# Town of Barnstable

## Barnstable Wastewater Energy Recovery (WWER) Pilot Study

## Final Report

April 2016

# TOWN OF BARNSTABLE

# WASTEWATER ENERGY RECOVERY (WWER) PILOT STUDY

# TOWN OF BARNSTABLE, MASSACHUSETTS

Prepared for

BARNSTABLE, MASSACHUSETTS

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# List of Common Acronyms

| | |
|---|---|
| AEC | Alternative Energy Credits |
| DOER | Department of Energy Resources |
| EER | Energy Efficiency Ratio |
| gpm | gallons per minute |
| HDPE | High Density Polyethylene |
| kWh | Kilowatt Hour |
| O&M | Operations and Maintenance |
| PVC | Polyvinyl Chloride |
| WPCF | Water Pollution Control Facility |
| WWER | Wastewater Energy Recovery |

# 1. Introduction

## 1.1 Background

The Town of Barnstable has actively pursued policies and implemented energy-efficiency improvements at its Water Pollution Control Facility (WPCF) to both lower energy costs and reduce carbon emissions for over two decades. In the Town's continuing effort to find ways to reduce energy consumption throughout its infrastructure, it became interested in piloting a wastewater energy recovery (WWER) unit at its largest wastewater pumping station in order to utilize the heat energy in wastewater for heating and cooling applications at some of its municipal buildings.

In 2014 the Town was awarded a grant through the Massachusetts Department of Energy Resources (DOER) Waste Water Energy Recovery Assistance Program to pilot a Huber ThermWin WWER unit at its largest wastewater pumping station. The Town retained GHD to assist in completing its obligations towards the above referenced grant.

The following tasks were included in the scope of the project:

1. Conduct a pilot installation.
    - Coordinate the pilot installation with the manufacturer.
    - Coordinate with the Town to hire an electrician, mechanical contractor, and fence installer.
    - Monitor unit operation and collect data from the manufacturer.
    - Coordinate the decommissioning of the pilot unit and temporary utilities via contractors.
2. Develop a Feasibility Memorandum.
    - Evaluate the collected pilot data.
    - Develop a feasibility memorandum to:
        - Assess background.
        - Describe the pilot program.
        - Summarize results.
        - Estimate simple payback.
3. Conceptual Design.
    - If the unit, along with available funding, is determined to be feasible on a cost and maintenance basis, then a conceptual design of the system will be completed and project costs will be further refined.

## 1.2 Wastewater Energy Recovery (WWER) Overview

An overview of the WWER process is provided through the following excerpt from the DOER PON-ENE-2014-025.

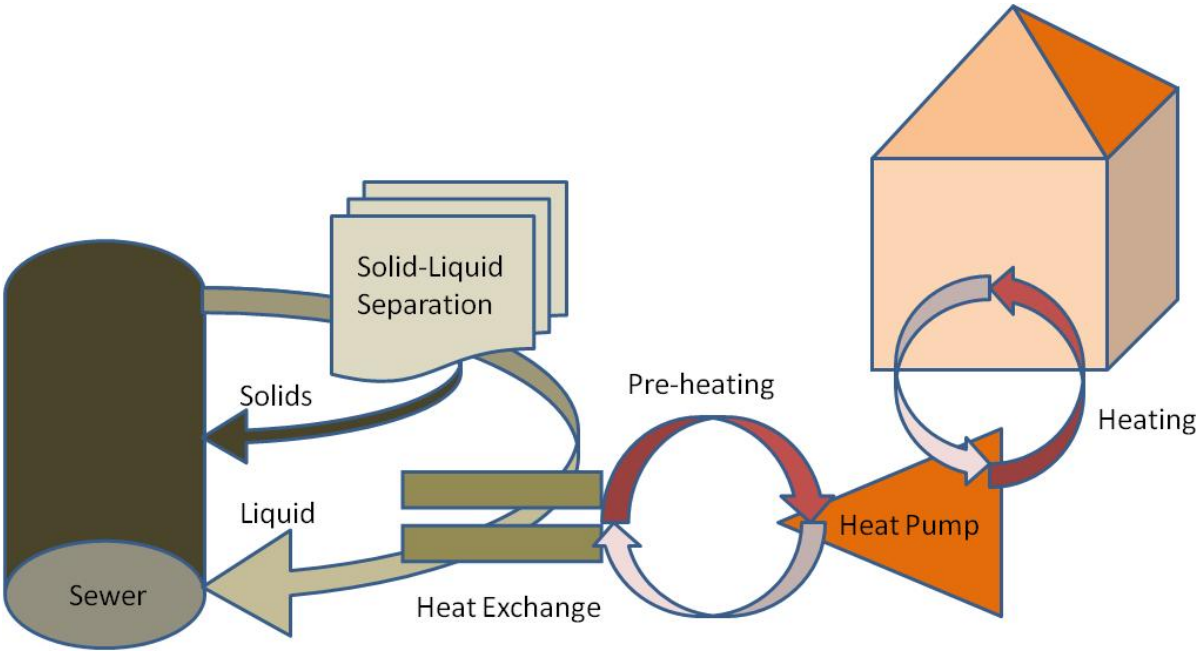
*'Thermal energy is used for heating and cooling buildings, as well as for certain industrial processes. Today almost all of this energy is generated from fossil fuels like natural gas, propane or heating oil. But there is an expanding opportunity to use local renewable energy resources such as*

*sunlight, sustainable biomass, the earth or ambient air. Technologies to use these renewable resources have been around for decades and are deployed around the world, but have recently become increasingly efficient, cost-effective and clean. One renewable technology that has received little attention in the United States to-date is "waste water energy recovery" (WWER). WWER is the process by which heat energy is transferred from or to waste water for heating or cooling applications, respectively.*

*Much of the energy used to heat water for domestic uses and industrial processes is lost as the heated water flows down the drain. WWER projects aim to re-capture some of that wasted energy to heat buildings and to use the waste water as a heat sink for cooling loads, similar to a ground-source heat pump using groundwater to heat and cool buildings. In contrast, however, WWER has the potential to be more efficient than ground-source heat pumps because the sewage water in pipes is generally much warmer than ground water. Additionally, WWER uses the pre-existing waste water pipes present in a building or sewer, rather than drilling for new pipes into the ground, and can be applied within a building or within a larger waste water system such as municipal sewer systems.*

*There are several components of WWER that function together in order to accomplish the transfer of energy to or from the waste water. The main components of a WWER system are the sewage source, the separation mechanism for solids and liquids, the heat exchanger, and the heat pump. Air- and water-source heat pumps have been widely used for decades and are beginning to be more widely deployed as their efficiency gains recognition. The innovation in WWER is using heat pumps in a new setting, namely in sewage. WWER technology works by adapting the screening technologies already in use by sewer systems for use in energy recovery applications.*

*The following is a diagram of a waste water energy recovery system with the building receiving the heating energy on the right. Note that the waste water is always maintained in its own independent loop on the left; after traveling through a screening and/or grinding process for solid-liquid separation, it flows through the heat exchanger and returns to the sewer. The energy is transferred to the fluid in the heat exchanger, to then enter the building and brought up to sufficient temperature through a heat pump to heat the building. Thus, the waste water never actually enters the building or its heating system.*




*WWER has been deployed in China, Germany and Switzerland, but only at a very few sites in the United States. These few sites have typically deployed WWER within the waste water treatment facility (WWTF) in the treated effluent as it is discharged, primarily because this is the cleanest point in a sewer system. However, deploying WWER at this location greatly limits its potential because WWTFs are typically located far from buildings having high heating and cooling loads.*

*In order to develop experience and familiarity with WWER in Massachusetts, the Massachusetts Department of Energy Resources (DOER) Waste Water Energy Recovery Assistance Program (WWER Program) provides financial assistance to WWER projects for technical studies or implementation. By assisting the first WWER projects, DOER is working to build a new alternative thermal technology market that has the potential to reduce energy costs, increase energy supply diversity, and reduce greenhouse gas emissions.'*

# 2. Pilot Design and Intentions

The Huber ThermWin unit was installed at the Old Colony Pumping Station, which is the Town's largest raw wastewater pumping station. The pumping station is located in the Village of Hyannis, which is within the Town of Barnstable. This location was chosen due to its proximity to two large municipal buildings—Barnstable Town Hall and the School Administration Building—as shown in Figure 1. Municipal buildings are ideal for this application because they represent a long-term stable energy user in comparison to commercial establishments which may change ownership frequently or go out of business.

The two buildings have been at their current location for over 50 years and are likely to be in continuous operation for many years to come, thereby providing a long-term user of heating or cooling capacity. The Town Hall building has approximately 25,000 square feet of conditioned space and currently utilizes an 80-ton chiller with evaporative cooling tower and natural gas boiler for cooling and heating, respectively. The School Administrative building has approximately 15,000 square feet of conditioned space and also utilizes a chiller with evaporative cooling tower and a natural gas boiler.

