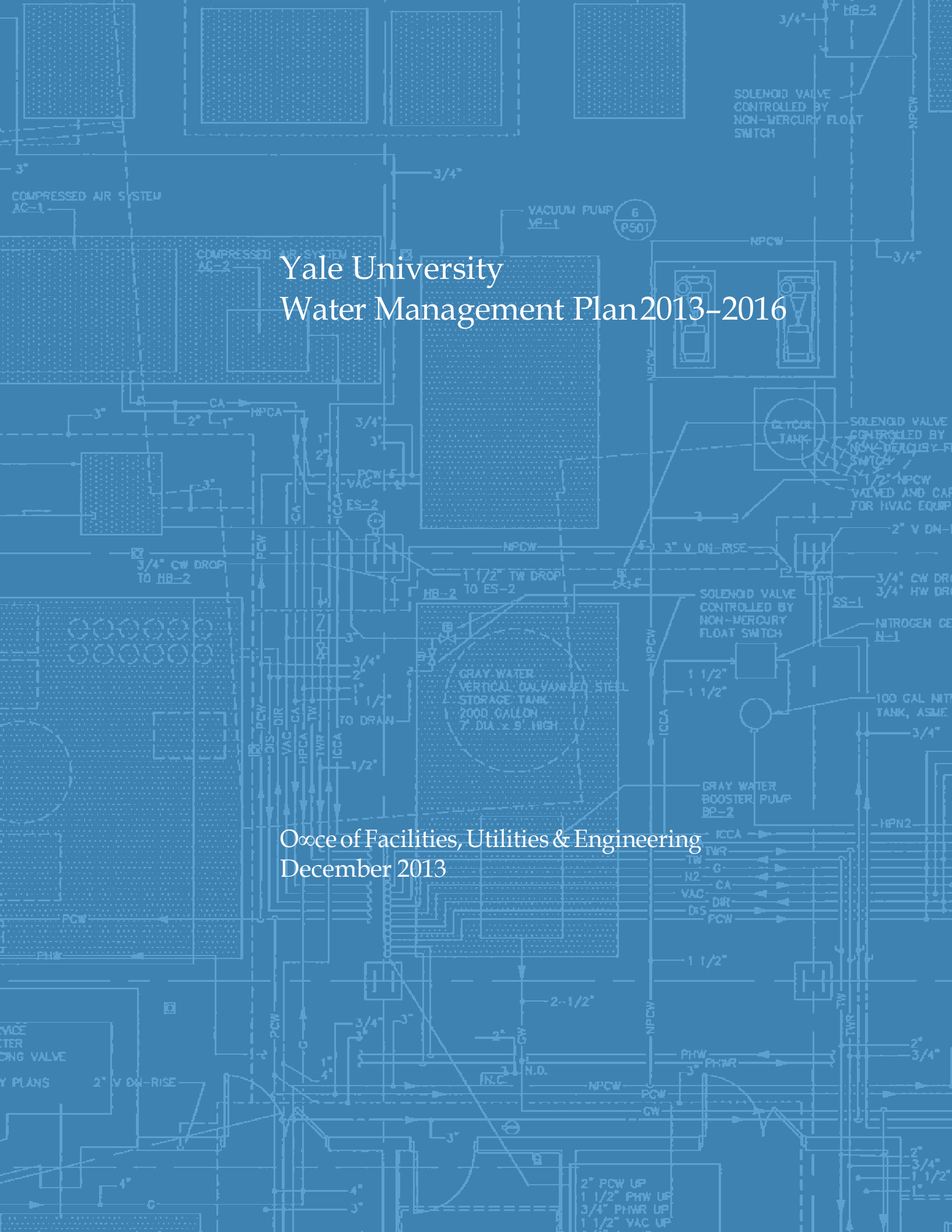

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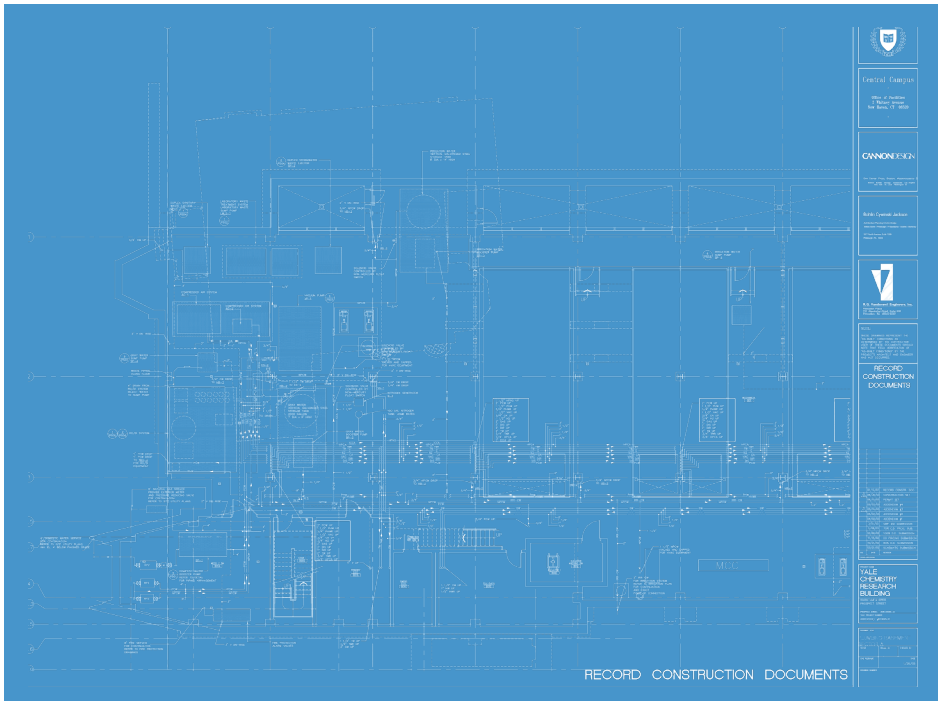
December 2013



on the cover

The cover image is a snapshot from Construction Document P200A issued June 30, 2003, showing a reclaimed water system at Chemistry Research Building. This system collects reverse osmosis reject water to be used for flushing demand within the building.

First Printing, December 2013

Yale University
Water Management Plan 2013–

2016

O∞ce of Facilities, Utilities & Engineering
December 2013

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Introduction

In 2010, Yale University's O∞ce of Sustainability released the Sustainability Strategic Plan 2010–2013. This comprehensive sustainability planning document identified a variety of goals and projects related to campus systems, administrative systems, earth systems, education, and engagement that would enhance Yale's commitment to maintaining a sustainable campus. As one aspect of Yale's focus on reducing its environmental impact, the plan set a specific goal to "Develop a Water Management Plan by June 2013" that is informed by "up-to-date water meters that enable accurate monitoring of building water usage" on "100% of Yale's buildings" and "water indicators to track and measure data on an annual basis."

This year, the O∞ce of Sustainability released the updated Sustainability Strategic Plan 2013–2016, which includes an unambiguous goal to "Reduce potable water use on campus 5% below 2013 levels by June 2016." The Water Management Plan 2013–2016 fulfills the goal of the Sustainability Strategic Plan 2010–2013 and presents context and strategies toward meeting the new goal defined in the Sustainability Strategic Plan 2013–2016.

The plan details the importance of water management on campus, various approaches taken to date with campus metering, building, irrigation, and process systems, and methodology for analyzing water data and metrics. The plan presents a suite of strategies identified toward the 5% water-use reduction goal and steps toward more comprehensive understanding, and active and adaptive management, of water use at Yale.

Importance ofWater Management

Water is a critical utility for Yale University, accounting for approximately 6–8% of Yale's annual utility budget. In addition to serving the daily domestic needs of more than 25,000 people, water is used for energy production, laboratory and critical research processes, dining services, and grounds maintenance for a campus consisting of more than 15 million square feet and 1,000 acres.

Although Yale is in the biome of New England, where fresh water is an abundant resource, concerns related to fresh water cost, supply, infrastructure, and extreme weather events warrant understanding and active management of Yale's water use.

Water is supplied by South Central Connecticut Regional Water Authority (RWA), while wastewater is managed by Greater New Haven Water Pollution Control Authority (WPCA).

- Supply: Over 27,000 acres of land are protected by RWA to ensure adequate fresh water supply and quality. More than 80% of water is supplied from lakes sustained

by river inflow situated in Hamden, Woodbridge, East Haven, Bethany, Guilford, Madison, Killingworth, Branford, and North Branford. The balance is supplied from the Quinnipiac and Mill River aquifers in Cheshire and Hamden, along with the Housatonic River aquifer in Derby and Seymour.[1]

- Distribution: RWA's interconnected distribution system allows water blended from two or more sources to be supplied to campus, providing redundancy in instances of heat waves and emergencies. The distribution system involves 1,700 miles of pipes, pumping stations, and storage tanks.[2]
- Supply Treatment: Water supplied undergoes a multistep treatment process: water is disinfected with chlorine, and fluoride is added, along with phosphate to inhibit pipe corrosion. Last year, over 120,000 tests were performed on 15,000 water samples to assure the quality of water supplied.[3]
- Wastewater Treatment: WPCA was created in 2005 to manage 500 miles of sewer mains that deliver the flow to the East Shore Water Pollution Abatement Facility on the New Haven Harbor, which is the second largest Connecticut wastewater treatment plant.[4]

Because Yale relies on significant quantities of high-quality fresh water year round, active water management is not only essential to the long-term planning of the university, but also critical to RWA and WPCA's long-term planning to serve the region.

Vision for Water Management

Yale envisions a campus where water is actively and adaptively managed as a valuable and reliable resource. While the two Sustainability Strategic Plans lay out concrete three-year goals toward this vision, Yale anticipates that these activities serve only as the foundation for more comprehensive, longer-term initiatives that are fully coordinated with energy, stormwater, and risk management planning. Sustained progress in all areas relies on such coordination:

- Energy: The relationship between energy and water, also known as the energy-water nexus, is evident on campus. Water reductions lead to energy savings in pumping, treating, and heating water. Energy reductions lead to water savings in campus power plants.
- Stormwater: Effective management of stormwater may reduce potable water used for irrigation. Infrastructure put in place to further manage stormwater may present opportunities for storing water to be used in lieu of potable water.
- Risk Management: Reducing Yale's water use and water impact alleviates stress on utility infrastructure, making the campus less vulnerable to unforeseen events and more resilient in the long term.

Future efforts in water management planning shall be further guided by a set of shared principles. Like the Sustainability Planning Principles, these principles capture the strength of near-term activities, provide direction for future development, and should be taken collectively to motivate and focus work:

Recognize Water as a Critical Resource

Water is essential to the daily operation of Yale. In addition to providing for domestic needs, water supports laboratory and critical research, and energy production on campus. Yale shall recognize the value of water beyond its utility costs in order to position the campus well for long-term resiliency.

Promote Water Metering, Conservation Technologies, and Conservation Research

Collecting water-use data and related activities offer and necessitate robust research and educational opportunities for students and faculty here and beyond Yale. Yale shall encourage university-wide participation and stewardship of water management strategies on campus.

Prioritize Adaptive Management Strategies

Strategies to inform and improve water management decisions and activities enable the most positive outcomes. Yale shall commit to collecting water-use data, sharing data, and using an iterative decision-making process for ongoing water management.

Approach to Water Management

The university has been engaged in various levels of water management activities for many years. This section describes the approaches taken to date as they relate to metering, building, irrigation, and process systems.

The campus metering system currently includes 299 revenue meters installed and maintained by RWA, and additional building- and system-level submeters installed and maintained by the university.

Metering Systems

Revenue Meters Meters in use include 237 meters that are tied to 120 electronically billed accounts, and 62 meters tied to 44 paper-billed accounts. All installed meters are Neptune meters that are read on a monthly or quarterly basis either automatically or manually. Yale receives water-use data as part of the billing statement from RWA. It should be noted that RWA transfers this water-use data to WPCA to generate billing statements for sewer charges. In addition to the 299 RWA meters, two meters are installed at the Central Campus chiller plant as submeters to a revenue meter owned by others. Because the water use measured by these submeters is substantial, use is recorded daily by Facilities.

University Submeters While the revenue meters capture the total extent of campus water use, Yale installed 23 additional building-level submeters in 2012 to obtain more detailed water-use data in locations where a single RWA meter accounts for multiple building types. The intent of this effort was not to have a meter on every building on campus, but rather to have enough meters so that building-level performance may be benchmarked. For example, if a single RWA meter served an administrative building and a laboratory building, then an additional meter

Submeter installed at laboratory for Surgery, Obstetrics, and Gynecology

Submeter installed at Central Campus chilled water plant

would be needed to understand the water performance in each building. If a single RWA meter served two separate administrative buildings, then the total water use may be apportioned to each building based on square footage. Yale also maintains several dozen submeters in order to understand water use within our central utility plants, dining halls, and select building systems. These data are tracked for various purposes and not detailed in this plan.

Appendix A includes a list of all revenue campus meters, with their meter numbers, responsible party, and frequency of readings.

Building Systems

Over the past 10 years, the university has installed a variety of plumbing systems that reduce consumption of potable water within new buildings and renovations. Many of these installations contributed to earning Water E∞ciency (WE) and Innovation in Design (ID) credits toward Leadership in Energy and Environmental Design (LEED) certification. These include:

- High-e∞ciency plumbing fixtures: The university has installed high-e∞ciency plumbing fixtures within all LEED-certified buildings and many additional renovation projects. Installations include generally: low-flow and dual-flush water closets, low-flow and waterless urinals, low-flow lavatory faucets, low-flow laboratory faucets, and low-flow showerheads. Flow rates, flush volumes, and performance outcomes vary by installation.
- Reclaimed water systems: A reclaimed water system is a general term to describe a system that retains nonpotable water to be used for nonpotable demand, such as cooling tower makeup, sewage conveyance, and irrigation. Yale has installed seven reclaimed water systems in six buildings since 2005, with various design and operational approaches and a range of performance outcomes.

Yale has initiated a detailed review of high-e∞ciency plumbing fixtures and reclaimed water installations on campus in order to inform capital projects and future design standards and planning documents.

Appendix B includes case studies of select reclaimed water systems installed on campus.

