Assessing Impacts of Tides and Precipitation Through Use of Real-Time Depth and Flow Monitoring

Downtown New Haven, CT
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CIRCA
Connecticut Institute for Resilience and Climate Adaptation

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Executive Summary

The City of New Haven, like many coastal cities and towns in Connecticut, is low-lying and susceptible to flooding due to the impacts of climate change. New Haven experiences frequent flooding of its downtown during high intensity rainfall coupled with high tide and coastal storm surge events. This flooding is exacerbated by sea level rise and the increasing volume and intensity of precipitation events in the Northeast. These flooding events impact areas crucial to the functioning of the City— including Union Station, Route 34, police headquarters, and the main post office— reducing quality of life for residents, commuters, and visitors to New Haven.

Since 2012, the City has invested significant funds into studying the downtown sewer system. During these studies, depth and flow monitoring data was collected from the storm sewer system. This data serves as a baseline upon which sophisticated computer models are calibrated and used to evaluate existing conditions and assess alternative solutions for future scenarios. However, significant gaps and inconsistencies still exist in the understanding of this large and complex drainage area, and significant further study is needed. Lack of observed storm sewer performance data is a key reason for these gaps in understanding.

Ideally, storm sewer monitoring would be performed for a long enough period to capture data over a range of precipitation events to observe how the system behaves in low and high flow conditions. Unfortunately, typical methods of storm sewer monitoring rely on consulting firms to deploy monitoring equipment for short durations at a cost of hundreds of dollars weekly per meter installed. With multiple meters necessary to capture needed information, this monitoring becomes extremely expensive very quickly and is particularly risky for stormwater systems (versus sanitary systems) as significant rain events are not guaranteed.

Long term monitoring data is needed to understand and evaluate the complex interactions between rainfall, land use, storm sewer hydraulics, and tides. To address this need, the City requested funds from CIRCA to create a low-cost, smart city stormwater sensor network to collect long term data and transmit it in real-time to a web-based dashboard. The generous financial assistance from CIRCA was used to purchase equipment to be deployed throughout the downtown storm sewershed. This one-time financial investment from CIRCA is approximately equivalent to the cost of 2-3 months of short term monitoring conducted during the City's past studies of downtown and yet will allow the City to collect data on its storm sewer system for years with minimal anticipated maintenance costs. This sensor network will be used to provide long term data upon which to refine the computer model and recommended mitigation solutions and for real-time response to flooding events.

For other municipalities interested in implementing a monitoring system, this report documents an approach to selecting and deploying equipment based on the goals of the program. Details of the equipment used in the City of New Haven's network including product specifications and costs are discussed along with options for collecting and viewing data.

Project Background and Context

The City of New Haven experiences frequent flooding at several locations in the heart of downtown during high intensity, short duration rainfall events. These locations- Route 34, Union Avenue, Temple Street- are not only crucial to the functioning of the City but support regional transportation systems as well. The flooding is exacerbated during high tide events such that a small storm (less than a one-year occurrence) can lead to flooding of critical facilities such as the City's main post office and Union Station. Precipitation volumes and intensities are expected to increase throughout the Northeast due to climate change, greatly increasing the need for strategic resiliency planning.

Figure 1: Flooding on Union Avenue during storm on April 16, 2018

The City of New Haven has already invested significant funds into studying the downtown sewer system with three major studies conducted since 2010. The latest study, completed in March 2015, modified and updated an existing Storm Water Management Model (SWMM) of the downtown storm sewershed to reflect current conditions. SWMM models are useful tools for analyzing sewer networks and developing alternative infrastructure solutions to improve performance of the system. SWMM models are based on the physical features of the pipes, manholes, and outfalls that make up the sewer system and the characteristics of the watershed that drains to it. Then, SWMM models are calibrated by selecting key junctures in the storm sewer system and monitoring the depth, velocity, and flow through that segment of the system. Monitoring is usually conducted over a short period of time based on availability of funding and timeline for the project. Parameters within the model are tweaked to reflect the volumes and peak flows observed within storm sewer system during a range of rain events. Once calibrated, the SWMM model is then used to assess alternatives to improve storm sewer performance, and in the case of downtown, reduce flooding.

Recommended solutions from these past studies of downtown indicate that there are no easy and/or inexpensive alternatives for addressing the system-wide capacity issues and alleviating flooding. However, significant gaps and inconsistencies still exist in the understanding of this large and complex drainage area, and significant further study is needed. Lack of observed storm sewer performance data is a key reason for these gaps in understanding. During the past studies, the monitoring equipment was deployed during drought conditions and little to no data was collected during high intensity rainfall events. Therefore, the SWMM model could only be calibrated for smaller storm events and much uncertainty exists about its ability to simulate conditions during larger, more intense storm events.