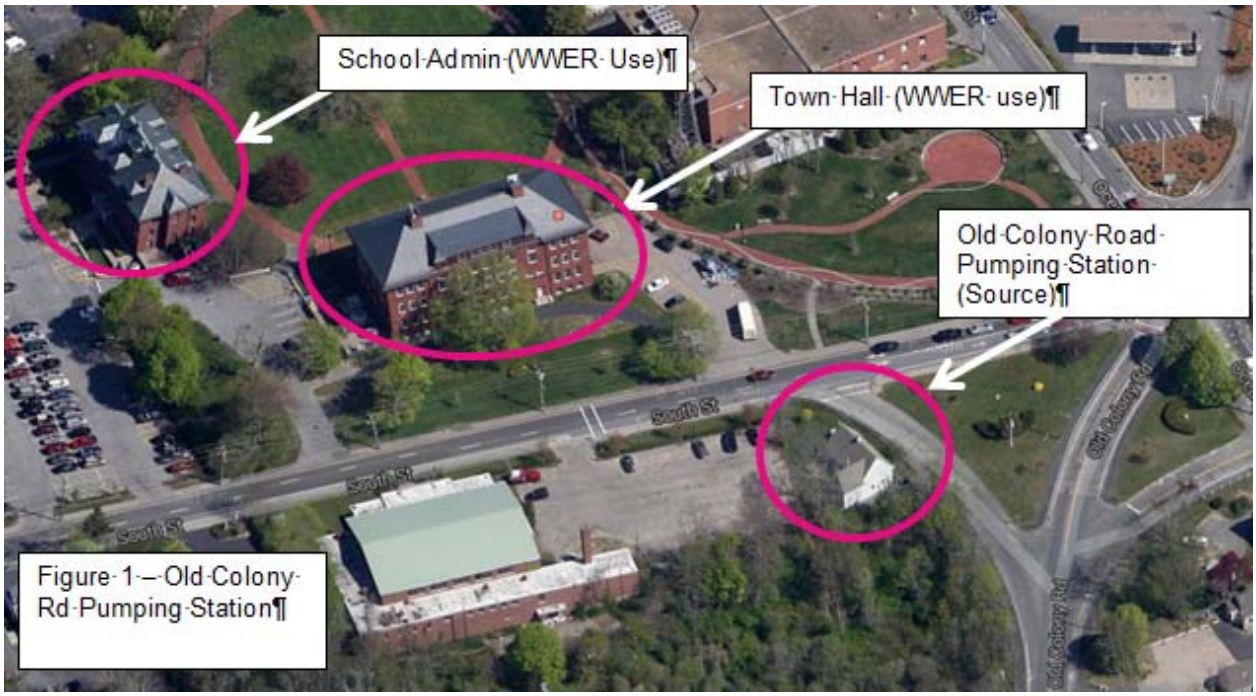



Figure 1 Pilot Location

Although Huber has several WWER installations in Europe, the technology has no operating installations in North America. The primary goal of piloting the WWER unit was to assess the operations and maintenance requirements of using a raw wastewater source for heat exchange.

## 2.1 Overview of ThermWin System

The Huber ThermWin unit, shown in Figure 2, consists of a series of horizontal heat exchange pipe modules enclosed in a stainless steel tank. Pre-screened wastewater flows by gravity through the ThermWin unit. Heat exchange occurs between the wastewater and clean water loop through "pipe modules". A mechanical wiper system is operated periodically (typically once a day) to minimize

biofilm growth on the heat exchange surfaces. Huber has indicated that the unit has minimal regular maintenance requirements and did not provide any monthly/quarterly/annual maintenance requirement guidelines. The manufacturer noted that the wiper system rings need to be replaced on an approximately five-year basis.

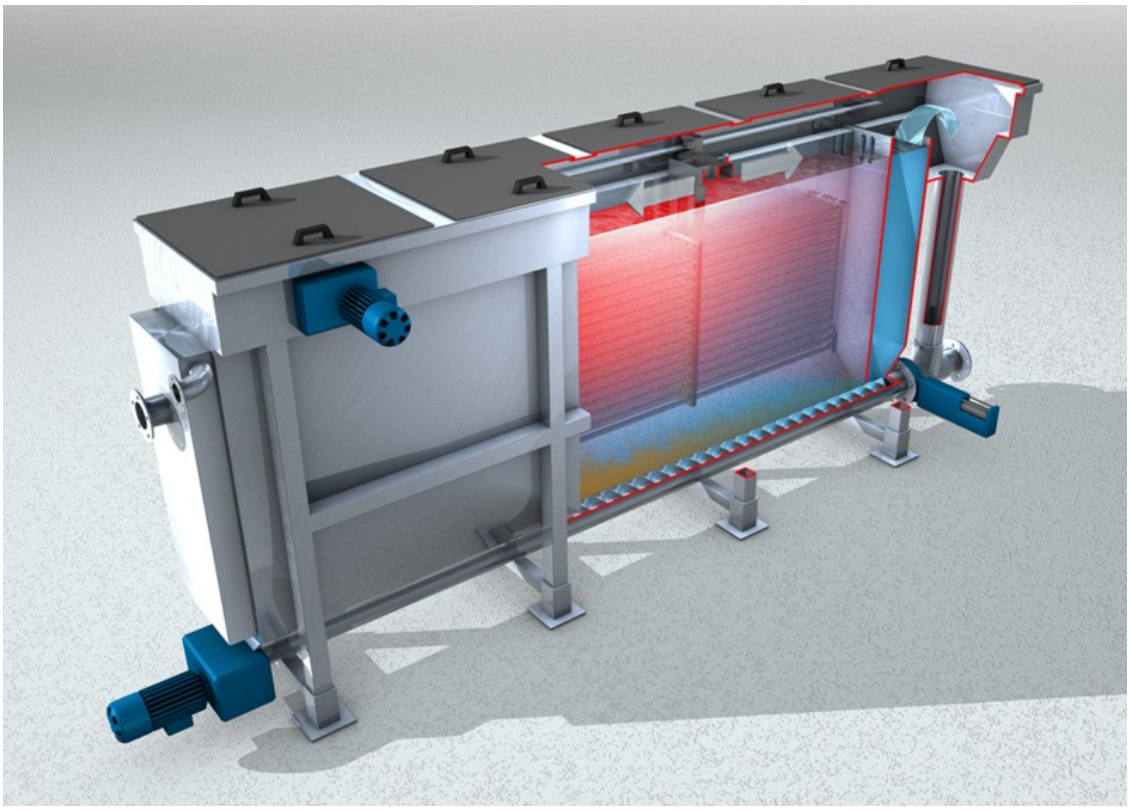


Figure 2 Huber ThermWin Unit (Provided by Huber)

## 2.2 Pilot Setup

The pilot setup consisted of the temporary installation of a Huber Strainpress coarse material separator unit and a Huber ThermWin BG4 WWER unit (Figure 3). The BG4 unit is rated for 238 gpm of wastewater flow. The approximate dimensions of the BG4 unit are listed below:

Length = 17 feet

Width = 5 feet

Height = 7 feet

The existing force main was tapped and piping was installed to convey flow to the screenings unit and WWER unit. Once flow passed through the two units it was returned to the pumping station's wet well. Due to heat exchange being a well-proven technology with multiple operational applications in the United States, the main goal of operating the pilot was to assess how well the unit operates with raw wastewater. The unit was not connected to the Town Hall's cooling system. Energy recovery potential calculations were based on industry established calculations for heat exchange.