Irrigation Systems

The irrigation system at Yale is composed of approximately 100 independent irrigation systems installed over time. Each system is composed of zones based on the type of landscape and vegetation. In past years, Yale has taken various approaches to reduce water used for irrigation:

Dual-flush water closet served by reclaimed water system at Kroon Hall

Low-flow automatic faucet at Kroon Hall

Reclaimed-water tank at Yale Sculpture Building and Gallery

The irrigation system at Berkeley South has 10 zones and includes a smart irrigation controller, flow valve, rain sensor, soil moisture sensor, drip irrigation for beds, and triangulated head-to-head coverage for lawn.

- Operational best practices: Grounds maintenance staff actively employ best practices in operating irrigation systems. Staff monitor irrigation controllers and scheduling on a daily basis from April to November.

- Reclaimed water systems: Three of the seven installed reclaimed water systems on campus supply connected irrigation systems with nonpotable water. These installations contributed to earning credits toward Leadership in Energy and Environmental Design (LEED) certification.

- Advanced sensors and controls: The majority of irrigation systems have been retrofit with flow sensors and master valves to monitor and prevent leakage. Additionally, rain sensors have been installed wherever possible. In some cases, irrigation systems are tied into the central building monitoring system. Three systems on Central campus have been retrofit with comprehensive smart irrigation controllers in conjunction with rain sensors, soil moisture sensors, and triangulated head-to-head coverage.

  Appendix C includes a case study of two irrigation systems for comparison, representing best and standard practices on campus.

  Appendix D lists all irrigation systems and zones on Central and Medical campuses, along with the number of heads for rotors and sprays for select systems. Future inventory will include Athletics and West Campus.

Process Systems

Campus power plants use significant volumes of potable water for central steam and chilled water generation. This water may be referred to generally as process water. Over time, plant operations continually adapt and have included various strategies for reducing process water, including:

- Advanced Water Treatment: A combination of proprietary and general water treatment strategies have enabled cooling tower cycles to increase, boiler cycles to increase, and bleed and blowdown volumes to decrease, while actively protecting equipment and reducing chemical consumption.

- Reclaimed Water Systems: At Central and Sterling Power Plants, basic reclaimed water systems are used to recover clear condensate from makeup air-handling units serving turbine inlets for cooling tower makeup. At Sterling Power Plant, water used to cool bearing is also recovered and used for cooling tower makeup.

- Water-Use Monitoring: Real-time monitoring of makeup and losses in campus distribution of steam and chilled water enables quick response in the case of leaks. Real-time monitoring of cooling tower makeup normalized for chilled water generation (gallons of makeup / ton-hours of chilled water) allows for operational modifications and seasonal performance trending.

  A significant amount of water is also used in laboratories for process needs, including equipment cooling and generation of reverse osmosis deionized water. Future

analyses of such process water needs may inform future capital projects, treatment standards, and equipment guidelines.

Analysis for Water Management Planning

Efforts to understand and evaluate water use at Yale have been under way for many years. Various metering technology and billing processes have been promoted with RWA, most recently focused on reducing the number of water meters estimated for quarterly bills from approximately 40% in fiscal year (FY) 2009 to 10% in 2012. During 2012, additional submeters were installed on campus to supplement utility meters and further allow benchmarking of water by building type. This section details analysis of the most current metering data and establishes a representative water-use baseline for future planning.

Metering

An evaluation of the current metering and billing system demonstrates that:

- Approximately 65% of meters are always read and billed quarterly. The balance, approximately 35% of meters, are read and billed either monthly or quarterly, depending on capacity.
- Less than 5% of water use by volume is estimated on an annual basis rather than determined by actual meter readings. Estimations are based on historic water use at the discretion of RWA.
- Roughly every 18 months, a change in billing rate occurs during a quarter. When this occurs, the water usage before and after the rate change may be prorated for billing purposes, and estimations are adjusted in following quarters. It is important to evaluate the adjustments when trending quarterly water use.
- 80% of annual water use may be attributed to 36 meters. A full 95% of annual water use may be attributed to 81 campus meters.

  Despite the high number of meters on campus, it is reasonable to consider the 36 meters that represent 80% of the annual water use to be highest priority for maintenance, calibration, and obtaining actual values as opposed to estimated values. Priority meters are listed at the top of the Water Meter Table included in Appendix A and in a separate table in Appendix E.

Representative Baseline

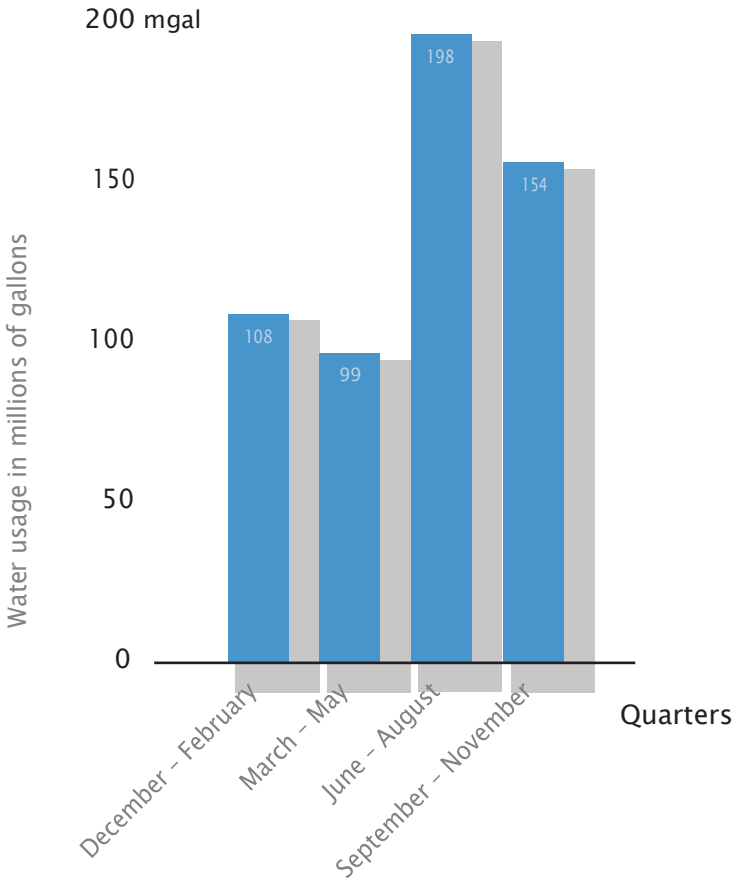
For water management planning, a baseline built from the four quarters of calendar year (CY) 2012 was established. CY2012 was selected as representative for the following reasons:

- Data Quality: CY2012 data is considered to be the highest-quality data available because it trended most appropriately with historic usage, included a low percentage of estimated values from RWA, contained no change in billing rate, and is composed of three of the four most recent billing quarters.

- Thermal Conditions: Because chilled water production drives a significant percentage of Yale's energy consumption and potable water use, CY2012 represents a year with largely typical cooling degree days.

  Over a representative year, Yale University used approximately 560 million gallons of potable water (Graph 1).

Graph 1: Annual Total Water Use by Quarter



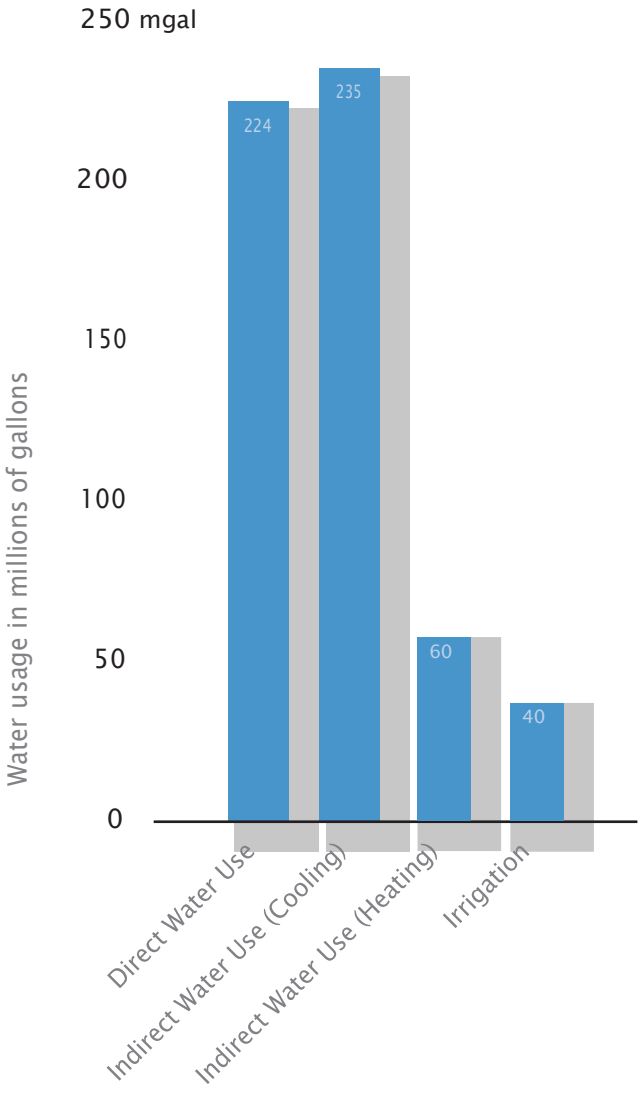
Please refer to Appendix A to view annual data collected from RWA at the building level and data collected from additional meters installed at the Central Campus chiller plant.

Water by End Use

The 560 million gallons of potable water used at Yale during the representative year may be apportioned to four major end-use categories (Graph 2):

- Direct Water Use: Potable water for domestic use, dining services, laboratory processes, critical research, as well as some building-level mechanical equipment.
- Indirect Water Use (Cooling): Potable water used for cooling tower makeup and chilled water makeup at the central plants.
- Indirect Water Use (Heating): Potable water used for steam condensate makeup, emissions control, and some direct humidification.
- Irrigation: Potable water used to irrigate grounds and athletic fields.

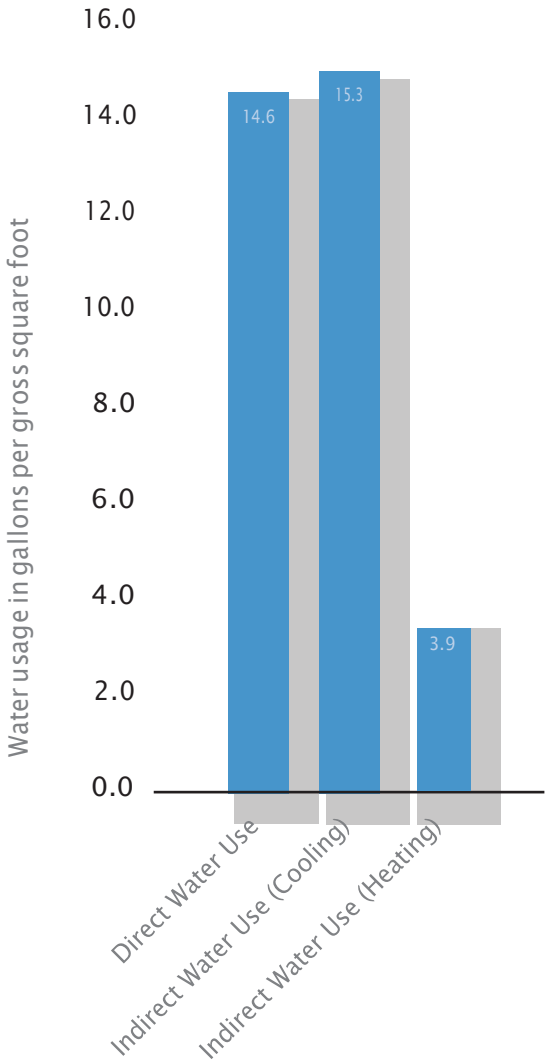
Graph 2: Annual Total Water Use by Major End Use



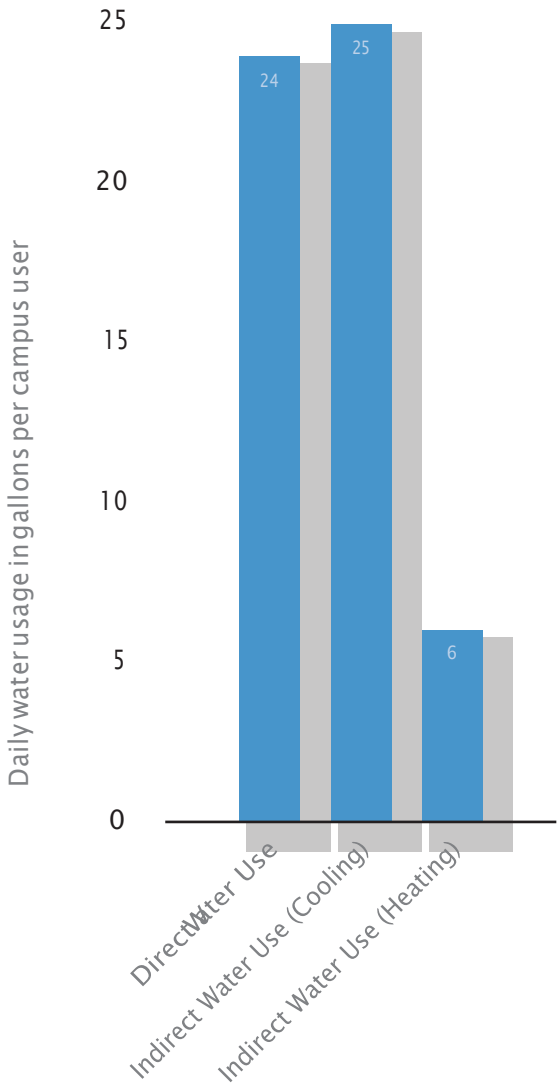
Benchmarking

The potable water used at Yale during the representative year may be normalized based on campus gross square footage (Graph 3) and user counts (Graph 4) in order to offer context. Normalized metrics may be further used to benchmark Yale's performance compared with peer institutions if those data were validated and available.