The City's strategy currently lacks a long-term data gathering component to provide empirical data on the performance of the City's stormwater infrastructure in widely varying conditions. Permanent monitoring greatly increases the chances of capturing significant events that would enable refinement of the SWMM model to reflect the full range of precipitation and tidal conditions and therefore attain a higher level of confidence in the model outputs. Since these model outputs are used to design and size large (i.e. very expensive) infrastructure investments, a high level of accuracy is desired to ensure the most cost-effective solution is selected.

While sensor networks for sanitary and stormwater systems are not new, the traditional approach is both quite expensive and cumbersome. Typically, a municipality hires a consulting company to deploy monitoring equipment at select locations for relatively short durations (2-3 months) at a cost of $500 per meter per week. This monitoring becomes extremely expensive very quickly and is particularly risky for stormwater systems (versus sanitary systems) as significant rain events are not guaranteed. Unfortunately, typical state and federal funding sources (such as CDBG-DR) are geared towards the procurement of services for set periods of time rather than investing in permanent monitoring equipment.

The City solicited funding from the Connecticut Institute for Resilience and Climate Adapation (CIRCA) to create its own low-cost "smart city" stormwater sensor network to collect long-term records of the complex interactions between rainfall, runoff, storm sewer system hydraulics, and tides. The generous financial assistance from CIRCA enabled the City to purchase a range of storm sewer monitoring equipment that will be deployed throughout the downtown drainage area to provide long-term data on this crucial portion of the storm sewer network. This one-time financial investment from CIRCA is approximately equivalent to the cost of 2-3 months of short term monitoring conducted during the City's past studies of downtown and yet will allow the City to collect data on its storm sewer system for years with minimal anticipated maintenance costs. This sensor network will be used to provide long term data upon which to refine the SWMM model and recommended solutions and for real-time response to flooding events.

In addition, the City has secured separate funds to install up to 200 right-of-way bioswales throughout the upland portions of the watershed. By implementing green stormwater infrastructure on a watershed-wide scale, the City estimates that up to 1 million gallons of runoff can be removed from the system during a storm event. The City is partnering with Yale University's School of Forestry and Environmental Studies (Yale FES) and Quinnipiac University to use these bioswale installations as a research opportunity and to quantify the cumulative impact of bioswales on water quantity in the storm sewer system. The stormwater sensor network will provide data on the performance of GSI using both pre- and post- monitoring, as well as provide direct readings of the utilization of the GSI installations during real rain events.

Project Description

This project will create a low-cost "smart city" stormwater sensor network that uses Internet of Things (IoT) techniques to reduce the cost of sensor networks and provide a granular, detailed record of the interaction of rainfall, tides, green stormwater infrastructure, and sewer conveyance systems on the hydrology of New Haven's urban core. A better understanding of system response during a range of hydrologic conditions will allow the City to value engineer cost-effective and resilient solutions. Furthermore, the techniques and approaches developed in New Haven can be easily transferred to other urban communities facing similar problems.

Goals of this project:

- Reduce impact of flooding on the Long Wharf, Hill, and Downtown neighborhoods through a better understanding of the hydrology of New Haven's urban core
- Improve the resiliency of our storm sewer system in light of increasing sea levels and precipitation events.
- Reduce the cost of acquiring real-time data on stormwater system performance by strategically mixing sensor types, installing and maintaining equipment in-house, and creating a platform to wirelessly transmit, process, and display collected data

To accomplish these goals, the City proposed the following four phase plan:

- Phase 1. Procurement and Deployment of Monitoring Equipment

  The City of New Haven's Engineering Department will procure the monitoring equipment including rain gauges, level loggers, Doppler flow meters, a tide gauge, pressure transducers, and associated dataloggers, power source, antennae, and mounting equipment. The proposed locations of the equipment within the storm sewer system will be based on past studies of the downtown sewershed. Our research partners will assist with final equipment selection and installation locations. In addition, up to five (5) bioswales will be selected by the project team to be monitored.

- Phase 2. Development of Dashboard Interface

  The project team will work to integrate the real-time feeds from the sensor network into a GIS-based dashboard to provide both a real-time decision-making tool for flash flood management and a database of real-world data to calibrate the SWMM model of the downtown sewershed. This will be built using both ready-to-use applications in ESRI GIS and business data analytics tools in Microsoft Power BI.