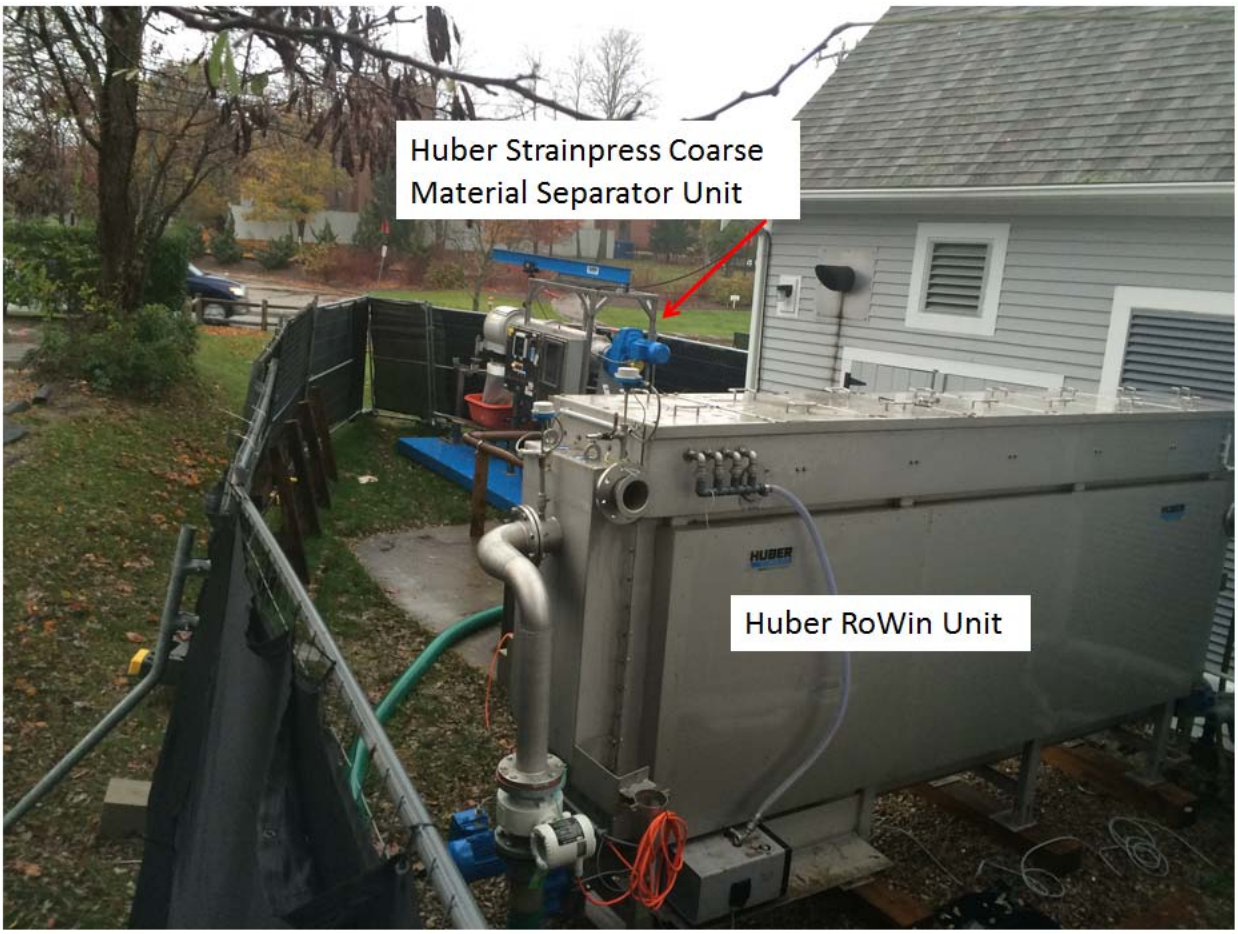



Figure 3 Pilot Setup

A pilot schematic is shown in Figure 4.

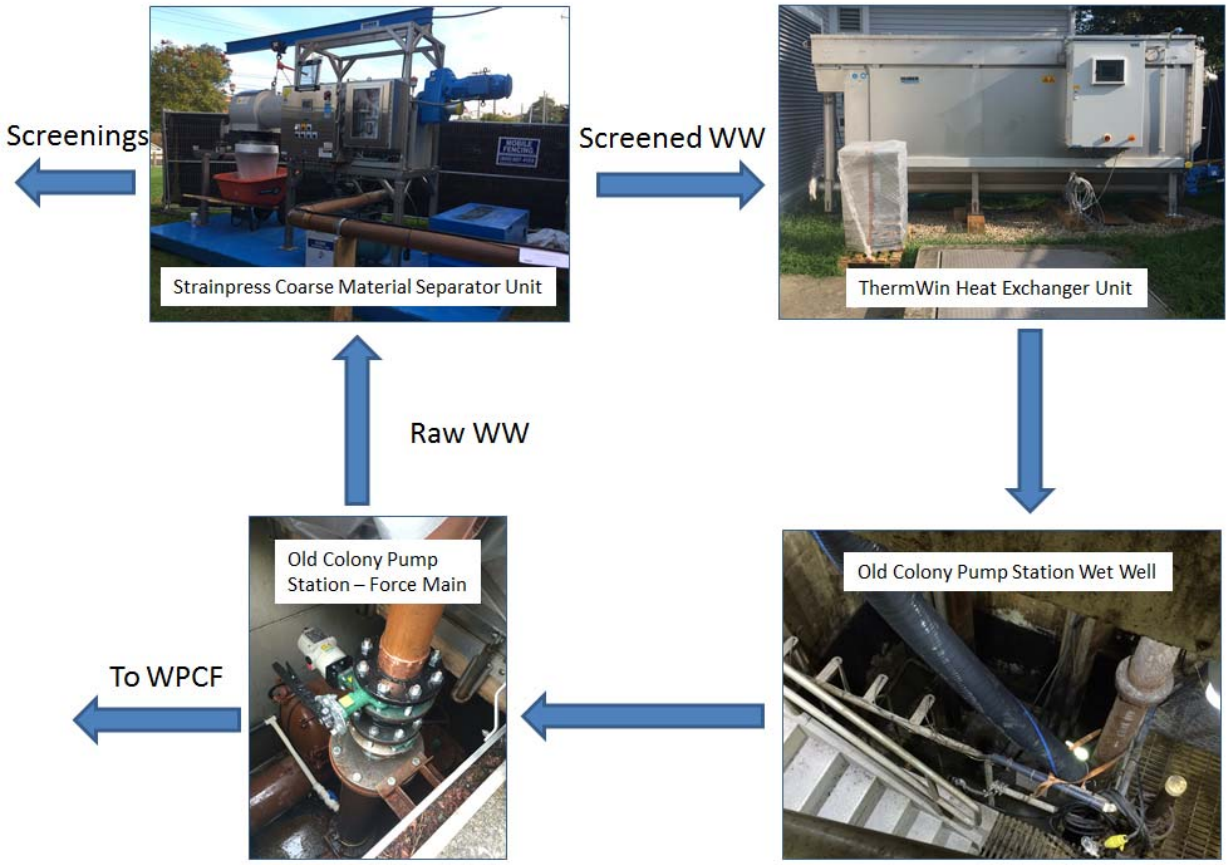



Figure 4 Pilot Schematic

## 2.3 Pilot Timeline

Prior to the delivery of the pilot unit the following work was performed on site:

- A temporary fence was installed around the site to restrict access to the pilot unit (due to security concerns).
- A mechanical contractor laid the base for the unit, which comprised of a gravel bed and two 8-inch by 8-inch timber planks to distribute the weight of the unit over the gravel bed.
- The screenings unit (provided by Huber) was delivered to the site.
- The wall of the pump station was core drilled to allow PVC drain piping to be installed from the unit to the wet well.

After the work described above had been completed the ThermWin unit was delivered to the site. After the unit was on site, the following work took place over a week long period (the time required to set up the unit was driven primarily by the availability of the contractors required to perform the work):

- Copper piping, a motorized shutoff valve, and a butterfly valve were installed between the force main and the inlet of the screenings unit.
- Flexible hosing (provided by Huber) was used to connect the outlet of the screenings unit to the inlet of the ThermWin unit.

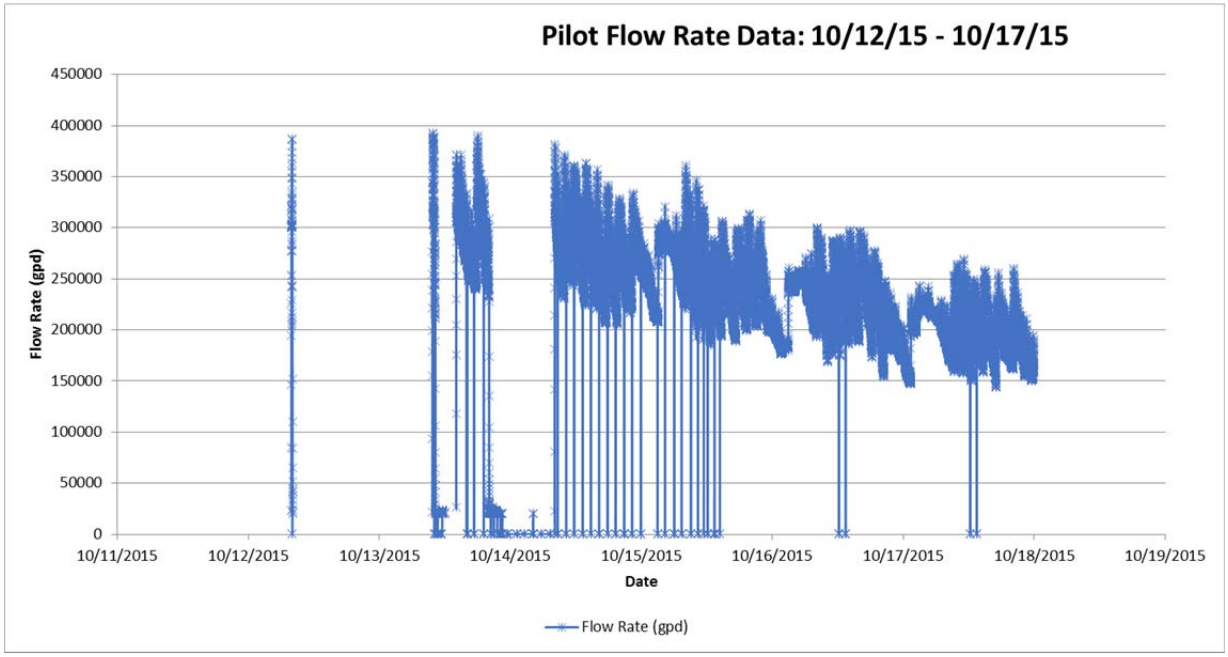
- A PVC drain line was installed to allow flow from the ThermWin unit to drain back to the pumping station wet well.
- An electrical contractor connected the motorized shutoff valve to the screenings unit control panel so that the valve would close and isolate the pilot system if the screenings unit registered a fault. The pilot system would remain isolated until an operator visited the site, diagnosed the fault, and brought the system back online. The electrical contractor also connected the pilot unit to the pumping station's electrical system.