Graph 3: Annual Total Water Use by Major End Use per Campus Gross Square Foot (GSF)



Graph 4: Daily Total Water Use by Major End Use per Campus User



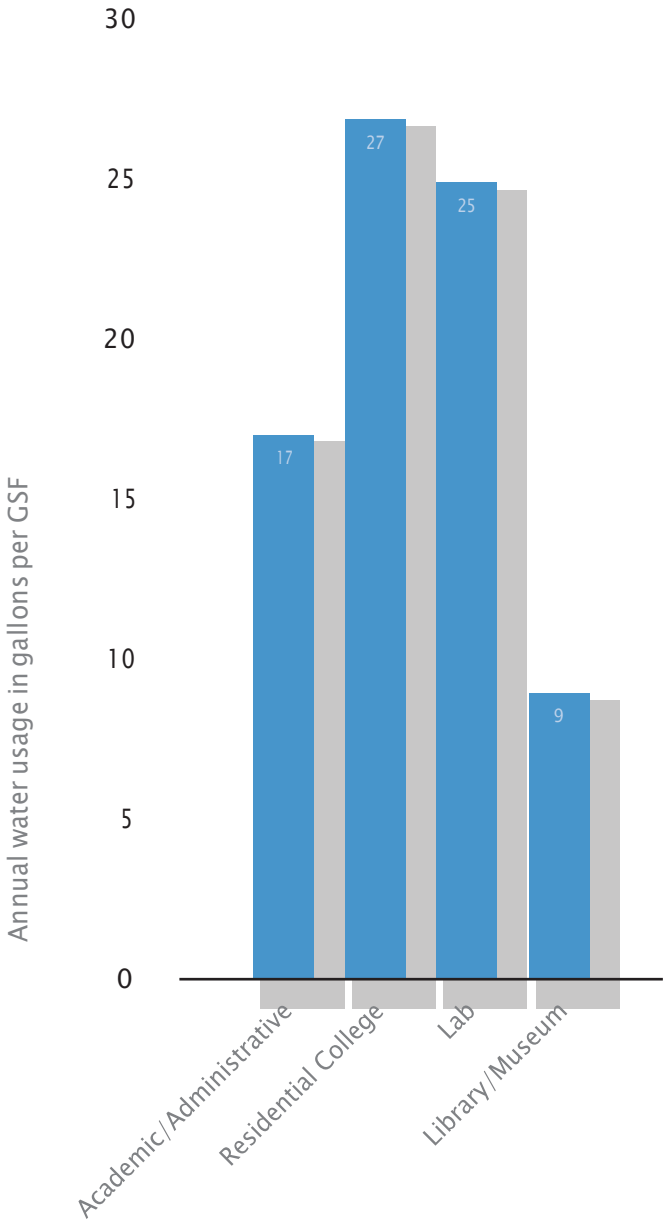
Please note that for these graphs, the following metrics were used:

- Campus GSF: 15,336,000 GSF
- Campus Users: 25,500 Users
- Days per Year: 365 Days

Indirect water use for cooling and heating was divided evenly across 365 calendar days regardless of variable cooling and heating degree days throughout the year.

In addition, Yale assessed normalized direct potable water use within various representative building categories. This assessment proved to be challenging for two primary reasons: data quality and abundance of mixed-use buildings. A representative 28 buildings were selected and grouped into four major building categories (Graph 5). This preliminary evaluation and future evaluations will allow Yale to benchmark building types against each other and to inform capital planning efforts.

Graph 5: Annual Direct Water Use per Campus GSF by Building Type



Strategies for Water Management

The Water Management Plan 2013–2016 includes four distinct strategies toward the university's immediate water conservation goal and longer-term vision for active and adaptive water management. These strategies are intended to build on the water management approaches and analyses to date and to provide a coherent and flexible framework for future activities.

Strategy 1 Maintain commitment to water metering and analysis

Strategy 2 Align design standards and planning documents with water management goals

Strategy 3 Implement water conservation projects and activities

Strategy 4 Adapt management plan goals

Strategy 1 Maintain commitment to water metering and analysis

Maintain current metering infrastructure and quarterly data collection processes. Analyze and publish data at the building level on an annual basis.

Access to accurate and detailed water data is a critical component in identifying opportunities to save water and setting appropriate goals. Water metering and processes to collect and analyze data represent important institutional infrastructure. As described above, Yale has made a significant investment in water meters and collection processes over the past several years. Yale recognizes that these data not only contribute to our own internal management activities, but also uniquely contribute to a broader understanding of campus and building-level water use and water-use patterns externally. This strategy will focus on the following three tactics:

Tactic A Maintain existing meters and install new meters as required for new construction. Commit resources as needed to ensure submeters are operational.

Tactic B Maintain existing quarterly data collection and quality control processes. Establish and maintain review with RWA to ensure that the most accurate numbers possible are provided on quarterly bills.

Tactic C Analyze and publish data at the building level on an annual basis.

Yale has committed staff time and resources to these tactics, including a dedicated Engineering Fellow for FY2014. Regular meetings with RWA are established beginning the second quarter of FY2014. A process has already been initiated to transition the majority of existing paper-billed accounts to electronic, which improves data quality and speed of processing. This plan serves as the first publication of representative annual water-use data.

Strategy 2 Align design standards and planning documents with water management goals

Update existing design standards and planning documents to reflect the most current requirements for water metering, water efficiency, and reclaimed water strategies.

As described above, Yale has piloted a number of systems over the past several years, particularly within our LEED-Certified buildings, and has reviewed the performance of many of these pilots to intentionally inform future direction on campus. Future projects, including those designated as Comprehensive, Small Scope, and Limited Scope, will be executed in accordance with design standards and planning documents updated and aligned with water management goals. This strategy will focus on the following two tactics:

Tactic A Update sections of Division 15 of Yale Design Standards for Capital Projects to reflect requirements for water-efficient plumbing fixtures, water metering, and water submetering within buildings.

Tactic B Prepare internal resources and guidelines to inform the design, installation, and operation of reclaimed water systems and irrigation systems on campus.

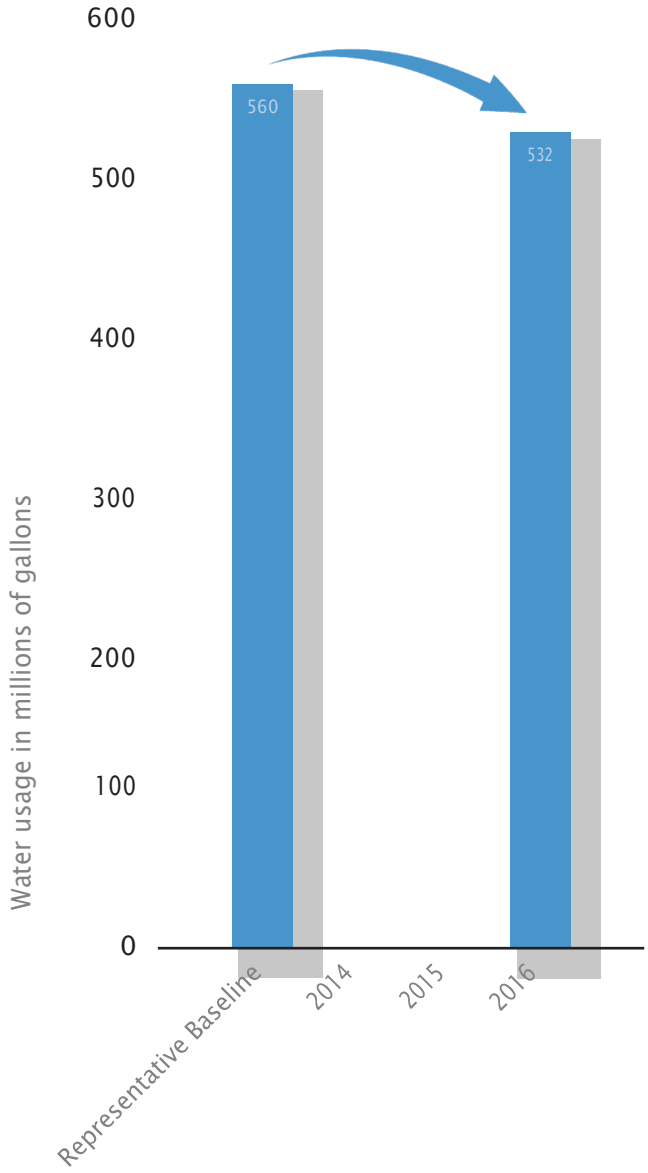
Yale has committed staff time and resources to these tactics, including a dedicated Engineering Fellow for FY2014. Considerable progress has been made to date toward internal reclaimed water and irrigation system guidelines.

Strategy 3 Implement water conservation projects and activities

Implement projects and activities to reduce annual potable water use on campus 5% below FY2013 levels by June 2016.

Yale has committed to an assertive water conservation goal within our Sustainability Strategic Plan 2013–2016 (Graph 6). Yale recognizes that achieving this goal will rely on successful implementation of multiple projects and activities over the next three years.

Graph 6: Proposed Water Reduction Target



Each tactic below represents a category of projects that are under consideration. Final results of approved projects shall be critically reviewed and published in future Water Management Plans.

Tactic A Develop and implement projects to increase the water e∞ciency of existing campus fixtures and systems in order to conserve approximately 20 million gallons of potable water.

- Retrofit existing showerheads within residential and athletic facilities with high-performance, low-flow showerheads.
- Decommission underutilized washing equipment serving critical research areas.

- Install equipment and improved water treatment and chemical control processes within power plants for makeup demand.
- Retrofit existing irrigation systems with high-performance systems at select high-volume locations.

Tactic B Develop and implement projects to provide nonpotable water demands with alternative sources of water in order to conserve approximately 3 million gallons of potable water.

- Utilize available clear condensate and dewatering streams for makeup demand within central plants and building equipment as feasible.
- Investigate strategies to develop campus-level reclaimed water infrastructure.

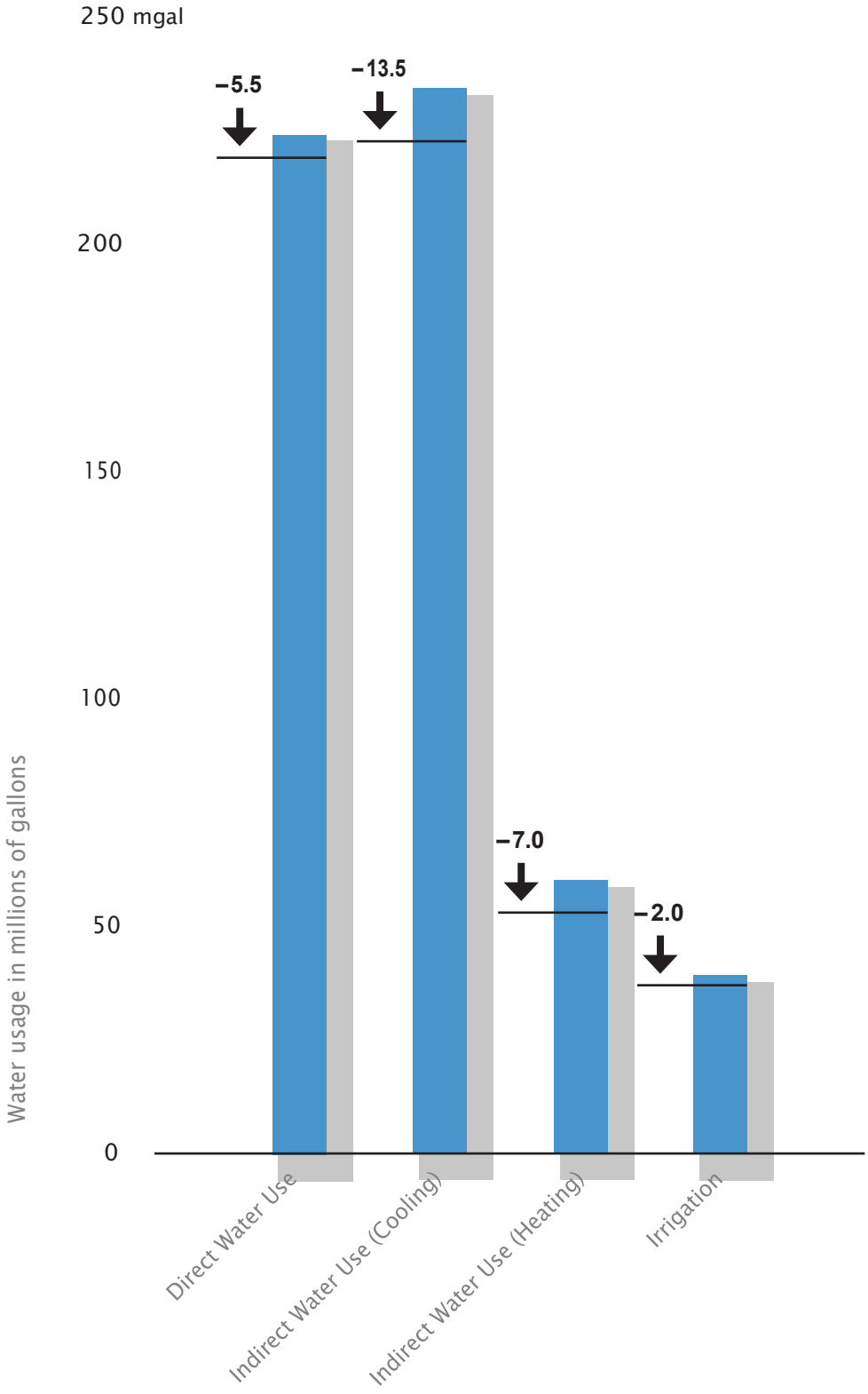
Tactic C Implement activities to minimize chilled water demand during peak cooling months in order to avoid the use of approximately 5 million gallons of potable water used as cooling tower makeup.

Tactic D Coordinate educational initiatives with Yale O∞ce of Sustainability, Sustainability Service Corps, and other relevant groups on campus to raise awareness about water use and influence behavior toward water conservation.

Tactic E Formulate longer-term projects for future development and implementation focusing on both water conservation and stormwater runoff reduction.

Yale has formulated projects and activities within each tactic, and committed staff time and resources at various levels. Progress has been made to date within each tactic.

Graph 7: Targeted Water-Use Reductions by Major End Use (Total 28 MGal)



Through a combination of all tactics, Yale intends to save approximately 28 million gallons of water over the next three years through the following major end-use reductions (Graph 7).