- Phase 3. Collection of Data and Troubleshooting

  Once the equipment is deployed and the real-time dataloggers are communicating with the web-based dashboard, the City Engineering Department will continue to monitor the system and ensure proper function. If any meter seems to be malfunctioning, the City will immediately respond and bring back into working order. This troubleshooting activity will be documented such that others can learn from our experience. The City will also utilize the system during rainfall events as an emergency operations tool and respond to any suspected flooding events.

- Phase 4. Data Analysis

  The collection of data- from rainfall to outfall- throughout the downtown sewershed will enable the City and partner researchers to perform analyses and improve the understanding of the sewer system. Four rain gauges will be installed to examine the variability of rainfall across the sewershed and to fine-tune the predicted runoff making its way into the sewer system. The green infrastructure systems will be assessed for their ability to infiltrate runoff over a range of rainfall intensities and volumes and their cumulative impact on the flow within the sewer system. The level and flow data will be analyzed against the rainfall and tidal data to ascertain any correlations and linkages that can be used in predicting potentially damaging events.

  Further, the equipment and real-time monitoring system itself will be critically reviewed with a focus on performance, value, ease of installation/use, and maintenance requirements. These lessons learned will be summarized and shared such that other communities can benefit from this experience.

Relationship with CIRCA Mission and Priority Areas

CIRCA's mission is "to increase the resilience and sustainability of vulnerable communities along Connecticut's coast and inland waterways to the growing impacts of climate change on the natural, built, and human environment." This stormwater sensor network project will advance the mission of CIRCA by 1) increasing the capability of the City to respond to flooding by providing real-time data in the storm sewer system during rain events and 2) providing long-term data on sewer system performance over a range of rainfall events that can be used for future resiliency planning and design. Further, long-term data collection will allow the City to assess trends and correlate rainfall patterns to flooding events for even better predictive ability and response. Both objectives will result in less damage and harm due to flooding and ultimately less flooding overall.

Multiple priority areas of CIRCA are addressed by the stormwater sensor network project. The project has developed a low-cost approach to long-term storm sewer and green infrastructure system monitoring that will increase understanding of the complex relationship between tidal levels, rainfall/runoff response, and storm sewer and green infrastructure capacity. The developed approach and lessons learned are transferable to other communities looking to deploy long-term monitoring at a low cost for improved climate resiliency planning. Additionally, real-time monitoring allows the City to respond more quickly and efficiently to flooding and reduce and/or prevent the associated damage and disruption.

CIRCA has undertaken and continues to research the hydrodynamics of the Long Island Sound and its impact on coastal communities. As part of the CREST project, storm wave characteristics were analyzed at five points in the Sound- one located just outside the New Haven Harbor. As the City moves forward with the data analysis phase of this project, we will benefit from this data as we further explore the impact of tides, sea level rise, and storm surge in the New Haven Harbor on the City's stormwater infrastructure. The wave scenarios and statistics developed during the CREST project can be used as boundary conditions in the City's stormwater management model for evaluating storm sewer system and green infrastructure performance under severe storm conditions.

Further, CIRCA is currently developing a real-time forecast modeling system of the New England region. Once this model is created, the City will link the forecasting information to our proposed dashboard and use it for decision-making related to flooding and resilience. Over the longer term, the City would like to work with CIRCA to integrate the local real-time monitoring data with the regional model that can be used to forecast potential inundation from storm surge and high intensity precipitation events.

Project Outcomes

The City has made progress on all four phases of the project but has not yet completed the entirety of the proposed workplan. Most of the effort completed during the grant period falls within the scope of Phase 1— the selection, procurement and deployment of the monitoring equipment. The City has selected and procured all the real-time monitoring sensors and associated equipment for the network. The equipment list for this project is as follows:

- Weather Station including rain gauge: One (1) Davis Instruments Wireless Vantage Pro2 with Fan
- Datalogger for Weather Station: One (1) Davis Instruments WeatherLinkIP Data Logger and One (1) Software for Vantage Weather Stations
- Ultrasonic Level Sensor: Eight (8) ADS ECHO Level Monitor LTE
- Doppler Flow Meter: Five (5) Unidata Starflow Ultrasonic Doppler Velocity, Depth, and Flow Meter, Model J
- Water Level Data Logger: Six (6) Onset MX2001 HOBO Bluetooth Low Energy Water Level Data Logger
- Communications Equipment: One (1) The Things Gateway, 915 Mhz Version PID: 3943

The sensor types mix a smaller number of doppler flow meters (5 meters) with a larger number of easier-to-install ultrasonic water level sensors (8 meters). Locations for the equipment have been selected and the weather station along with two ultrasonic water level sensors have been installed thus far (See map in Appendix A). The remaining ultrasonic water level sensors will be installed in Winter/Spring 2019 (dependent on weather). The Doppler flow meters require enclosed space entry certification for installation which will be obtained by staff in Winter 2019.