Once the pilot setup was complete a representative from Huber started up the unit. The representative was on site for a week to troubleshoot the unit during initial operation. During this time period the pilot system was shut down whenever no one was at the site.

After the month-long pilot operation, the unit was decommissioned and removed from site over a one-day period. Once the unit was removed the site was restored to its original condition.

# 3. Data Collection

Flow, inlet temperature, and outlet temperature data were collected for the duration of the pilot through instrumentation provided by Huber. Pilot flow data is summarized in the following Figure 5.



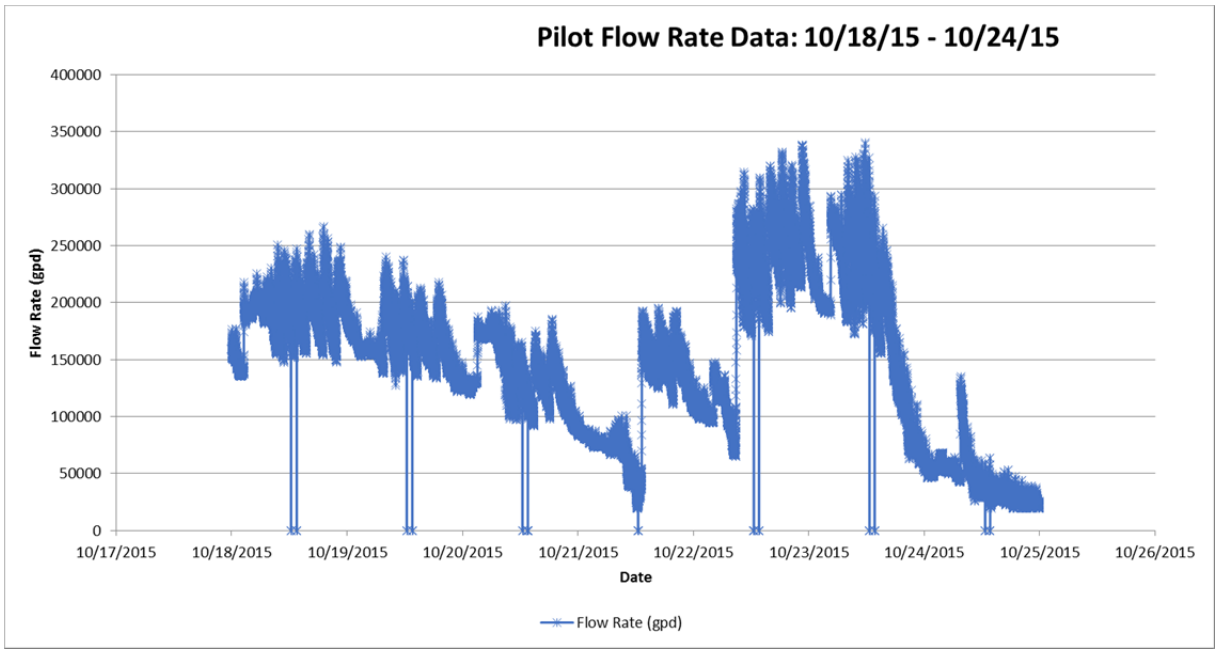
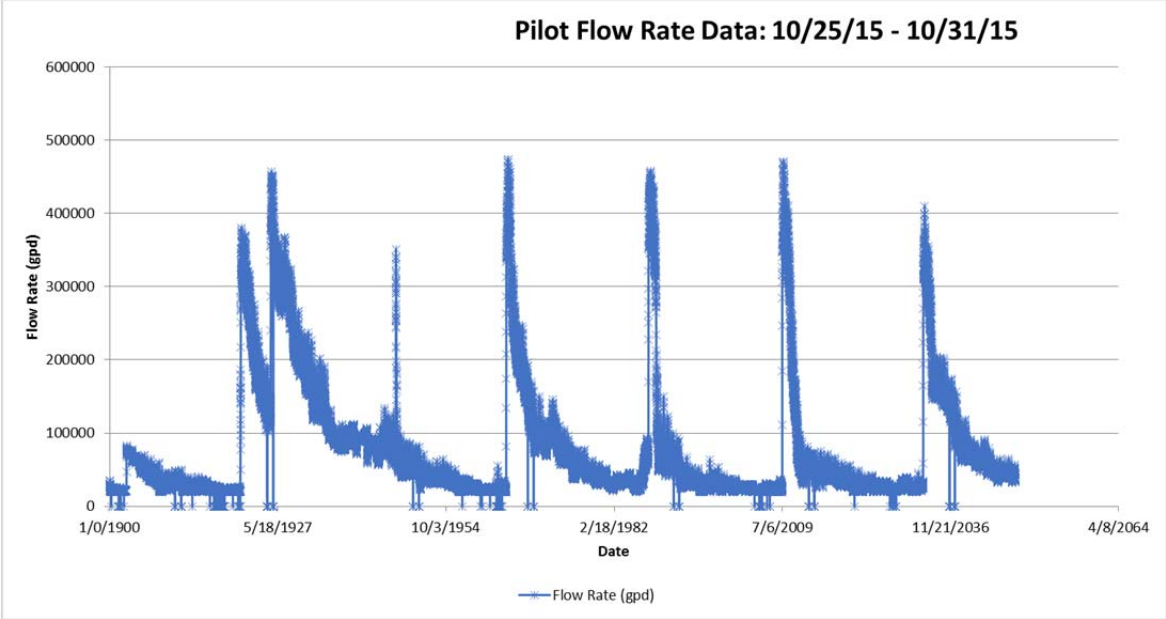




Figure 5 Pilot Flow Rate Data

(Figure 5 continued on following page.)