Strategy 4 Adapt management plan goals

Identify next progressive water conservation goal by June 30, 2016.

The Water Management Plan is presented to support an adaptive and iterative process to promote water conservation at Yale. Over the next three fiscal years, Yale will have a more robust water-use data set, as well as a portfolio of projects implemented explicitly for water conservation. It will be important to critically assess the performance of these projects and the level of activity necessary to fulfill all of the commitments outlined in this plan as part of the adaptive management process. The next progressive water conservation goal shall be set by June 30, 2016. This will require the following two tactics:

Tactic A Establish best practice methodology for evaluating representative water use given that data quality and thermal conditions vary annually.

Tactic B Formulate preliminary costs and benefits for water conservation projects and activities prior to goal-setting, so that goals and respective tactics are appropriately defined.

Yale has committed staff time and resources to project formulation and goal setting within Utilities and Engineering, and will build on the successes and lessons learned to date moving forward.

Conclusion

Yale is committed to reducing its potable water usage by 5% over the next three years. With active and adaptive management, Yale has the opportunity to serve as a leader in sharing water data and water conservation initiatives with the broader public. This plan presents a suite of strategies to reduce water, improve water-use data, collaborate further with RWA and WPCA, and plan for the future. In recognizing the value of water beyond its utility costs, Yale strives to position the campus well for long-term resiliency.

References

Greater New Haven Water Pollution Control Authority. 2011. http://www.gnhwpca.com/.

South Central Connecticut Regional Water Authority. 2012. Water Quality Report. http://www.rwater.com/wp-content/uploads/2013/05/RWA-Water-Quality-Report-2012-online.pdf.

Notes

1 2012 South Central Connecticut Regional Water Authority Water Quality Report.

2 Ibid.

3 Ibid.

4 GNHWPCA website, www.gnhwpca.com.

Appendix A

Comprehensive Water Meter Table

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27 Table 1: Revenue Meters Accounted for in the Representative Baseline (December 2011–November 2012)

36 South Central Connecticut Regional Water Authority Rate Schedules

Table 2: Quarterly Water Rates (Effective July 21, 2011)

Table 3: Quarterly Water Rates (Effective May 7, 2013)

Table 1: Revenue Meters Accounted for in the Representative Baseline (December 2011–November 2012)

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
1	18 Ashmun St	31904141	rwa	Quarterly	59,427,104	10.6
2	309 Congress Avenue	70030356	rwa	Quarterly	49,992,580	8.9
3	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	36,396,932	6.5
4	0 Heffernan B-45 Water Pit 4	0001568651	rwa	Quarterly/ Monthly	35,679,600	6.4
5	18 Ashmun St	31904141	rwa	Quarterly	29,920,000	5.3
6	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	22,484,880	4.0
7	309 Congress Avenue	70030356	rwa	Quarterly	22,027,852	3.9
8	0 Heffernan Rd York Cooling Tower	0001587444	rwa	Quarterly/ Monthly	18,501,780	3.3
9	300 Cedar St	0001577905	rwa	Quarterly/ Monthly	18,026,800	3.2
10	10 Amistad St	0059293682	rwa	Quarterly/ Monthly	17,685,712	3.2
11	295 Congress Ave	6702526	rwa	Quarterly	10,016,468	1.8
12	Mh 34Ft S Ul Pole #388	1577907	rwa	Quarterly	8,299,808	1.5
13	0 Heffernan Rd-West Campus	007704335	rwa	Quarterly/ Monthly	8,257,920	1.5
14	Kline Chemistry 245 Prospect	1587445	rwa	Quarterly	7,851,756	1.4
15	Pinhall Rmt Grove rear kit	1554447	rwa	Quarterly	6,803,060	1.2
16	Mnsachem Rmt Pst Tree	30780133	rwa	Quarterly	6,622,792	1.2
17	70 Tower Pky	31952680	rwa	Quarterly	6,471,696	1.2
18	CCCP Bottom City Water Meter		Yale Office of Facilities	Daily	6,300,784	1.1
19	CCCP Top City Water Meter		Yale Office of Facilities	Daily	6,278,144	1.1
20	150 Yale Ave Yale Bowl	0005702503	rwa	Quarterly/ Monthly	6,277,964	1.1
21	354 Temple St / Silliman	7701535	rwa	Quarterly	6,164,268	1.1
22	Derby Ave	10704214	rwa	Quarterly	5,580,080	1.0
23	Branford College 98 High St	1554449	rwa	Quarterly	5,011,600	0.9
24	Pierson College 221 Park St	1554437	rwa	Quarterly	4,591,972	0.8
25	Rmt bx Inside Wall Twr	1577988	rwa	Quarterly	4,546,344	0.8
26	Corner Grove & Prospect	1554433	rwa	Quarterly	4,515,676	0.8
27	206 Elm Street	11704876	rwa	Quarterly	4,220,216	0.8
28	Timothy Dwight College 116 Grove	1554430	rwa	Quarterly	4,136,440	0.7
29	125-135 College St	0007707439	rwa	Quarterly/ Monthly	4,084,080	0.7
30	184 Liberty St - YPI	8702700	rwa	Quarterly	3,526,820	0.6
31	240Yrkdvnptrmtltftdrst*	10700001	rwa	Quarterly	3,393,676	0.6

*Davenport College 240 York St

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
32	Berkeley College Elm St	6705741	rwa	Quarterly	3,351,788	0.6
33	Conn Hall Welch Meter	7701538	rwa	Quarterly	3,305,412	0.6
34	Rmt Rt Entr Across Toads	54572592	rwa	Quarterly	3,170,772	0.6
35	150 Yale Ave	8805702503	rwa	Quarterly/ Monthly	3,127,388	0.6
36	Rmt-Campus-Farnhm Hl	57864750	rwa	Quarterly	3,017,432	0.5
37	Helen Hadley Hall-420 Temple	1554427	rwa	Quarterly	2,954,600	0.5
38	141 Frontage Rd W-D-18 Visitor C	0031933416	rwa	Quarterly/ Monthly	2,831,928	0.5
39	Becton Lab Prospect St	10704175	rwa	Quarterly	2,804,252	0.5
40	Wh Athlt Fld Rmt Pst	7707394	rwa	Quarterly	2,699,532	0.5
41	New Residence Hall	11704879	rwa	Quarterly	2,558,908	0.5
42	409 Prospect St	1572971	rwa	Quarterly	2,543,200	0.5
43	Soccer Field	1633237	rwa	Quarterly	2,535,720	0.5
44	Morse College Tower Pkwy (99 Tower Pkwy)	8702677	rwa	Quarterly	2,305,336	0.4
45	Central Avenue	12700045	rwa	Quarterly	2,297,108	0.4
46	275-285 Prospect St Crb	0053994177	rwa	Quarterly/ Monthly	2,245,496	0.4
47	Rmt Ft Door 400 Temple	7701585	rwa	Quarterly	2,230,536	0.4
48	55 Lock St	0009708524	rwa	Quarterly/ Monthly	2,226,048	0.4
49	Rmt Frt Dr Art Gal Arch	1554436	rwa	Quarterly	2,219,316	0.4
50	Morse College Tower Pkwy	10702113	rwa	Quarterly	2,068,968	0.4
51	400 Morgan Lane Water Pit 1	0031909347	rwa	Quarterly/ Monthly	2,051,016	0.4
52	1156 Chapel Street	7706713	rwa	Quarterly	2,031,568	0.4
53	Yale Avenue	6708352	rwa	Quarterly	2,014,364	0.4
54	Rmt Lt Ft 165 Prospect	11704059	rwa	Quarterly	1,979,956	0.4
55	Stiles College Broadway	10702123	rwa	Quarterly	1,960,508	0.4
56	19 Tower Pkwy Rmt Rtfrt On Brdwy Sid	8703269	rwa	Quarterly	1,890,944	0.3
57	200 Conrad Dr	1588076	rwa	Quarterly	1,855,040	0.3
58	170 Whitney Ave	7706090	rwa	Quarterly	1,751,816	0.3
59	344 Winchester	31931549	rwa	Quarterly	1,727,132	0.3
60	Whitehall Apts 511 Prospect	6704463	rwa	Quarterly	1,608,948	0.3
61	Calhoun College 189 Elm St	8705900	rwa	Quarterly	1,551,352	0.3
62	32 Edgewood Ave	0007701515	rwa	Quarterly/ Monthly	1,522,180	0.3
63	Rmt Rt Bsmt Dor 434 College	8702673	rwa	Quarterly	1,465,332	0.3
64	Rmt Left Side 800 Rear	7701567	rwa	Quarterly	1,446,632	0.3
65	Rmt On Pole Sidewalk	7707256	rwa	Quarterly	1,445,884	0.3
66	Berkeley College Wall St	1554428	rwa	Quarterly	1,419,704	0.3
67	Sterl Law Sch	1554446	rwa	Quarterly	1,418,208	0.3

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
68	34 Hillhouse Luce Hall	7701499	rwa	Quarterly	1,293,292	0.2
69	Rmt Lt Ft 205 Prospect	8705895	rwa	Quarterly	1,291,796	0.2
70	Whitehall Apts 375-85 Canner	7701671	rwa	Quarterly	1,271,600	0.2
71	241 Elm St	6701630	rwa	Quarterly	1,261,876	0.2
72	Sloane Lab 217 Prospect St	8705896	rwa	Quarterly	1,218,492	0.2
73	Rmt On Pole Sidewalk - Elm	61929694	rwa	Quarterly	1,211,760	0.2
74	Mh 8" Comb Ser 6" Fire	1633280	rwa	Quarterly	1,196,800	0.2
75	High St Bfd Clg-Rnw	1554448	rwa	Quarterly	1,196,800	0.2
76	Trumbull Coll 241 Elm St	1554443	rwa	Quarterly	1,122,000	0.2
77	Whitehall Apts 545 Prospect	56724299	rwa	Quarterly	1,119,756	0.2
78	Rmt In Machine Rm	8705883	rwa	Quarterly	1,113,024	0.2
79	307 Mansfield Street	7701690	rwa	Quarterly	1,101,804	0.2
80	109 Grove St	7707595	rwa	Quarterly	1,084,600	0.2
81	Dwight Hall 85 High St	11701211	rwa	Quarterly	1,033,736	0.2
82	73 Sachem Street - Ingalls Rink	0007706679	rwa	Quarterly/ Monthly	1,031,492	0.2
83	304 Elm St	6704431	rwa	Quarterly	1,009,800	0.2
84	307 Mansfield Street	7701440	rwa	Quarterly	883,388	0.2
85	350 Congress Ave	7701653	rwa	Quarterly	879,648	0.2
86	141 Frontage Rd W D-18 Visitor C	8831933416	rwa	Quarterly/ Monthly	878,152	0.2
87	Rmtmhltfrt10hillhse Av	1554434	rwa	Quarterly	845,240	0.2
88	200 York St	7701502	rwa	Quarterly	830,280	0.1
89	276 Prospect Grad St Dorm	40289966	rwa	Quarterly	789,888	0.1
90	147 Leeder Hill Drive	6705597	rwa	Quarterly/ Monthly	786,148	0.1
91	Hendrie Hall 165 Elm St	53993492	rwa	Quarterly	745,756	0.1
92	Pst Insde Fen Accr#305	30780130	rwa	Quarterly	724,064	0.1
93	135 Prospect St	7707587	rwa	Quarterly	700,876	0.1
94	212 York St 2Nd R.R.	11704188	rwa	Quarterly	681,428	0.1
95	55 Hillhouse	56724081	rwa	Quarterly	673,200	0.1
96	43 Hillhouse Ave	7701692	rwa	Quarterly	670,208	0.1
97	300 College St	12700064	rwa	Quarterly	624,580	0.1
98	Street Hall	6701651	rwa	Quarterly	623,084	0.1
99	Rmt Grate Air Shaft Lt	31901402	rwa	Quarterly	596,904	0.1
100	221 Whitney Ave	26244074	rwa	Quarterly	575,212	0.1
101	55 Prospect St	0057864772	rwa	Quarterly/ Monthly	563,992	0.1
102	341 Crown St	0041406906	rwa	Quarterly/ Monthly	561,000	0.1
103	317 Crown	9702483	rwa	Quarterly	548,284	0.1
104	33-55 College St	8705341	rwa	Quarterly	512,380	0.1

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
105	Peabody Museum 198 Whitney	7706041	rwa	Quarterly	504,900	0.1
106	227 Mansfield House	60034766	rwa	Quarterly	478,720	0.1
107	871 Prospect St	007704201	rwa	Quarterly/ Monthly	463,760	0.1
108	117 Frontage Rd E-29 Day Care	007706105	rwa	Quarterly/ Monthly	460,768	0.1
109	314 Prospect St	11702298	rwa	Quarterly	442,068	0.1
110	McClellan Hall, Edwin	7707418	rwa	Quarterly	433,092	0.1
111	Maltby Avenue	7707564	rwa	Quarterly	421,872	0.1
112	400 Temple -Mason Lab Rear	7701541	rwa	Quarterly	368,764	0.1
113	111 Prospect (38 Hillhouse)	11701860	rwa	Quarterly	364,276	0.1
114	Rmt Lft Rear Sd Of Elm	7707251	rwa	Quarterly	362,780	0.1
115	60 Sachem St Sch Bus Mgmt	6705744	rwa	Quarterly	359,788	0.1
116	63 High Street	10704173	rwa	Quarterly	357,544	0.1
117	Rmt Outside Boiler Rm	11704893	rwa	Quarterly	344,828	0.1
118	202 York St	10701553	rwa	Quarterly	343,332	0.1
119	270 Crown Street	0006700124	rwa	Quarterly/ Monthly	332,860	0.1
120	Rmt Pst On Trumbull St	6707356	rwa	Quarterly	332,112	0.1
121	College Street	8705880	rwa	Quarterly	323,884	0.1
122	125 Frontage Rd W-D-221	006708216	rwa	Quarterly/ Monthly	314,908	0.1
123	1 Hillhouse Ave	0059293680	rwa	Quarterly/ Monthly	312,664	0.1
124	24 Hillhouse Rmt Rt	53981459	rwa	Quarterly	310,420	0.1
125	51 Prospect St	7706100	rwa	Quarterly	306,680	0.1
126	137 Frontage Rd	007706691	rwa	Quarterly/ Monthly	306,680	0.1
127	101 Ashmun St	0055903372	rwa	Quarterly/ Monthly	305,932	0.1
128	302 Temple St	6705750	rwa	Quarterly	305,184	0.1
129	64 Mansfield St B.D.	9706008	rwa	Quarterly	298,452	0.1
130	246 Church St	6708276	rwa	Quarterly	288,728	0.1
131	27 Hillhouse	11700191	rwa	Quarterly	284,988	0.1
132	149-57 York Street	8705352	rwa	Quarterly	281,996	0.1
133	Mh 34Ft S Ul Pole #388	7708234	rwa	Quarterly	276,012	0.0
134	10 Sachem St/158 Whitney Ave	6705611	rwa	Quarterly	268,532	0.0
135	470 College St	0007707273	rwa	Quarterly/ Monthly	264,044	0.0
136	35 Hillhouse	11701897	rwa	Quarterly	259,556	0.0
137	Yale Armory 70 Central Ave	7706038	rwa	Quarterly	253,572	0.0
138	258 Church St	0058443977	rwa	Quarterly/ Monthly	248,336	0.0
139	393 Prospect St Davies	7701556	rwa	Quarterly	239,360	0.0