Additionally, data collection has commenced for those sensors that have been deployed. Weather station data can be viewed on computers using the associated software free of charge. This data is also linked to Weather Underground webpage. Access to a proprietary software platform was purchased for a year to view the ultrasonic level sensor data and to obtain assistance with troubleshooting any issues with the meters. The data from the level sensors has already enabled the City to respond to flooding events in real-time. Three flooding events have occurred since the installation of the level sensor at Brewery Street (see Figures 1 and 2). The software has been programmed to send an alarm via email when the level reading exceeds the level of the manhole allowing us to inform the proper authorities of the hazardous conditions.

Figure 2: Flooding at Brewery Street on Dec 21, 2018

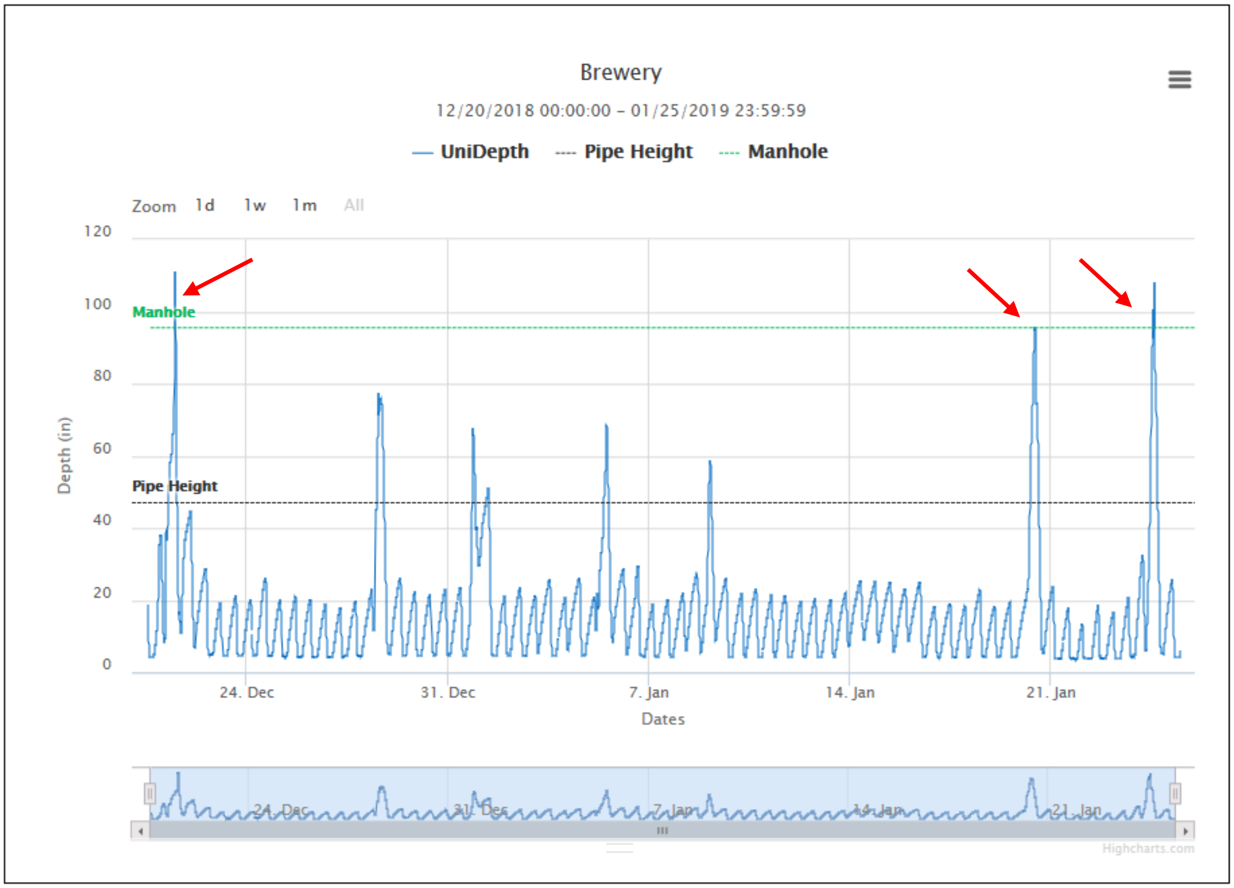


Figure 3: Hydrograph from level sensor at Brewery Street from Dec 20, 2018 through January 25, 2019. The red arrows indicate events when the water level exceeded the manhole cover and flooded the site.