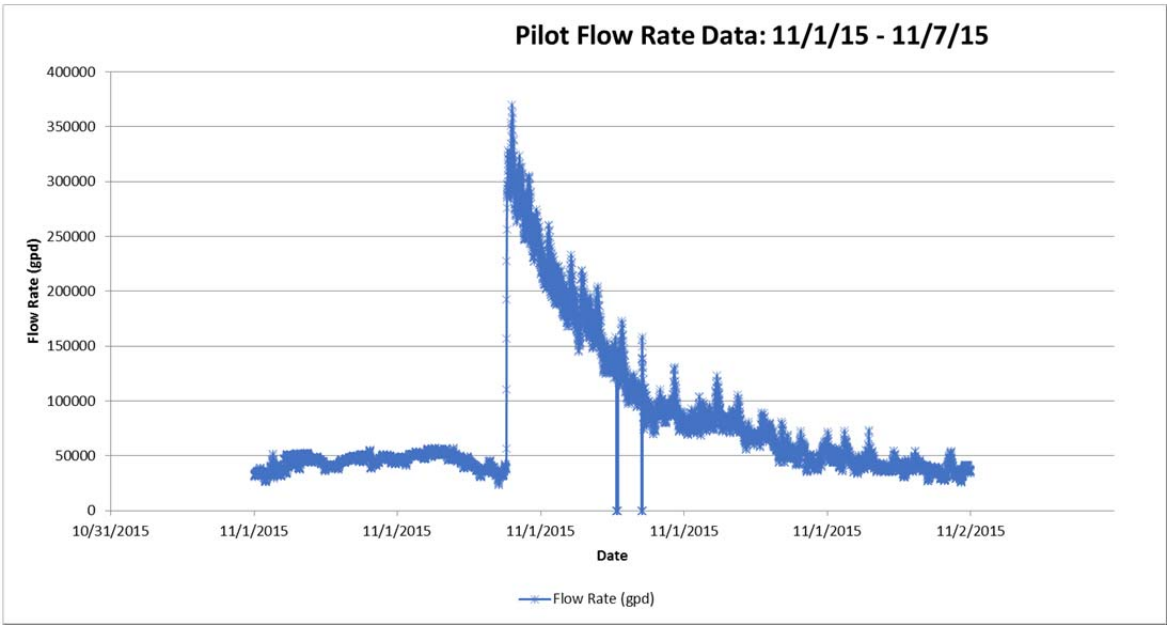
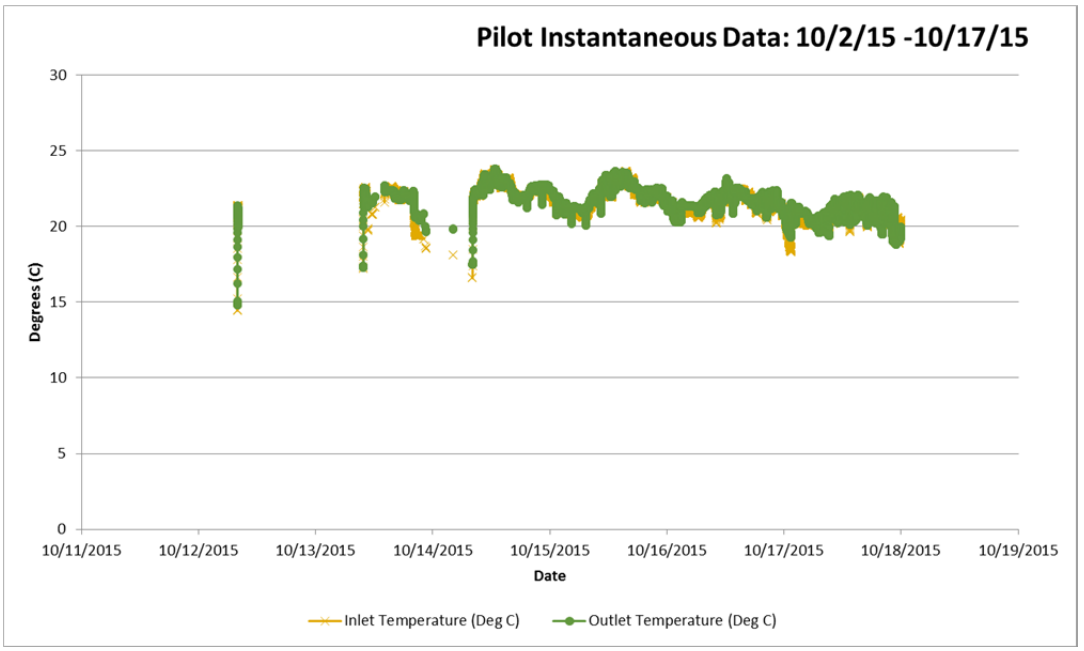




Figure 5 Pilot Flow Rate Data (continued)

Inlet and outlet temperature data are summarized in the following Figure 6.



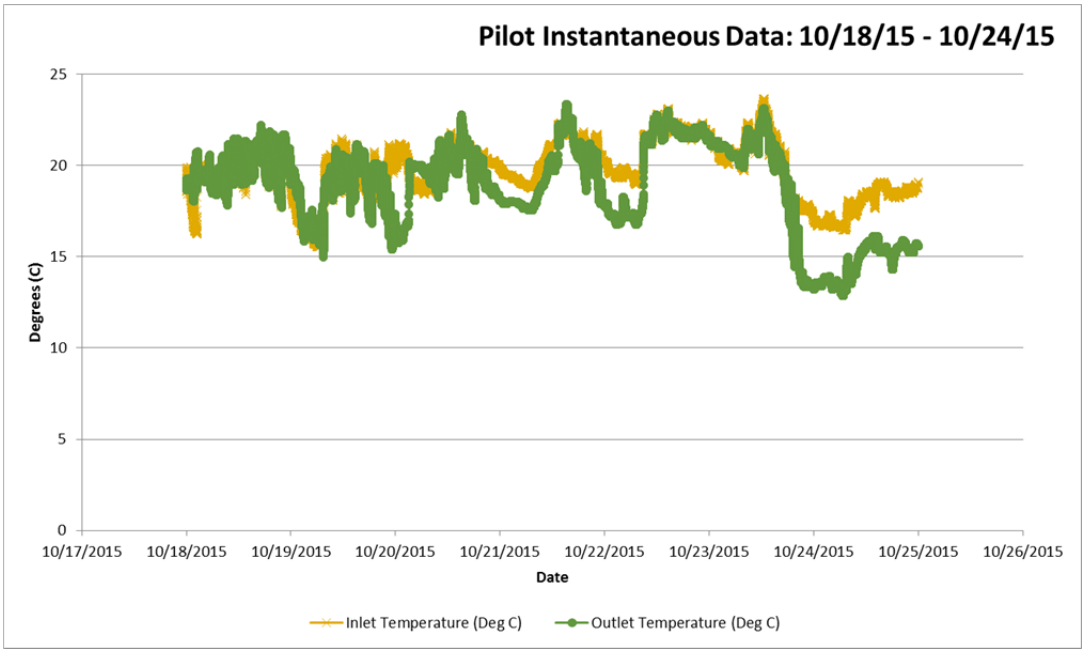
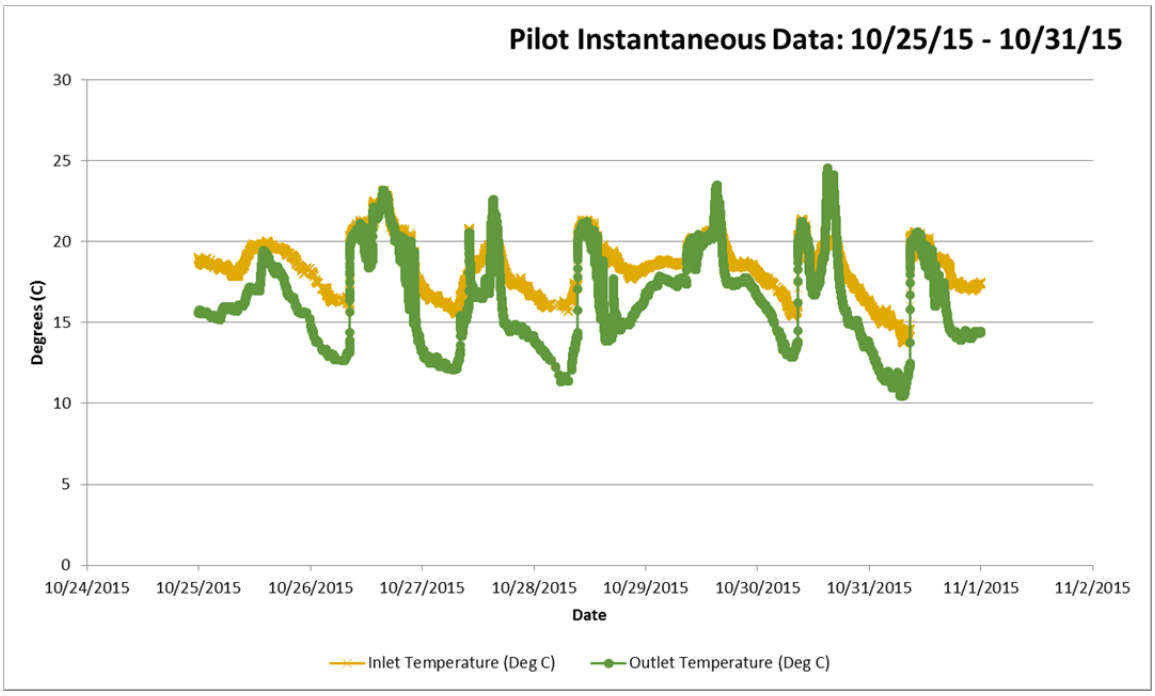




Figure 6 Pilot Instantaneous Temperature Data

(Figure 6 continued on following page.)