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
140	68 High St JE College	7707353	rwa	Quarterly	234,872	0.0
141	Jon Edwards Col 197-223 York	7707388	rwa	Quarterly	234,124	0.0
142	810 Howard Ave - Parking Garage	7701555	rwa	Quarterly	234,124	0.0
143	155 Whitney Ave	60437598	rwa	Quarterly	225,896	0.0
144	335 Prospect St Farnham Gardens	7700497	rwa	Quarterly	224,400	0.0
145	165 Whitney Ave Evans Hall	6705729	rwa	Quarterly/ Monthly	221,408	0.0
146	300 Prospect St	40289915	rwa	Quarterly	219,164	0.0
147	Theatre Annex 205 Park St	8706018	rwa	Quarterly	216,172	0.0
148	103 Wall Woodbridge Hall	11700642	rwa	Quarterly	213,180	0.0
149	280 Roosevelt Dr Derby	0070159119	rwa	Quarterly/ Monthly	204,204	0.0
150	York Crown Apts 141 York St	8703211	rwa	Quarterly	203,456	0.0
151	459 Prospect St	41407668	rwa	Quarterly	201,212	0.0
152	Payne Whitney (90 York Square)	63868207	rwa	Quarterly	200,464	0.0
153	71 Goffe St	9704514	rwa	Quarterly	192,236	0.0
154	254 Prospect St	7704217	rwa	Quarterly	188,496	0.0
155	202 Prospect St	8704473	rwa	Quarterly	178,772	0.0
156	238 Prospect St	0011704729	rwa	Quarterly/ Monthly	173,536	0.0
157	363 St Ronan St Berkeley Cnt	56724071	rwa	Quarterly	172,040	0.0
158	Woolsey Hall	10702121	rwa	Quarterly	167,552	0.0
159	442 Temple St	9704453	rwa	Quarterly	162,316	0.0
160	150 Highland Street	63147687	rwa	Quarterly	154,836	0.0
161	115 Prospect St Rosenkranz Hall	8702670	rwa	Quarterly	142,868	0.0
162	52 Hillhouse	53981463	rwa	Quarterly	140,624	0.0
163	60 Sachem St	10704174	rwa	Quarterly	135,388	0.0
164	195 Prospect St	8702652	rwa	Quarterly	134,640	0.0
165	1120 Chapel St	8702556	rwa	Quarterly	131,648	0.0
166	310 Prospect St	11702471	rwa	Quarterly	131,648	0.0
167	53 Wall St	58438285	rwa	Quarterly	129,404	0.0
168	Sofn Line Masonic Rmt	1633276	rwa	Quarterly	127,160	0.0
169	Greeley Lab 270 Prospect	1633243	rwa	Quarterly	125,664	0.0
170	55 Lock St	0008700516	rwa	Quarterly/ Monthly	124,168	0.0
171	0 Heffernan Rd Water Pit 3	0007704335	rwa	Quarterly/ Monthly	116,688	0.0
172	141 Frontage Rd W D-18 Visitor C	0056219771	rwa	Quarterly/ Monthly	116,688	0.0
173	38 Mansfield St Mudd Library	10703434	rwa	Quarterly	115,940	0.0
174	34 Hillhouse Ave Luce Hall	7704582	rwa	Quarterly	109,956	0.0

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
175	Kirtland Hall - 2 Hillhouse	53964916	rwa	Quarterly	107,712	0.0
176	432 Temple St	9704221	rwa	Quarterly	106,216	0.0
177	309 Edwards St	63152329	rwa	Quarterly	103,224	0.0
178	165 Whitney Ave Evans Hall	0011701220	rwa	Quarterly/ Monthly	103,224	0.0
179	30 Hillhouse	53981452	rwa	Quarterly	102,476	0.0
180	217 Park St Rmte Left Fr	53993499	rwa	Quarterly	89,760	0.0
181	301 Crown St	8702137	rwa	Quarterly	89,012	0.0
182	37 Hillhouse	11701843	rwa	Quarterly	88,264	0.0
183	380 Edward St	11702636	rwa	Quarterly	86,768	0.0
184	237 Mansfield Old Greenhouse	11701283	rwa	Quarterly	85,272	0.0
185	15 Hillhouse Ave	11703513	rwa	Quarterly	83,776	0.0
186	393 Prospect St	8705337	rwa	Quarterly	82,280	0.0
187	295-297 Crown St	58300441	rwa	Quarterly	77,792	0.0
188	435 College St Admission Bld	58438320	rwa	Quarterly	71,808	0.0
189	17 Hillhouse Ave	7701494	rwa	Quarterly	71,808	0.0
190	Faculty Club 149 Elm St	9704554	rwa	Quarterly	71,060	0.0
191	Mh 202-Rmt Wall Rt Of	11702591	rwa	Quarterly	70,312	0.0
192	Elizabethan Club	59002275	rwa	Quarterly	70,312	0.0
193	96 Wall St Stoeckel Hall	6709681	rwa	Quarterly	69,564	0.0
194	211 Park Street	6705543	rwa	Quarterly	64,328	0.0
195	305 Crown St	58429209	rwa	Quarterly	59,840	0.0
196	400 Morgan La W A-42	007706682	rwa	Quarterly/ Monthly	59,840	0.0
197	230 Prospect St	7702751	rwa	Quarterly	59,092	0.0
198	215 Park St	8702598	rwa	Quarterly	58,344	0.0
199	451 College St	6703324	rwa	Quarterly	58,344	0.0
200	18 Ashmun St	31952679	rwa	Quarterly	56,100	0.0
201	210 Prospect St	0058443885	rwa	Quarterly/ Monthly	53,856	0.0
202	320 Temple St	9703122	rwa	Quarterly	52,360	0.0
203	75 Howe Street	0006705641	rwa	Quarterly/ Monthly	51,612	0.0
204	77 Prospect St	0058429228	rwa	Quarterly/ Monthly	50,116	0.0
205	294 Elm St Rear	53981461	rwa	Quarterly	44,880	0.0
206	301 Prospect St	11703775	rwa	Quarterly	41,140	0.0
207	204 Prospect St	0044518158	rwa	Quarterly/ Monthly	41,140	0.0
208	Marsh Hall 360 Prospect St	7708408	rwa	Quarterly	37,400	0.0
209	Maltby Avenue	7707519	rwa	Quarterly	37,400	0.0
210	31 Hillhouse	58443904	rwa	Quarterly	36,652	0.0
211	124 Prospect St B D	7701687	rwa	Quarterly	36,652	0.0

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
212	234 York St	9706496	rwa	Quarterly	32,164	0.0
213	252 Derby Ave	6702566	rwa	Quarterly	29,920	0.0
214	51 Hillhouse Avenue	9704174	rwa	Quarterly	29,172	0.0
215	270 Congress Avenue	0056223032	rwa	Quarterly/ Monthly	28,424	0.0
216	1201 Chapel St	0008705334	rwa	Quarterly/ Monthly	27,676	0.0
217	87-R Goffe Street	9703157	rwa	Quarterly	26,928	0.0
218	125-135 College St	0007707350	rwa	Quarterly/ Monthly	24,684	0.0
219	294 Elm St Boiler Rm	53981455	rwa	Quarterly	22,440	0.0
220	70 Sachem St Beech Tree	0011704427	rwa	Quarterly/ Monthly	22,440	0.0
221	65 Wall Street	1588568	rwa	Quarterly	18,700	0.0
222	55 Lock Street	0011704424	rwa	Quarterly/ Monthly	17,204	0.0
223	340 Edwards St	63867989	rwa	Quarterly	14,960	0.0
224	405 Temple St	44892409	rwa	Quarterly	14,212	0.0
225	339 Prospect St Woodworking	5700739	rwa	Quarterly	13,464	0.0
226	143 Elm St	53964927	rwa	Quarterly	12,716	0.0
227	89 Trumbull	6707091	rwa	Quarterly	10,472	0.0
228	279 Mansfield St Lt Of	58795926	rwa	Quarterly	10,472	0.0
229	87 Trumbull St	53338437	rwa	Quarterly	8,228	0.0
230	Science Hill Parking Garage	6704396	rwa	Quarterly	8,228	0.0
231	18 Ashmun Street	1633286	rwa	Quarterly	8,228	0.0
232	28 Edgewood Ave	0058443971	rwa	Quarterly/ Monthly	8,228	0.0
233	132 Davenport Ave	40241184	rwa	Quarterly	6,732	0.0
234	66-68 Wall	53981462	rwa	Quarterly	5,984	0.0
235	Whitney Avenue	6706576	rwa	Quarterly	4,488	0.0
236	Morse College Tower Pkwy	10702116	rwa	Quarterly	3,740	0.0
237	406 Prospect St	0051840432	rwa	Quarterly/ Monthly	3,740	0.0
238	344 Winchester	11701534	rwa	Quarterly	2,992	0.0
239	46 Hillhouse - Rear	58473458	rwa	Quarterly	2,244	0.0
240	505 College St	6708213	rwa	Quarterly	2,244	0.0
241	200 Conrad Dr	56221770	rwa	Quarterly	748	0.0
242	Rmt Ft/Opp 230 Pros Street	7706091	rwa	Quarterly	748	0.0
243	117 Frontage Rd E-29 Day Care	0007705841	rwa	Quarterly/ Monthly	748	0.0
244	Yale Block#622	7701518	rwa	Quarterly	0	0.0
245	56 High Rmt Stone Wall	8702657	rwa	Quarterly	0	0.0
246	17 Hillhouse Ave	7705771	rwa	Quarterly	0	0.0
247	8 Prospect Pl (Modular Bldg)	6707385	rwa	Quarterly	0	0.0

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
248	393 Prospect St	7708356	rwa	Quarterly	0	0.0
249	409 Prospect St	58795984	rwa	Quarterly	0	0.0
250	77 Prospect St (95 Trumbull)	53981457	rwa	Quarterly	0	0.0
251	St Anthony Hall 493 College		rwa	Quarterly	0	0.0
252	80 Sachem St B.D.	7701548	rwa	Quarterly	0	0.0
253	Mh 8" Comb Ser 6" Fire	7708339	rwa	Quarterly	0	0.0
254	285 Derby Ave Cullman Courts	7701417	rwa	Quarterly	0	0.0
255	19 Tower Pkwy Rmt Rtfrt On Brdwy Side	62249835	rwa	Quarterly	0	0.0
256	Rmt Rt Bsmt Dor 434 College	62249852	rwa	Quarterly	0	0.0
257	Rmt On Brkwl Lt Side	7708455	rwa	Quarterly	0	0.0
258	Wier Hall	64590225	rwa	Quarterly	0	0.0
259	Morse College Tower Pkwy (99 Tower Pkwy)	59136170	rwa	Quarterly	0	0.0
260	Morse College Tower Pkwy	58492204	rwa	Quarterly	0	0.0
261	Morse College Tower Pkwy	53559251	rwa	Quarterly	0	0.0
262	Stiles College Broadway	60034933	rwa	Quarterly	0	0.0
263	344 Temple Rm 327 Rmtwndfr	9702497	rwa	Quarterly	0	0.0
264	Silliman College 505 College		rwa	Quarterly	0	0.0
265	100 J W Murphy Dr	53981453	rwa	Quarterly	0	0.0
266	87 Goffe Street	9706467	rwa	Quarterly	0	0.0
267	Science Hill Parking Garage	6706780	rwa	Quarterly	0	0.0
268	150 York Street - Park Garage	6708329	rwa	Quarterly	0	0.0
269	150 York Street - Park Garage	7708155	rwa	Quarterly	0	0.0
270	Old Hammond Hall 14 Mansfield	8705880	rwa	Quarterly	0	0.0
271	Old Hammond Hall 14 Mansfield	8705880	rwa	Quarterly	0	0.0
272	Edwards Col 70 High St	1554429	rwa	Quarterly	0	0.0
273	Rmt Outside Boiler Rm	62249842	rwa	Quarterly	0	0.0
274	211 Park St	54572142	rwa	Quarterly	0	0.0
275	Whtnyklnegeogymhrmtpst	30786211	rwa	Quarterly	0	0.0
276	Rmt Ft Bd Rt Of Dwy205	55131245	rwa	Quarterly	0	0.0
277	Sloan 217 Pros Ft Wind	58429200	rwa	Quarterly	0	0.0
278	51 Hillhouse Ave	58443907	rwa	Quarterly	0	0.0
279	14 Mansfield St	6708212	rwa	Quarterly	0	0.0
280	14 Mansfield St	6708212	rwa	Quarterly	0	0.0
281	305 Congress Rmt Bx Left Side	8831909803	rwa	Quarterly	0	0.0
282	175 Whitney Ave Computer Cnt	26260861	rwa	Quarterly	0	0.0