Moving forward, over the next few months, the City will install the remaining ultrasonic level meters and doppler flow meters. Working with the City's GIS analyst, the disparate data viewing platforms will be integrated into a single, GIS-based dashboard for real-time assessment of flooding. As significant data is collected, it will be analyzed and used to update the SWMM model. The City will continue to work with and coordinate with CIRCA as the equipment deployment and data collection and analysis progresses.

Lessons Learned

There are a number of lessons learned through from this project that can provide insight to other Connecticut municipalities seeking to incorporate long term rainfall and storm sewer monitoring in their communities. The below approach offers guidance to municipalities that are considering implementation of a storm sewer monitoring network for their community.

Define the goal(s) of the storm sewer monitoring system

In New Haven's case, there were multiple goals for the monitoring system. The first goal is to collect long-term data on the downtown storm sewer system to assess performance of the system over a range of precipitation and tidal events. In addition to analyzing the observed data, the collected data will be used for refinement of the existing SWMM model which will be used to assess and design future infrastructure investments to prevent future flooding. The second goal is to provide real-time data on surcharging and flooding throughout New Haven. And the third goal is to collect performance data on our green stormwater infrastructure installations and quantify the cumulative impact of these installations on the downtown storm sewer system.

These goals drive remaining decisions on which equipment to buy, where to deploy the equipment, and how best to transmit and/or collect the data from the equipment for use. Having a clear goal for the monitoring system will assist a community in making the most economical choices to meet the needs of the project.

Selecting locations for monitoring

The goal(s) of the storm sewer monitoring system will define what type of data needs to be collected and from which locations. Knowing some initial information about the system to be studied is crucial to selecting and optimizing the number of locations that require monitoring. In the case of developing a real-time monitoring network to report on flooding, it is important to identify the known problem areas that experience frequent flooding. If there are too many to monitor, then it will be necessary to prioritize locations. Some factors that influence priority can include frequency of flood occurrence, the impact of the flood occurrence on the municipality's operations and surrounding community, the actions that need to be taken if flooding is occurring in this location, and who is interested in receiving notification of this flood event. Once the flood locations are known, identify the lowest lying manhole within the flood area that can be used for installing equipment.

If in addition to real-time assessment of flooding, the municipality would like to gather long term data regarding the influence of precipitation, land use, and tides (if applicable) on the functioning of the storm sewer system, then define the sewershed of interest. Defining the sewershed will require information on the physical assets of the system (manholes, pipe sizes and inverts, outfalls) along with topographical information. Once the sewershed of interest is defined, break the system into sub-sewersheds that can be monitored to define the incoming flow and select a downstream location(s) that characterizes the outgoing flow. The size of the sub-sewersheds will be influenced by the size and complexity of the existing system, the number of monitoring locations that are desired by the municipality, and level of detail needed.

Some locations can serve multiple needs. In New Haven, there are two manholes located on outfall pipes that provide data on outgoing flow for the downtown system. These manholes also happen to be in low lying areas that experience frequent flooding thereby capturing data that serves two goals.

Accurate precipitation data is useful for all the goals listed. Precipitation provides basic information that can be used as an input to a SWMM model, to correlate with flooding events and to assess capacity within a storm sewer system. Precipitation can vary greatly within relatively short distances. For example, on September 25, 2018, a large rain event hit southern CT. New Haven received 2.26 inches while just north in Hamden received 8.51 inches! Due to this potential for variation, a municipality would ideally install at least one rain gauge within the sewershed of interest. Rain gauges are generally located on rooftops, far from any obstructions that may influence precipitation capture.

Equipment Selection Considerations

After the proper sites are chosen for monitoring, sensor equipment must be selected. The typical parameters for storm sewer monitoring include depth and velocity. Depth alone is useful if the goal is to indicate whether a site is flooding. Flow can be also calculated from this depth measurement by applying the manning's equation. This calculation works best in areas where the cross section of the pipe is regular and the system does not experience backwater. For locations where the system often surcharges and/or experiences backwater conditions, collecting additional velocity data is important to correctly interpret the depth readings.