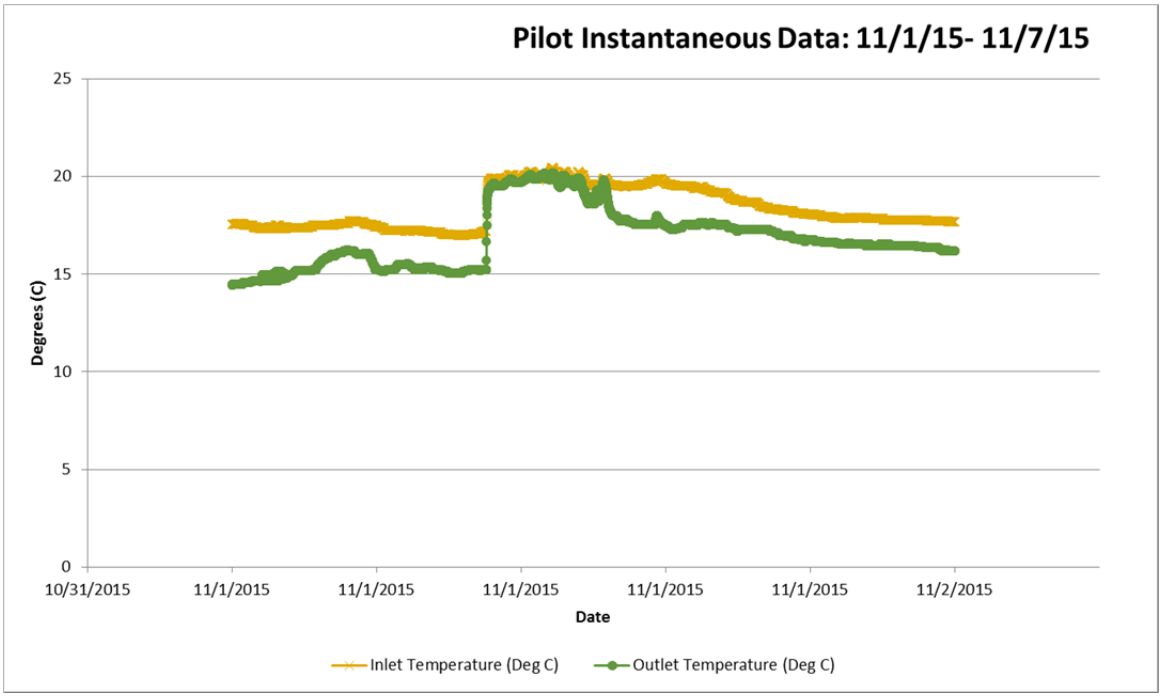




Figure 6 Pilot Instantaneous Temperature Data (continued)

Effluent WPCF flow data from 2015 is shown in Figure 7.

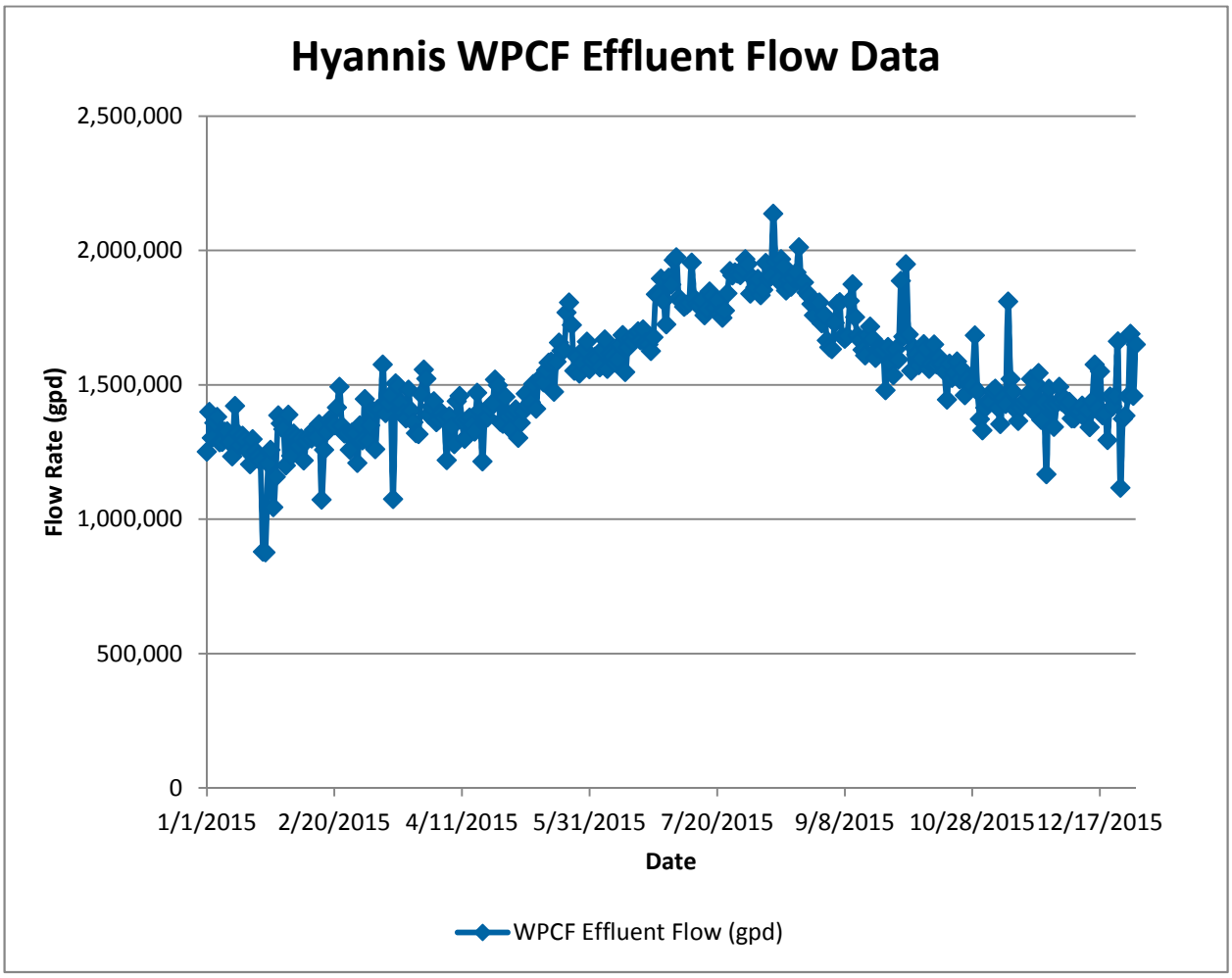



Figure 7 Hyannis WPCF Flow Rate Data

Detailed logs of the collected flow and temperature data are included in Appendix A. Based on the anticipated heating and cooling loads of the two Town buildings, Huber recommended its largest ThermWin model (BG8) be used in a permanent installation (a smaller unit, the BG4, was piloted during this study). The BG8 has a maximum flow capacity of 480 gallons per minute (gpm), which represents approximately 45% of the average flow to the facility. Further analysis should be conducted to determine whether there are any potential impacts to the biological process at the WPCF due to the temperature change in this stream.

# 4. Operations and Maintenance Observations and Findings

The pilot was operated for one month. A press article describing the pilot operation is included in Appendix B. During the first week the operators were trained in the operation of the unit and the system was operated for limited hours during the day to allow the operator's time to gain familiarity with its operational requirements. For the remainder of the pilot, the installation was operated continuously, 24-hours a day.

## 4.1 Screenings Removal Operations & Maintenance Requirements

The screenings unit was installed with a continuous bagging system (Figure 8), which needs to be emptied on a periodic basis. One of the goals of the pilot was to assess how often screenings would need to be removed from the pumping station. The amount of screening in raw wastewater is heavily dependent on the composition of the wastewater, and the manufacturer was unable to comment on the quantity of screenings that would be expected at this location.

Currently an operator conducts a daily visit to each of the Town's pumping stations. If the number of visits required to remove screenings was found to be in excess of the daily scheduled pumping station visit, the system could represent a large operational (and time) burden on facility staff.

It was found that the bag needed to be changed out and removed several times a week; this could be conducted during the operator's regularly scheduled visits.

Figure 8 Continuous Bagging System

## 4.2 Cleaning System Effectiveness

When the pilot was decommissioned, the WWER unit was partially drained and a visual inspection was performed of the wiper systems effectiveness with raw wastewater. Figure 9 shows the cleaned

pipe modules immediately after the wiper mechanism was run. Based on a visual inspection the wiper system functioned well.

The visual inspection also revealed that screenings had made their way past the screenings removal unit to the WWER unit. This indicates that a finer screen would be required in a permanent installation to protect the WWER unit. The installation of a finer screen would potentially increase the amount of screenings generated through the setup. Further piloting would be required to determine the amount of screenings generated by the finer screen.