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
283	147 Leeder Hill Drive	6705326	rwa	Quarterly/ Monthly	0	0.0
284	0 Heffernan Rd Water Pit 3	0059126738	rwa	Quarterly/ Monthly	0	0.0
285	400 Morgan Lane	0031909347	rwa	Quarterly/ Monthly	0	0.0
286	400 Morgan Lane Fire Pit 1	0011702205	rwa	Quarterly/ Monthly	0	0.0
287	55 Lock St	0009708524	rwa	Quarterly/ Monthly	0	0.0
288	26 High Street	0011704374	rwa	Quarterly/ Monthly	0	0.0
289	100 Prospect St	0051840439	rwa	Quarterly/ Monthly	0	0.0
290	275-285 Prospect St Crb	0061188024	rwa	Quarterly/ Monthly	0	0.0
291	150 Yale Ave Yale Bowl	0006703756	rwa	Quarterly/ Monthly	0	0.0
292	146 York St	0006709034	rwa	Quarterly/ Monthly	0	0.0
293	182-00 Winchester Ave	0059136073	rwa	Quarterly/ Monthly	0	0.0
294	137 Frontage Rd	0064590239	rwa	Quarterly/ Monthly	0	0.0
295	493 College Street	0010704179	rwa	Quarterly/ Monthly	0	0.0
296	89 Goffe St	0060367679	rwa	Quarterly/ Monthly	0	0.0
297	Yale Sailing Cntr Branford	0060034809	rwa	Quarterly/ Monthly	-	-
298	Rmt Lt Frt 222 York St	11704893	rwa	Quarterly	-	-
299	15 Mansfield O&M Dining Hall	58492332	rwa	Quarterly	-	-
300	252 Derby Ave	6702551	rwa	Quarterly	-	-
301	Esplanade Apts 386 Prospect	12700030	rwa	Quarterly	-	-

Table 2: Quarterly Water Rates (Effective July 21, 2011)

meter size	service charges	cost of consumption per 100 cubic feet
5/8"	$42.87	For All Meter Sizes First 1,000,000 Cubic Feet 3.179 Over 1,000,000 Cubic Feet 2.5
3/4"	47.68	
1"	59.17	
1-1/2"	93.09	
2"	125.83	
3"	220.19	
4"	320.72	
6"	535.44	
8"	993.88	
10"	1,420.05	
Privately owned	12.09	

Table 3: Quarterly Water Rates (Effective May 7, 2013)

meter size	service charges	cost of consumption per 100 cubic feet
5/8"	$49.79	$3.416
3/4"	58.09	3.416
1"	76.78	3.151
1-1/2"	116.22	3.151
2"	176.44	3.151
3"	516.02	2.921
4"	774.50	2.921
6"	1,449.20	2.921
8"	2,362.60	2.690
10"	3,358.94	2.690
12"	4,355.58	2.690
Privately owned	16.55	

Appendix B

Reclaimed Water System Case Studies

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Chemistry Research Building system

Chemistry Research Building
RODI system

Chemistry Research Building
irrigation

Case Study #1: Chemistry Research Building

System Overview

Chemistry Research Building is a 118,000-square-foot laboratory constructed in 2005 earning LEED Silver Certification. Chemistry Research Building includes two separate reclaimed water systems to provide nearly 100% of the flushing and irrigation demand with nonpotable water. In conjunction with low-flow fixtures and irrigation control, the design of the systems met the requirements of LEED NC WEc1, and exceeded the requirements for LEED NC WEc2 and LEED NC WEc3.

The first system utilizes water rejected from the reverse osmosis system for flushing. Reject is collected and pumped through an inline filter into a 2,000-gallon storage cistern. When the cistern is at capacity, overflow discharges to the sanitary sewer, as it would if no reclaimed water system were in place. A booster pump delivers water through a riser where blue dye is added to indicate its nonpotable status to 30 water closets and 6 urinals. If the float-level sensors in the cistern indicate low levels, potable water is added to accommodate the demand and keep the system operating. Altogether, the system supplies approximately 610 gallons per day of flushing water, saving more than 200,000 gallons per year.

The second system uses clear condensate collected from the cooling coils of the three air-handling units. This seasonal stream of water is an ideal source for meeting irrigation demand as the conditions that produce the highest volume of condensate coincide with peak irrigation needs. Condensate is collected in a 4,500-gallon storage cistern that supplies permanent irrigation to 10,250 square feet of turf and 2,550 square feet of shrub and tree beds. There is no additional treatment provided. The system supplies a peak demand of 7,500 gallons per week, saving an estimated 45,000 gallons per year.

Lessons Learned

Source

RODI backwash water is an attractive source of reclaimed water for toilet flushing because the supply is consistent, the water is low in pollutants, the supply and demand are closely matched, and the supply and demand systems are physically close in proximity.

Clear condensate is an attractive source of water for irrigation because condensate is available primarily during irrigation season.

Storage

The storage cistern is too large for the toilet-flushing demand of 610 gallons per day. Considering that enough RODI backwash water is produced daily for toilet flushing, the tank could be sized to store one or two days of flushing water.

Operation

The irrigation system has not been utilized since 2011, partially due to the construction occurring at nearby Kline Chemistry Laboratory during 2012 and 2013. Prior to this construction, the irrigation system was being used, but access to the control box within a basement mechanical room was less convenient than an exterior box. At times, it was easier to leave the system off and not irrigate than to turn on and off as needed.

Malone Engineering Center
RODI system

Malone storage cistern

Malone booster pump

Case Study #2: Malone Engineering Center

System Overview

Malone Engineering Center is a 65,000-square-foot laboratory constructed in 2005 earning LEED Gold Certification. The system at Malone Engineering Center was designed to reduce potable water demand by reusing the water rejected from a laboratory water purification process for toilet flushing. The system supplies the entire annual 70,500-gallon flushing demand with reclaimed water, helping to exceed the requirements for LEED NC WEc2 and WEc3.

A reverse osmosis system located on the penthouse level of the Malone Center is used to generate purified water for laboratory demand. Reject from the reverse osmosis process drains by gravity to a 2,000-gallon storage cistern located on the basement level. Duplex booster pumps call for water for toilet flushing from this storage cistern as needed. Blue dye is added to the flushing water to indicate nonpotable status. If reclaimed water is unavailable, potable makeup water fills the cistern. This system uses the least amount of energy of all the reclaimed water systems at Yale, operating with only one pump system and no additional treatment.

Lessons Learned

Source

Reverse osmosis reject water is an attractive source of reclaimed water for toilet flushing because the supply is consistent, the water is low in pollutants, the supply and demand are closely matched, and the reject water would otherwise be discharged as waste to the sanitary sewer.

Design

The 2,000-gallon storage cistern is unnecessarily large for the predicted toilet flushing demand of 10 water closets, calculated to be 297 gallons per day. Given the consistency of the supply, the storage cistern could have been reduced to a day tank size of twice-daily demand, about 600 gallons.

Operation

This reclaimed water system requires the least amount of pumping of all the systems installed at Yale. The reject water is transferred via gravity to the storage cistern, so only one booster pump system is needed to distribute water through the riser to toilets.

Sculpture day tank

Sculpture landscape

Sculpture rain garden

Case Study #3: Sculpture Building

System Overview

The Sculpture Bulding is a 64,000-square-foot academic building constructed in 2007 with a LEED Platinum Certification. The system was designed to provide approximately 30,000 gallons of nonpotable water for toilet flushing and to capture stormwater runoff from about 90% of storm events annually. In conjunction with low-flow fixtures, the system design exceeded the requirements of LEED NC WEc2 and LEED NC WEc3. The storage capacity and additional green infrastructure features of the project reduce stormwater runoff from the site to meet the requirements of LEED NC SSc6.1.

Stormwater runoff from the roof of the Sculpture Building along with any overflow from the landscaped rain garden is collected in an exterior underground 5,000-gallon storage cistern. Water is pumped from the exterior tank into a 400-gallon day tank located in the building basement. The water in the day tank is continuously circulated through an ozone treatment system for disinfection. In the event that water is not available for flushing, potable water is pumped to fill the day tank as backup. When called upon for toilet flushing needs, booster pumps send water into the riser and blue dye is added to indicate its non-potable status. The system supplies flushing water to 18 water closets with a daily demand of 132 gallons, saving approximately 30,000 gallons per year.

Lessons Learned

Storage

Given an average daily demand of 132 gallons per day, water within a full storage cistern requires about three weeks to be used entirely. The original design had provisions for an irrigation system that would also be supplied from this tank. But with the native plantings and green infrastructure landscaping, irrigation was deemed unnecessary and therefore was never installed. The long storage periods increase the need for treatment, and the volume of water within the exterior tank reduces the capacity to store additional stormwater.

The original design for interior storage included a custom-made stainless steel day tank to be installed horizontally. Necessary modifications during construction resulted in a vertical installation and required changes to piping and level sensors post occupancy.

Treatment

The system uses ozone technology to disinfect the reclaimed water. While ozone has the ability to achieve higher levels of disinfection than chlorine or UV, it requires more energy to operate. Given that UV has been shown to provide su∞-cient disinfection with lower energy costs, ozone treatment is not recommended for future installations.

Controls

The original control panel required proprietary software to retrieve information about the system operations. Therefore, in order for the physical plant managers and maintenance staff to obtain access to this data, an employee from the outside company had to be scheduled to come to the site and download the information. Without real-time readings of data, staff had no way of troubleshooting and solving emergency situations. As an interim solution, the physical plant manager installed a water level on the outside of the day tank and wrote key operational levels on the tank wall. The control panel has since been upgraded to a user-friendly version complete with a display screen that shows current tank levels.

Appendix C

Irrigation System Case Study

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50 Case Study: Berkeley College

Berkeley South bed

Berkeley South lawn

Berkeley South control box
(Hunter I-CORE system)

Berkeley South control box with bed

Berkeley South lawn, with
triangulated head-to-head
coverage

Presented is a case study comparison of a best and standard managment practice currently being implemented at Yale.

Example of Irrigation Best Management Practice: Berkeley South

This past year, a pilot project at Berkeley South was successfully implemented to improve irrigation e∞ciency on campus. This system represents an innovative irrigation setup for water management purposes. With its improved technology, it has the proper sprinkler system layout that should be utilized for all irrigation systems on campus—triangulated head-to-head coverage. All surfaces have the same level of water throughout to obtain proper coverage with sprinklers operating at similar pressures. Berkeley South has 10 zones, and includes a flow valve, rain sensor, Hunter I-CORE controller, soil sensor, triangulated head-to-head coverage, and a weather station to be installed soon. In the future, the I-CORE controllers will be able to talk to each other and use past usage statistics to control watering. Hunter I-CORE controller assets include a sensor that can be programmed by zone, and a total run-time calculator that contains a memory to overshadow any amount overwatered in the future.

Berkeley North lawn

Berkeley North control box
(Hunter Pro-C)

Berkeley North sprinkler layout, with
water spraying on walkways

Example of Irrigation Standard Management Practice: Berkeley North

In contrast, in Berkeley North, the sprinkler head systems are not set up with the proper layout scheme. Triangulated head-to-head coverage is preferred and not utilized here. However, so far, this method has not been widely implemented on campus.

Appendix D

Irrigation System Survey

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59 Table 1: Yale School of Medicine Irrigation Systems

61 Table 2: Yale Central Campus South Irrigation Systems

64 Table 3: Yale Central Campus North Irrigation Systems

67 Table 4: Yale Science Campus Irrigation Systems

A survey was completed of Yale's School of Medicine, Central Campus South and Central Campus North, and Science Hill irrigation systems. Future work includes analysis of West Campus and Athletic Fields.

Table 1: Yale School of Medicine Irrigation Systems

yale school of medicine campus	rotor or spray?	weekly schedule	system size (# heads)	where system is fed from (building and control box location)
1. Child Study Center – 230 South Frontage Rd. (9 zones)	spray	1.5 hours/day for 3 days/week	6 heads/ zone	220 South Frontage Road
2. Frog Pond at back of Child Study Center – 220 South Frontage Rd. (2 zones)	rotor	20 min/zone for 3 days/week	4 heads/ zone	220 South Frontage Road
3. Harkness Lawn – 367 Cedar St. (12 zones)	mix of rotors and sprays; more rotors than sprays	3.5 hours/day for 5 days/week		333 Cedar Street
4. I- and B-Wing (Rose Garden) – 333 Cedar St. (10 zones)	sprays and 1 drip line	10 min/zone for 4 days/week	5 heads/ zone	333 Cedar Street
5. Adjacent to Harkness Memorial Auditorium on the left side of Sterling Hall of Medicine – 333 Cedar St. (1 zone)	spray	10 min/zone for 3 days/week		333 Cedar Street
6. Adjacent to Yale-New Haven Hospital on Cedar St. – 20 York St. (5 zones)	spray	10 min/zone for 2 days/week		Yale-New Haven Hospital
7. Hope Memorial Building – 315 Cedar St. (4 zones)	spray	10 min/zone for 3 days/week		
8. Brady Memorial Lab – 310 Cedar St. (3 zones)	spray	10 min/zone for 3 days/week		
9. Brady Memorial Lab – 310 Cedar St. (3 zones) with old control box	spray	10 min/zone for 3 days/week		
10. Boyer Center for Molecular Medicine – 295 Congress St. (1 zone)	do not need to run	do not need to run		

yale school of medicine campus	rotor or spray?	weekly schedule	system size (# heads)	where system is fed from (building and control box location)
11. Cushing Courtyard/ LEPH – (17 zones)	mix of rotors (14) and stream sprays (3)	20 min/zone for 5 days/week		
12. Front of LEPH – 60 College St. (7 zones)	3 pop-up gear; 1 drip line; 3 stream spray	3 hours total for 5 days/week		from well
13. Anlyan Center – 300 Cedar St. (14 zones)	drip line/ stream spray	20 min/zone for 4 days/week		
14. PET Center (right side) –801 Howard Ave. (2 zones)	drip line	2 hours total for 2 days/week—rarely turned on		
15. PET Center (left side) – 801 Howard Ave. (2 zones)	1 spray, 1 drip line	2 hours total for 2 days/week—rarely turned on		
16. Yale Physicians Building (right side) – 800 Howard Ave. (3 zones)	spray	60 min total for 2 days/week		
17. Yale Physicians Building (left side) – 800 Howard Ave. (10 zones)	spray/pop-up gear drives	230 min total for 5 days/week		control box in Howard Ave. garage
18. Amistad Park (15 zones)	spray	5 days/week, usually Tuesday–Saturday (prefer to mow on Sunday/ Monday)	3–4 heads/ zone at 3–5 gal/min	control box using city water
19. Amistad Street Building–10 Amistad St.(2 zones)	do not need to run (spray/ pop-up rotor)	has not been run in 4 years, but if were to run, then typically 20 min/ zone		
Note Spray: ~3 gal/min (more water, less distance); Rotor: ~1.5 gal/min (less water, more distance)				

Table 2: Yale Central Campus South Irrigation Systems

yale central campus south (see notes for number of heads/zone)	rotor or spray?	weekly schedule
1. Old Campus (15 zones)	PGPs/sprays	
2. Trumbull (18 zones)	PGPs/sprays/drip line	run every other day: zones with PGP heads—20 min/zone; zones with smaller spray heads—10–15 min/zone
3. Trumbull Masters Rose Walk (2 zones)	drip line/sprays	
4. Trumbull Potty Court (4 zones)	drip line/sprays	
5. Saybrook–High Street Side (6 zones)	sprays	
6. Saybrook–York Street Side (4 zones)	sprays	
7. Branford (14 zones)	PGPs/sprays	
8. Branford Middle Court near Master's Office (4 zones)	sprays	
9. Library Walk (14 zones)	sprays/PGPs	
10. Jonathan Edwards (21 zones)	sprays/rotors/drip line	
11. Davenport (18 zones)	PGPs/sprays/drip line	
12. Davenport Rear (12 zones)	sprays/PGPs/drip line	
13. Davenport Masters (6 zones)	sprays/drip line	
14. Pierson (12 zones)	PGPs/sprays	
15. Pierson Masters (5 zones)	PGPs/sprays	
16. Chapel Street – Old Campus (7 zones)	sprays/rotors/drip line	
Note Spray: ~3 gal/min (more water, less distance); Rotor: ~1.5 gal/min (less water, more distance)		

Central Campus South Irrigation "Head Count"

OLD CAMPUS

1- 8 PGPs
2- 3 PGPs
3- 26 Sprays
4- 23 Sprays
5- 4 PGPs
6- 3 PGPs
7- 5 PGPs
8- 3 PGPs
9- 4 PGPs
10- 3 PGPs
11- 4 PGPs
12- 6 PGPs
13- 1 PGP & 12 Sprays
14- not working
15- 20 Sprays

TRUMBULL

1- 3 PGPs & 1 Spray
2- 3 PGPs & 2 Sprays
3- 5 PGPs
4- 3 PGPs & 1 Spray
5- 3 PGPs
6- 6 Sprays
7- 7 Sprays
8- 7 Sprays
9- 8 Sprays
10- 7 Sprays
11- 12 Sprays
12- 7 Sprays
13- 7 Sprays
14- 7 Sprays
15- Drip Line
16- Drip Line
17- 6 Home-owner rotary—smaller rotary
18- 6 Sprays

TRUMBULL MASTERS ROSE WALK

1- Drip Line
2- 12 Sprays

TRUMBULL POTTY COURT

1- 8 Sprays
2- Drip Line
3- 9 Sprays
4- Drip Line

SAYBROOK – HIGH STREET SIDE

1- 14 Sprays
2- 19 Sprays
3- 16 Sprays
4- 13 Sprays
5- 6 Sprays
6- 10 Sprays

SAYBROOK – YORK STREET SIDE

1- 15 Sprays
2- 28 Sprays
3- 20 Sprays
4- 18 Sprays

BRANFORD

1- 5 PGPs
2- 5 PGPs
3- 5 PGPs
4- PGPs
5- 4 PGPs
6- 5 Sprays
7- 1 PGP & 4 Sprays
8- 16 Sprays
9- 18 Sprays
10- 1 PGP & 10 Sprays
11- 9 Sprays
12- 3 PGPs & 1 Sprays
13- 10 Sprays
14- 14 Sprays

BRANFORD MIDDLE CT. NEAR MASTERS OFFICE

1- 8 Sprays
2- 8 Sprays
3- 6 Sprays
4- 7 Sprays

LIBRARY WALK

1- 4 Sprays
2- 6 Sprays
3- 5 PGPs
4- 6 PGPs
5- 6 Sprays
6- 6 Sprays
7- 6 Sprays
8- 5 Sprays
9- 6 Sprays
10- 5 Sprays
11- 6 Sprays
12- 6 Sprays
13- 6 Sprays
14- 7 Sprays

JONATHAN EDWARDS

1- 4 Sprays
2- 3 Sprays
3- 3 Home-owner rotary
4- 3 Home-owner rotary
5- 3 Home-owner rotary
6- 3 Home-owner rotary
7- 3 Home-owner rotary
8- 3 Home-owner rotary
9- 3 Home-owner rotary
10- 5 Sprays
11- 5 Sprays
12- Drip Line
13- Drip Line
14- Drip Line
15- Drip Line
16- 1 Spray
17- Drip Line
18- Drip Line
19- Drip Line
20- Drip Line
21- Drip Line

DAVENPORT

1- 5 PGPs
2- 5 PGPs
3- 4 PGPs

4- 5 PGPs
5- 6 PGPs
6- 3 PGPs
7- 3 PGPs
8- 7 Sprays
9- 5 Sprays
10- 6 Sprays
11- 7 Sprays
12- 8 Sprays
13- 12 Sprays
14- 12 Sprays
15- 9 Sprays
16- 8 Sprays
17- 8 Sprays
18- Drip Line

DAVENPORT REAR

1- 7 Sprays
2- 6 Sprays
3- 7 Sprays
4- 3 PGPs
5- 4 PGPs
6- 6 Sprays
7- 3 Sprays
8- 6 Sprays
9- 6 Sprays
10- 14 Sprays
11- 7 Sprays
12- Drip Line

DAVENPORT MASTERS

1- 6 Spray
2- 8 Sprays
3- 2 Sprays & Drip Line
4- 2 Sprays & Drip Line
5- 4 Sprays
6- Drip Line

PIERSON

1- 8 PGPs & 1 Spray
2- 4 PGPs & 5 Sprays
3- 8 PGPs
4- 7 PGPs
5- 4 PGPs
6- 10 Sprays
7- 9 Sprays
8- 14 Sprays
9- 13 Sprays
10- 12 Sprays
11- 8 Sprays
12- 12 Sprays

PIERSON MASTERS

1- 5 Sprays
2- 5 Sprays
3- 4 PGPs
4- 4 PGPs & 1 Spray
5- 6 Sprays

CHAPEL STREET – OLD CAMPUS

1- 4 Sprays
2- 8 Home-owner rotary & 2 Sprays
3- 6 Home-owner rotary & 2 Sprays
4- 7 Home-owner rotary & 1 Spray
5- Drip Line
6- Drip Line
7- Drip Line

Table 3: Yale Central Campus North Irrigation Systems

yale central campus north (see notes for number of heads/zone)	rotor or spray?	weekly schedule
1. Woodbridge Hall (5 zones)	rotors/PGJs/sprays/ drip line	
2. Cross Campus (11 zones)	I-40s/sprays/I-25s/KPS	
3. Berkeley South (10 zones)	PGJs/mp rotors/PGP ultra/ mp rotors/PGPs/sprays	Watered every other day: 30 min/ zone for lawns; once a week for beds
4. Rose Walk (2 zones)	PGPs	
5. Berkeley North (8 zones)	PGJs/sprays/rotors/PGPs	Watered every other day: 30 min/ zone for lawns; once a week for beds
6. Calhoun (17 zones)	sprays/PGJs	
7. Swing Dorm (7 zones)	PGPs/sprays/rotors	
8. Stiles (8 zones)	sprays/PGPs/PGJs	
9. Stiles Main (15 zones)	PGPs/sprays/auto fill/rain bird (c500)	
10. Morse (32 zones)	PGPs/sprays/rotors/PGJs/ drip line/auto fill/tree emitters	
11. Back of Toad's next to Morse (9 zones)	PGPs/sprays/drip lines	
12. Back of Toad's (8 zones)	PGPs/sprays/mp rotors/ PGPs	
13. Law School	PGPs	
14. Hall of Graduate Studies (8 zones)	sprays/heads	
15. Timothy-Dwight (16 zones)	sprays/mp rotors/heads	
16. College St. outside Silliman (4 zones)	sprays	
17. Silliman top deck (14 zones)	sprays/PGJs	
18. Silliman bottom deck/yard (23 zones)	sprays/drip line/PGJs/ heads	
19. 451 College St. (5 zones)	sprays/heads	
Note Spray: ~3 gal/min (more water, less distance); Rotor: ~1.5 gal/min (less water, more distance)		

Central Campus North Irrigation "Head Count"

Woodbridge Hall—5 zones

1- 5 Rotors
2- 4 Rotors
3- 6 Small Rotors – PGJ
4- 7 Sprays
5- Drip on trees

Cross Campus—11 zones

1- 51-40s
2- 5 1-40s
3- 12 1-40s
4- 5 sprays
5- 9 Hunter 1-25
6- 6 I-40s
7- 12 KPS^
8- 6 I-40s
9- 6 sprays
10- 16 sprays
11- 5 I-40s

Berkeley South—10 zones

1- Ivy Bed 7 PGJ
2- 6 PGJ
3- 23 mp rotors
4- 4 PGP ultra
5- 5 mp rotors-lawn area
6- 5 mp rotors
7- 8 PGP
8- 8 PGP
9- 5-wall along east
10- 9 sprays—dining hall side

Rose Walk—2 zones

1- 4 PGP
2- 3 PGP

Berkeley North—8 zones

1- 4 PGJ
2- 6 sprays
3- 3 rotors
4- 7 rotors PGP
5- 4 sprays
6- 8 sprays
7- 6 sprays
8- 6 sprays

Calhoun—17 zones

1- 8 sprays
2- 5 sprays
3- 6 PGJ rotors
4- 5 PGJ rotors
5- 6 sprays
6- 10 sprays
7- 6 sprays
8- 8 sprays
9- 4 sprays
10- 8 sprays
11- 10 sprays
12- 10 sprays
13- 7 sprays
14- 7 sprays
15- 12 sprays
16- 6 sprays
17- 10 sprays

Swing Space Dorm—7 zones

1- 16 PGP
2- 14 sprays
3- 16 PGP (mix of heads)
4- 10 PGP
5- 20 PGP
6- 10 sprays
7- 13 rotors; 1 spray

Stiles—8 zones

1- 5 sprays
2- 5 sprays
3- 5 sprays
4- 2 PGP (Broadway)
5- 3 PGP
6- 4 PGJ
7- 4 sprays
8- 4 sprays

Stiles Main—16 zones

1- 4 PGP
2- 4 PGP
3- 5 sprays
4- 10 Rain Birds (c500)
5- 6 sprays
6- 6 sprays
7- 9 sprays
8- 12 sprays
9- 6 sprays
10- 6 sprays
11- 9 sprays
12- 15 sprays
13- 11 sprays
14- Trees-5
15- 8 sprays
16- Autofill

Morse—32 zones

1- 7 PGP; 4 sprays
2- 5 PGP; 3 sprays
3- n/a
4- 28 sprays
5- Wired with 4
6- 6 sprays
7- 18 sprays
8- 10 sprays
9- 11 sprays
10- 8 sprays
11- 8 sprays; 4 Hunter sprays
12- 17 sprays
13- 11 sprays
14- 6 sprays
15- 5 sprays
16- 7 sprays
17- 8 rotors; 1 spray
18- 5 rotors
19- 7 rotors
20- 6 PGJ
21- n/a
22- Tree emitters

^(Komet Precision Sprays)

23- Drip
24- 8 rotors
25- 8 sprays
26- 4 PGP; 2 sprays
27- 6 PGP
28- 6 PGP
29- 7 PGP
30- 13 sprays
31- 16 sprays
32- Autofill

Back of Toads—9 zones *(next to Morse)*

1- 3 PGP
2- 4 PGP
3- 6 sprays
4- 5 sprays
5- 7 sprays
6- 6 sprays
7- 8 sprays
8- 7 sprays
9- Drips

Back of Toads (2)—8 zones

1- 2 PGP; 1 mp rotor; 1 spray
2- 4 PGP; 1 spray
3- 3 PGP
4- 7 sprays
5- 5 mp rotors
6- 5 rotors 7-PGP
7- 8 sprays
8- 6 sprays

Law School

13 PGP

Hall of Graduate Studies—8 zones

1- 7 sprays
2- 4 sprays
3- 1 spray 4-heads
4- 4 heads
5- 4 heads
6- 4 heads
7- 4 heads
8- 2 heads

Timothy Dwight—16 zones

1- 15 sprays
2- 30 sprays
3- 6 mp rotors
4- 6 mp rotors
5- 4 mp rotors
6- 5 mp rotors
7- 7 mp rotors
8- 10 sprays
9- 4 sprays
10- 4 heads
11- 4 heads
12- 8 sprays
13- 7 sprays
14- 18 sprays
15- 2 sprays
16- 15 mp rotors

College Street outside Silliman—4 zones

1- 12 sprays
2- 9 sprays
3- 8 sprays
4- 8 sprays

Silliman Top Deck—4 zones

1- 10 sprays
2- 10 sprays
3- 7 sprays
4- 5 sprays
5- 4 PGJ
6- 4 sprays
7- 5 sprays
8- 9 sprays
9- 5 sprays
10- 4 sprays
11- 4 sprays
12- 5 sprays
13- 5 sprays
14- 4 PGJ

Silliman Bottom Deck/Yard—23 zones

1- 18 sprays
2- Drip Line
3- 11 sprays
4- 13 sprays
5- 26 sprays
6- 14 sprays
7- 24 sprays
8- 22 sprays
9- 11 sprays
10- 4 PGJ
11- 24 sprays
12- 26 sprays
13- 17 heads
14- 4 sprays
15- 5 sprays
16- 6 sprays
17- 9 heads
18- 10 heads
19- 15 sprays
20- 10 heads
21- 4 sprays
22- 13 heads
23- 9 heads