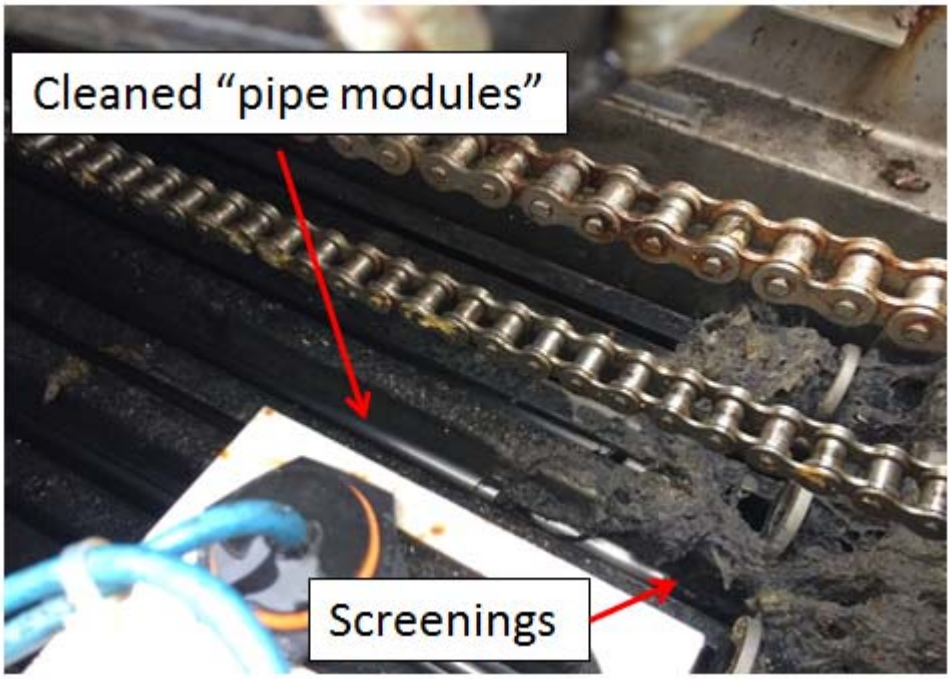



Figure 9 WWER Unit After Month-Long Operation

## 4.3 Operators Experience

Due to the pilot projects proximity to downtown Hyannis, one of the operator's main concerns was odor generation. A continuous bagging system was installed on the screenings unit to minimize potential odors. During pilot operation, minimal odors were observed at the site and the Town did not receive any complaints of odors.

The operators were also concerned about leaks within the pilot setup. Although an automatic shutoff valve was provided to isolate the system, the pilot unit did not have a leak detection system. In order to mitigate this concern the pilot was initially operated for limited hours during the work day, in the presence of an operator. As the operators became more comfortable with the system setup the unit's hours of operations were increased. After the first week the unit was operated continuously (24 hours a day) for the remainder of the pilot.

Lastly, the operators were concerned about the scale of operational maintenance that may be required with the unit. It was found that the majority of the unit's maintenance during its month-long operation could be accomplished during an operator's regularly scheduled daily visit to the site, including screenings removal.

The Division Supervisor of the Water Pollution Control Division was asked to comment on the operators experience operating the unit. He noted "We only had to empty the screenings unit about

once every week or two. The odors were really a non-issue. We did need to manually press the screenings on a daily basis in order to keep flow moving, but again, that was not any added labor on our end aside from pushing a button." He also commented "our operators were extremely skeptical of this unit, and the work it would take to maintain it, and in the end they were seemingly satisfied that there was not much additional labor. We would still prefer to carry out grit and rag separation in one central location, but if this project was found to be cost-effective, we would certainly make an exception to this rule."

## 4.4 Summary of Operation and Maintenance Findings

Below is a summary of the operations and maintenance (O&M) findings, based on the month long operation of the pilot unit with raw wastewater:

- The volume of screenings was small enough that it could be removed during the operator's regularly scheduled visits. The operators were not required to make additional visits to the station to handle the screenings.
- The wiper system functioned well, based on a visual inspection.
- The visual inspection revealed that screenings had made their way past the screenings removal unit to the WWER unit. This indicates that a finer screen would be needed in a permanent installation.
- The operators noted that the O&M requirements of the unit did not significantly increase their labor requirements at the pumping station.

# 5. Potential Energy Savings and Simple Payback

## 5.1 WWER System Retrofit Setup

The buildings cooling system currently utilizes a clean water loop. The water gains heat during the cooling process and “dumps” the heat through an evaporative cooling tower. In order to utilize WWER with the existing cooling setup the existing chiller would be decoupled from the cooling tower. Instead of being pumped to the cooling tower, the clean water would be pumped across the street to the WWER unit, where the heat absorbed by the clean water during the building’s cooling process would be transferred into the wastewater.

For a heating application the Town’s existing natural gas boilers would need to be replaced with a heating system that is compatible with the WWER system and operates with a clean water loop. A heat pump would be used to pump clean water across the street to the WWER unit. During the heat exchange process heat from the wastewater would be transferred to the clean water loop and used to heat the two buildings across the street.

In order to retrofit the existing heating and cooling system at the Town Hall, the following major components would be needed:

- Huber ThermWin BG8 unit (proposal included in Appendix D).
- A dedicated pump to circulate raw wastewater through the Huber unit.
- Screenings removal and compaction unit (screenings unit).
- Pre-engineering structure to house the ThermWin and Screenings Unit.
- New 4-inch HDPE supply and return piping from the Huber system directionally drilled from the pumping station, under South Street and to the Town Hall. This piping would be connected to the existing chiller in lieu of the existing cooling tower.
- A pump to circulate clean water between the chiller and the Huber System. This pump could either be variable speed or mixing valve controlled by the chiller head pressure.
- Controls for flow control to avoid production of saturated/condensed refrigerant from the low condenser water temperature which could enter the compressor.
- Heat pump.
- Replacement of the buildings existing natural gas heating system with equipment that is compatible with the WWER system.
- Head pressure controls may need to be added to the chiller, if not currently installed.

The installed cost of the new equipment is estimated to be at least $1,300,000.

## 5.2 Potential Cooling Application Energy Savings

Historical Hyannis WPCF wastewater temperature effluent data is shown in Figure 10 and Table 1. The Hyannis WPCF collects a daily effluent wastewater temperature grab every day between 12:00 p.m. and 1:00 p.m.

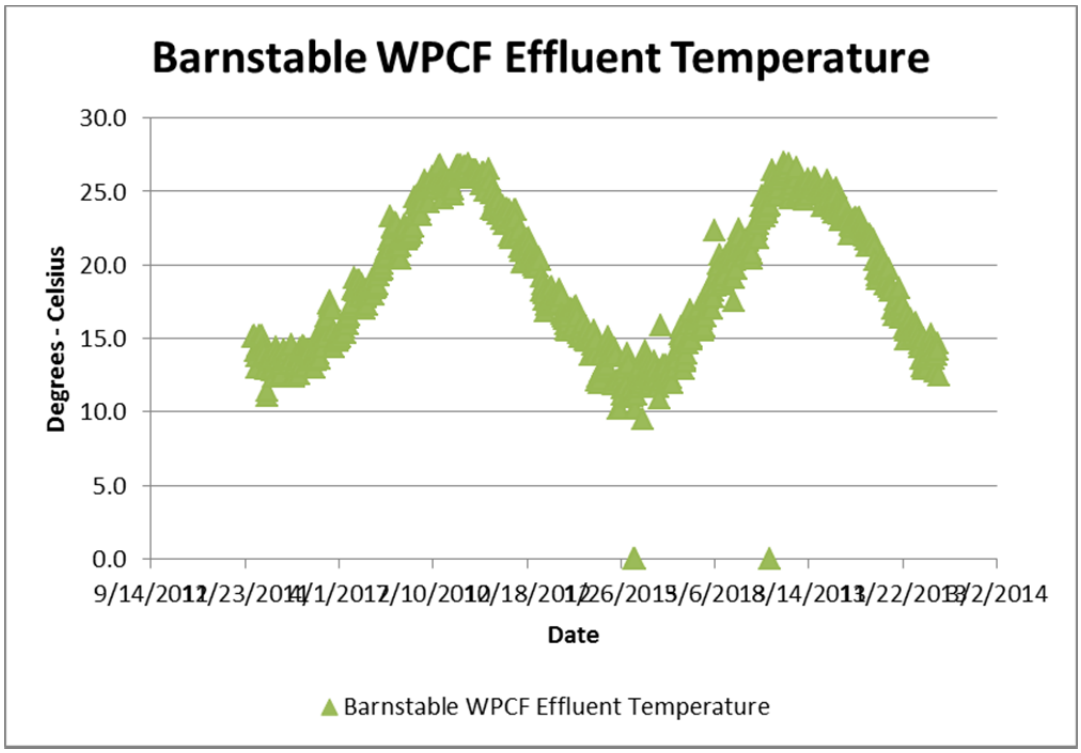



Figure 10 2012 to 2013 Hyannis WPCF Effluent Wastewater Temperature

Table 1 2012 to 2013 Average Hyannis WPCF Effluent Wastewater Temperature

| Month | Temperature (C) 2012 | Temperature (C) 2013 | Temperature (C) Average 2012 to 2013 |
|---|---|---|---|
| December to February | 14.3 | 13.1 | 13.7 |
| March to May | 17.4 | 16.2 | 16.8 |
| June to August | 24.9 | 24.4 | 24.6 |
| September to November | 21.1 | 20.9 | 21.0 |

Instantaneous wastewater temperature data was collected at the pilot during its operation. Based on the data correlation shown in Figure 11, it was assumed that the wastewater temperature at the pumping station in the summer months would be similar to that recorded at the WPCF. This is a conservative assumption because the data trend typically shows an increase in temperature at the end of the WPCF treatment process. The installation of a temperature probe at the Old Colony Pumping Station would allow the Town to gather long-term data on the temperature at the pumping station and to refine the assumptions made in this study.

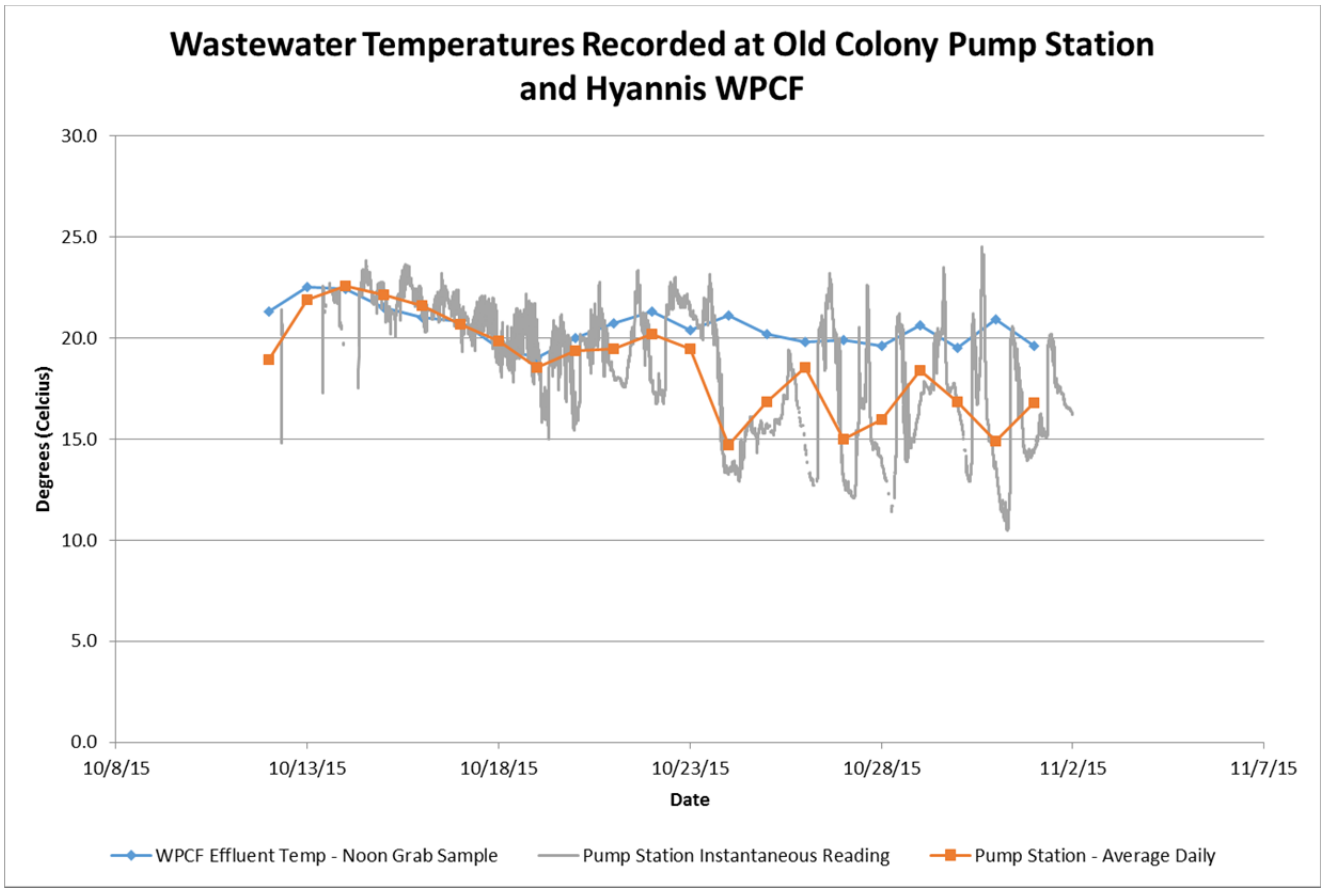



Figure 11 Wastewater Temperatures Recorded at Old Colony Pumping Station and Hyannis WPCF

## 5.1 Permanent Installation Heating and Cooling Capacity

Huber recommended that the ThermWin BG8 unit be installed in a permanent installation, which is a larger unit than the one that was piloted. Based on the annual effluent wastewater temperatures at the WPCF it is estimated that the heating capacity of the BG8 unit is approximately 1090 MBH and the cooling capacity is 100 tons. Calculations are included in Appendix C.

## 5.2 Potential Energy Offset of Permanent WWER Installation

An eQuest model was developed to determine the energy offset potential of a permanent WWER installation. Results from the model are outlined in Table 2.

Table 2 WWER Energy Offset

| | Town Hall | School Administration Building | Total (Both Buildings) |
|---|---|---|---|
| Annual Heating and Cooling Electric – Current (kWh) | 129,000 | 58,000 | 187,000 |
| Annual Heating and Cooling Electric – WWER System (kWh) | 129,000 | 69,000 | 198,000 |
| Electrical Usage Offset (%) | 0% | -19% | -6% |

| | Town Hall | School Administration Building | Total (Both Buildings) |
|---|---|---|---|
| Annual Gas Heating – Current (therms) | 13,000 | 6,900 | 19,900 |
| Annual Gas Heating – WWER System (therms) | 0 | 0 | 0 |
| Gas Usage Offset (%) | 100% | 100% | 100% |

The model shows a slight increase in electricity costs to operate the WWER system and a savings in gas heating.

Cooling efficiency could theoretically be increased by pumping the condenser water through the Huber heat exchanger in lieu of the evaporative cooling tower, resulting in lower condenser return water temperatures and improved chiller energy efficiency ratio (EER). Typical condenser return water temperatures from cooling towers are around 29°C. Discussions with the manufacturer indicated that using the design temperature of 25°C (the average effluent wastewater temperature from June through August based on 2012 to 2013 WPCF data) return water temperatures from the WWER system would also be about 29°C, indicating no increase in efficiency or electricity savings between the WWER system and the existing evaporative cooling tower.

The manufacturer indicated that, due to the high wastewater temperature in the summer, the biggest cost savings of a WWER system would be in reducing potable water consumption. Based on the Town's current water rates, it was estimated that an annual savings of $611.00 could be achieved by eliminating the evaporative cooling tower.

## 5.3 Cost-Effectiveness Analysis

In FY13 the Town of Barnstable paid the following average rates for utilities:

Gas = $0.39/therm

Electricity =$0.08/kWh

The net energy savings for the WWER system based on the eQuest model results summarized in Section 5.2 and the Town's current utility rates is estimated to be $6,900.00. Calculations are provided in Appendix C.

The DOER Waste Water Energy Recovery Assistance Program is currently offering investment assistance grants for the implementation of a WWER project up to $500,000 with a 25% cost-share with the receiving applicant. If the Town were to receive a $500,000 grant, the required cost-share would be $167,000 and the total project costs would be $667,000. As noted in Section 5.1, it is anticipated that the costs of a full-scale implementation of the system would be greater than $1,300,000.

The simple payback on the Town's cost-sharing portion of the WWER project would far exceed the typical municipal payback period of 20 years.

Additional funding opportunities that could be explored include a potential revenue source for the project from the generation of Alternative Energy Credits (AECs) if heat pumps are included in the Alternative Portfolio Standard as an alternative form of thermal energy. Although no cost value has been associated with potential AECs a stakeholder process is currently underway. Cape Light Compact also offers energy efficiency incentives which could be explored further.

# 6. Next Steps

The month-long pilot showed that the Huber ThermWin unit did not require excessive maintenance in a raw wastewater application. The wiper system was shown to work effectively (based on a visual inspection) and the amount of screenings collected by the system did not exceed the quantity that could be removed by operators on their daily visit to the site.

Due to the high wastewater temperatures in the summer it was found that the WWER system offered no cooling efficiency over the existing cooling system during the summer months and no potential electricity savings. The estimated savings in potable water use reduction through the elimination of the evaporative cooling tower were found to be minimal and far outside of a typical municipal payback period of 20 years.

The net annual gas saving for the WWER installation is approximately 19,900 therms. However the buildings existing heating systems would need to be replaced with systems that are compatible with a WWER system. The Town has indicated that the existing equipment is still well within its design life. The scenario would likely only be cost-effective if the Town were looking to replace the two systems due to age or known operational issues.

The WWER installation was not found to be cost-effective at the Town's current utility prices. However the prices of both natural gas and electricity have historically fluctuated significantly. Future rates may have a significant impact on the calculated simple payback for the WWER system. If the Town wished to pursue the conceptual design of a heating and cooling WWER system it is recommended that a sensitivity analysis be conducted to determine what the cost of electricity, natural gas, and potable water would need to be to make the system cost-effective.

It is also recommended that a temperature sensor be installed at the Old Colony Pump Station to gather long-term (at least a year's worth) of influent temperature data at the station.

Proceeding with the conceptual design and investigation of the above items would present the best opportunity to determine the cost-effectiveness of this technology for the Town.

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