451 College Street—5 zones

1- 4 sprays
2- 4 sprays
3- 3 heads
4- 3 heads
5- 12 heads

Table 4: Yale Science Campus Irrigation Systems

yale science campus	rotor or spray?	weekly schedule
1. SSS – Prospect & Grove St.; Kirkland Hall (rear) – 2 Hillhouse Ave. & corner of SSS (3 systems)		
2. Becton/Dunham Lab – 10 Hillhouse Ave. (1 system)		
3. Statistics – 24 Hillhouse Ave. (1 system) (6 zones)	sprays/ rotors	30 min/zone
4. Provosts Office/Language Lab – 370 Temple, 1 Hillhouse Ave., and Grove St. (1 system) (10 zones)	sprays/ rotors	10 min/zone (4 zones); 40 min/zone (5 zones); 45 min/zone (1 zone) – 5 times/week
5. Mason Lab – 9 Hillhouse Ave. (1 system)		
6. Music Instruments Museum – 15 Hillhouse Ave. for St. Mary's to the Canal (1 system)		
7. Old Health Center – 17 Hillhouse Ave. (1 system)		
8. 27 and 31 Hillhouse Ave. (1 system)		
9. Provost residence – 35 and 37 Hillhouse Ave. (1 system)		
10. President's Residence – 43 Hillhouse Ave. (1 system)		
11. Horchow Hall/Anthropology – 51 and 55 Hillhouse Ave. (1 system)		
12. SOM – 56/54 Hillhouse Ave. (1 system)		
13. SOM – 46 Hillhouse Ave. (1 system)		
14. Admissions – 38 Hillhouse Ave. (1 system)		
15. Luce Building – 34 Hillhouse Ave (1 system); also runs Rosencrantz		
16. Economics – 28 and 30 Hillhouse Ave. (1 system)		
17. Asian Studies – 442 Temple St. (1 system)		
18. Rosenfeld Hall – 109 Grove St. (1 system)		
19. ESC and Peabody Museum – 40 Sachem St. and 170 Whitney Ave. (1 system)		
20. Kroon Hall (1 system that uses rain water)		not irrigated in two years
21. ITS/HR – 221 Whitney Ave. (1 system)		
22. Chem. Research Building – 275 Prospect St. (1 large system not running)		not running
23. Divinity School – 423 Prospect St. – front, inner courtyard, and rear (2 Systems)		
24. Divinity School – 459 Prospect St. (1 system)		

yale science campus	rotor or spray?	weekly schedule
25. Betts House Prospect St. (1 system)		
26. 310–314 Prospect St. (1 system)		
27. 270 Prospect St. (1 system)		
28. Health Center – 55 Locke St. (5 systems)		
29. Rose Centre – Ashmun St. (1 system)		

Appendix E

Priority Water Meters

Contents

73 Table 1: Yale University Priority Water Meters–Top 80% of Annual Water Usage

75 Table 2: Yale University Priority Water Meters–Top 95% of Annual Water Usage

Table 1: Yale University Priority Water Meters – Top 80% of Annual Water Usage

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
1	18 Ashmun St	31904141	rwa	Quarterly	59,427,104	10.6
2	309 Congress Avenue	70030356	rwa	Quarterly	49,992,580	8.9
3	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	36,396,932	6.5
4	0 Heffernan B-45 Water Pit 4	0001568651	rwa	Quarterly/ Monthly	35,679,600	6.4
5	18 Ashmun St	31904141	rwa	Quarterly	29,920,000	5.3
6	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	22,484,880	4.0
7	309 Congress Avenue	70030356	rwa	Quarterly	22,027,852	3.9
8	0 Heffernan Rd York Cooling Tower	0001587444	rwa	Quarterly/ Monthly	18,501,780	3.3
9	300 Cedar St	0001577905	rwa	Quarterly/ Monthly	18,026,800	3.2
10	10 Amistad St	0059293682	rwa	Quarterly/ Monthly	17,685,712	3.2
11	295 Congress Ave	6702526	rwa	Quarterly	10,016,468	1.8
12	Mh 34Ft S Ul Pole #388	1577907	rwa	Quarterly	8,299,808	1.5
13	0 Heffernan Rd - West Campus	007704335	rwa	Quarterly/ Monthly	8,257,920	1.5
14	Kline Chemistry 245 Prospect	1587445	rwa	Quarterly	7,851,756	1.4
15	Pinhall Rmt Grove rear kit	1554447	rwa	Quarterly	6,803,060	1.2
16	Mnsachem Rmt Pst Tree	30780133	rwa	Quarterly	6,622,792	1.2
17	70 Tower Pky	31952680	rwa	Quarterly	6,471,696	1.2
18	CCCP Bottom City Water Meter		Yale Office of Facilities	Daily	6,300,784	1.1
19	CCCP Top City Water Meter		Yale Office of Facilities	Daily	6,278,144	1.1
20	150 Yale Ave Yale Bowl	0005702503	rwa	Quarterly/ Monthly	6,277,964	1.1
21	354 Temple St / Silliman	7701535	rwa	Quarterly	6,164,268	1.1
22	Derby Ave	10704214	rwa	Quarterly	5,580,080	1.0
23	Branford College 98 High St	1554449	rwa	Quarterly	5,011,600	0.9
24	Pierson College 221 Park St	1554437	rwa	Quarterly	4,591,972	0.8
25	Rmtbx Inside Wall Twr	1577988	rwa	Quarterly	4,546,344	0.8
26	Corner Grove & Prospect	1554433	rwa	Quarterly	4,515,676	0.8
27	206 Elm St	11704876	rwa	Quarterly	4,220,216	0.8
28	Timothy Dwight College 116 Grove	1554430	rwa	Quarterly	4,136,440	0.7
29	125-135 College St	0007707439	rwa	Quarterly/ Monthly	4,084,080	0.7
30	184 Liberty St - YPI	8702700	rwa	Quarterly	3,526,820	0.6
31	240Yrkdvnptrmtltftdrst*	10700001	rwa	Quarterly	3,393,676	0.6
32	Berkeley College Elm St	6705741	rwa	Quarterly	3,351,788	0.6

*Davenport College 240 York St

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
33	Conn Hall Welch Meter	7701538	rwa	Quarterly	3,305,412	0.6
34	Rmt Rt Entr Across Toads	54572592	rwa	Quarterly	3,170,772	0.6
35	150 Yale Ave	8805702503	rwa	Quarterly/ Monthly	3,127,388	0.6
36	Rmt-Campus-Farnhm Hl	57864750	rwa	Quarterly	3,017,432	0.5

Table 2: Yale University Priority Water Meters – Top 95% of Annual Water Usage

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
1	18 Ashmun St	31904141	rwa	Quarterly	59,427,104	10.6
2	309 Congress Avenue	70030356	rwa	Quarterly	49,992,580	8.9
3	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	36,396,932	6.5
4	0 Heffernan B-45 Water Pit 4	0001568651	rwa	Quarterly/ Monthly	35,679,600	6.4
5	18 Ashmun St	31904141	rwa	Quarterly	29,920,000	5.3
6	305 Congress Rmt Bx Lt Side	31909803	rwa	Quarterly	22,484,880	4.0
7	309 Congress Avenue	70030356	rwa	Quarterly	22,027,852	3.9
8	0 Heffernan Rd York Cooling Tower	0001587444	rwa	Quarterly/ Monthly	18,501,780	3.3
9	300 Cedar St	0001577905	rwa	Quarterly/ Monthly	18,026,800	3.2
10	10 Amistad St	0059293682	rwa	Quarterly/ Monthly	17,685,712	3.2
11	295 Congress Ave	6702526	rwa	Quarterly	10,016,468	1.8
12	Mh 34Ft S Ul Pole #388	1577907	rwa	Quarterly	8,299,808	1.5
13	0 Heffernan Rd - West Campus	007704335	rwa	Quarterly/ Monthly	8,257,920	1.5
14	Kline Chemistry 245 Prospect	1587445	rwa	Quarterly	7,851,756	1.4
15	Pinhall Rmt Grove rear kit	1554447	rwa	Quarterly	6,803,060	1.2
16	Mnsachem Rmt Pst Tree	30780133	rwa	Quarterly	6,622,792	1.2
17	70 Tower Pky	31952680	rwa	Quarterly	6,471,696	1.2
18	CCCP Bottom City Water Meter		Yale Office of Facilities	Daily	6,300,784	1.1
19	CCCP Top City Water Meter		Yale Office of Facilities	Daily	6,278,144	1.1
20	150 Yale Ave Yale Bowl	0005702503	rwa	Quarterly/ Monthly	6,277,964	1.1
21	354 Temple St / Silliman	7701535	rwa	Quarterly	6,164,268	1.1
22	Derby Ave	10704214	rwa	Quarterly	5,580,080	1.0
23	Branford College 98 High St	1554449	rwa	Quarterly	5,011,600	0.9
24	Pierson College 221 Park St	1554437	rwa	Quarterly	4,591,972	0.8
25	Rmtbx Inside Wall Twr	1577988	rwa	Quarterly	4,546,344	0.8
26	Corner Grove & Prospect	1554433	rwa	Quarterly	4,515,676	0.8
27	206 Elm St	11704876	rwa	Quarterly	4,220,216	0.8
28	Timothy Dwight College 116 Grove	1554430	rwa	Quarterly	4,136,440	0.7
29	125-135 College St.	0007707439	rwa	Quarterly/ Monthly	4,084,080	0.7
30	184 Liberty St - YPI	8702700	rwa	Quarterly	3,526,820	0.6
31	240Yrkdvnptrmtltftdrst*	10700001	rwa	Quarterly	3,393,676	0.6
32	Berkeley College Elm St	6705741	rwa	Quarterly	3,351,788	0.6

*Davenport College 240 York St

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
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34	Rmt Rt Entr Across Toad's	54572592	rwa	Quarterly	3,170,772	0.6
35	150 Yale Ave	8805702503	rwa	Quarterly/ Monthly	3,127,388	0.6
36	Rmt-Campus-Farnhm Hl	57864750	rwa	Quarterly	3,017,432	0.5
37	Helen Hadley Hall - 420 Temple	1554427	rwa	Quarterly	2,954,600	0.5
38	141 Frontage Rd W-D-18 Visitor C	0031933416	rwa	Quarterly/ Monthly	2,831,928	0.5
39	Becton Lab Prospect St	10704175	rwa	Quarterly	2,804,252	0.5
40	Wh Athlt Fld Rmt Pst	7707394	rwa	Quarterly	2,699,532	0.5
41	New Residence Hall	11704879	rwa	Quarterly	2,558,908	0.5
42	409 Prospect St	1572971	rwa	Quarterly	2,543,200	0.5
43	Soccer Field	1633237	rwa	Quarterly	2,535,720	0.5
44	MorseCollegeTowerPkwy (99Tower Pkwy)	8702677	rwa	Quarterly	2,305,336	0.4
45	Central Avenue	12700045	rwa	Quarterly	2,297,108	0.4
46	275-285 Prospect St Crb	0053994177	rwa	Quarterly/ Monthly	2,245,496	0.4
47	Rmt Ft Door 400 Temple	7701585	rwa	Quarterly	2,230,536	0.4
48	55 Lock St	0009708524	rwa	Quarterly/ Monthly	2,226,048	0.4
49	Rmt Frt Dr Art Gal Arch	1554436	rwa	Quarterly	2,219,316	0.4
50	MorseCollegeTowerPkwy	10702113	rwa	Quarterly	2,068,968	0.4
51	400 Morgan Lane Water Pit 1	0031909347	rwa	Quarterly/ Monthly	2,051,016	0.4
52	1156 Chapel Street	7706713	rwa	Quarterly	2,031,568	0.4
53	Yale Avenue	6708352	rwa	Quarterly	2,014,364	0.4
54	Rmt Lt Ft 165 Prospect	11704059	rwa	Quarterly	1,979,956	0.4
55	Stiles College Broadway	10702123	rwa	Quarterly	1,960,508	0.4
56	19TowerPkwy Rmt Rtfrt On BrdwySide	8703269	rwa	Quarterly	1,890,944	0.3
57	200 Conrad Dr	1588076	rwa	Quarterly	1,855,040	0.3
58	170 Whitney Ave	7706090	rwa	Quarterly	1,751,816	0.3
59	344 Winchester	31931549	rwa	Quarterly	1,727,132	0.3
60	Whitehall Apts 511 Prospect	6704463	rwa	Quarterly	1,608,948	0.3
61	Calhoun College 189 Elm St	8705900	rwa	Quarterly	1,551,352	0.3
62	32 Edgewood Ave	0007701515	rwa	Quarterly/ Monthly	1,522,180	0.3
63	Rmt Rt Bsmt Dor 434 College	8702673	rwa	Quarterly	1,465,332	0.3
64	Rmt Left Side 800 Rear	7701567	rwa	Quarterly	1,446,632	0.3
65	Rmt On Pole Sidewalk	7707256	rwa	Quarterly	1,445,884	0.3
66	Berkeley College Wall St	1554428	rwa	Quarterly	1,419,704	0.3
67	Sterl Law Sch	1554446	rwa	Quarterly	1,418,208	0.3
68	34 Hillhouse Luce Hall	7701499	rwa	Quarterly	1,293,292	0.2
69	Rmt Lt Ft 205 Prospect	8705895	rwa	Quarterly	1,291,796	0.2
70	WhitehallApts 375-85 Canner	7701671	rwa	Quarterly	1,271,600	0.2

	"logical device name" (ecap)	meter number	responsible party	frequency	cy12 representative baseline (gallons)	% of total
71	241 Elm St	6701630	rwa	Quarterly	1,261,876	0.2
72	Sloane Lab 217 Prospect St	8705896	rwa	Quarterly	1,218,492	0.2
73	Rmt On Pole Sidewalk - Elm	61929694	rwa	Quarterly	1,211,760	0.2
74	Mh 8" Comb Ser 6" Fire	1633280	rwa	Quarterly	1,196,800	0.2
75	High St Bfd Clg-Rnw	1554448	rwa	Quarterly	1,196,800	0.2
76	Trumbull Coll 241 Elm St	1554443	rwa	Quarterly	1,122,000	0.2
77	Whitehall Apts 545 Prospect	56724299	rwa	Quarterly	1,119,756	0.2
78	Rmt In Machine Rm	8705883	rwa	Quarterly	1,113,024	0.2
79	307 Mansfield Street	7701690	rwa	Quarterly	1,101,804	0.2
80	109 Grove St	7707595	rwa	Quarterly	1,084,600	0.2
81	Dwight Hall 85 High St	11701211	rwa	Quarterly	1,033,736	0.2

Acknowledgments

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