There are multiple products that could be used to capture this depth, velocity and flow data. For the project in New Haven, partnering with local university researchers provided useful expert knowledge on equipment selection. Through their research, professors have experimented with multiple types of equipment and have narrowed down the best products weighing factors such as cost, function/accuracy, and ease of installation and use. Below is a list of the equipment purchased as part of this project, its function, and the reason why it was selected over other options.

- Weather Station (including rain gauge) and Data Logger: Davis Instruments Wireless Vantage Pro2 with Fan, Davis Instruments WeatherLinkIP Data Logger and Software for Vantage Weather Stations
    - Affordable, easy-to-install, all-inclusive package from sensor to datalogger to data-viewing software
- Ultrasonic Level Sensor: ADS ECHO Level Monitor LTE
    - The major advantages to this level sensor is its compact, all-in-one sensor configuration and its easy-to-install design. Multiple sensors, including the ultrasonic level sensor along with a pressure tranducer to record surcharged depths, are housed in a single unit. This unit can be installed with an installation bar mounted onto the manhole frame. This installation can be completed without entry into the manhole itself and without using hardware to secure. This installation method is particularly valuable if monitoring locations are temporary and it is desired to move the monitors around to different sites.

- Doppler Flow Meter: Unidata Starflow Ultrasonic Doppler Velocity, Depth, and Flow Meter, Model J
  - Inexpensive compared to other units, compact design, based on decades of research in partnership with the University of Western Australia
- Water Level Data Logger: Onset MX2001 HOBO Bluetooth Low Energy Water Level Data Logger (4m range with 5m cable)
  - This water level data logger is used to assess the performance of the bioswale installations during storms. PVC pipe was installed to serve as a well in a number of the bioswale installations. This sensor is placed in the well to measure the level of water within the stone layer (3 to 5 feet below the surface of the bioswale). The major advantage to this data logger is its wireless capabilities and use of Bluetooth Low Energy to transmit data to mobile devices. Another advantage in the design is the ability to adjust the depth of this sensor by swapping out the cable that connects the sensor to the datalogger.
- Communications Equipment: The Things Gateway, 915 Mhz Version PID: 3943
  - Using LoRa technology, this device provides a long range, low power wireless platform for collecting data from sensors and transmitting to internal servers. The data can then be used to populate the dashboard with real-time sensor information. This platform is inexpensive, does not require monthly maintenance fees (like cellular), and uses less power than other technologies. LoRa fills the technology gap of cellular and Wi-Fi/BLE based networks that require either high bandwidth or high power or have limited range or inability to penetrate deep indoor environments.

For more details on the equipment, Appendix B lists all the equipment purchased as a part of this project with its costs and the product specification sheet.

Transmitting/Collecting Data

The goals of your system will define whether data needs to be transmitted in real-time or collected in regular intervals. Real-time data collection and viewing requires a wireless system and a system for collecting that data and transmitting to a web-based viewing platform. If this is not necessary for your system, you can download the data from the sensor itself at regular intervals (e.g. weekly, monthly) using a wireless connection (e.g. Bluetooth) or a direct connection (e.g. USB) depending on the capabilities of the sensor. This option requires more manpower to visit each site but eliminates the need to develop a system for transmitting data to local servers.

While the City of New Haven continues to work on this aspect of the project, in the meantime, it has been useful to take advantage of proprietary software and data viewing platforms. Utilizing these platforms allows us to immediately start collecting, viewing, and analyzing real-time data while the details of the LoRa data collection system and the custom dashboard are developed. The downside of using these proprietary systems long-term is the cost associated with maintaining them (i.e. monthly fees) and the inability to condense them into one singular dashboard. If this is not a concern of your municipality, then using these proprietary methods for data collection and viewing is a good option.

Final Project Schedule

As this project involves long-term monitoring, many of the tasks will be conducted on an ongoing basis. The grant funds were spent during Phase 1 of this project to procure and deploy the monitoring equipment. The remaining tasks will be completed using in-kind staff time.

	2018				2019	
Task	Q1	Q2	Q3	Q4	Q1	Ongoing
Finalize Grant Agreement						
Phase 1: Procurement & Deployment of Monitoring Equipment						
Phase 2: Development of Dashboard Interface						
Phase 3: Collection of Data and Troubleshooting						
Phase 4: Data Analysis						

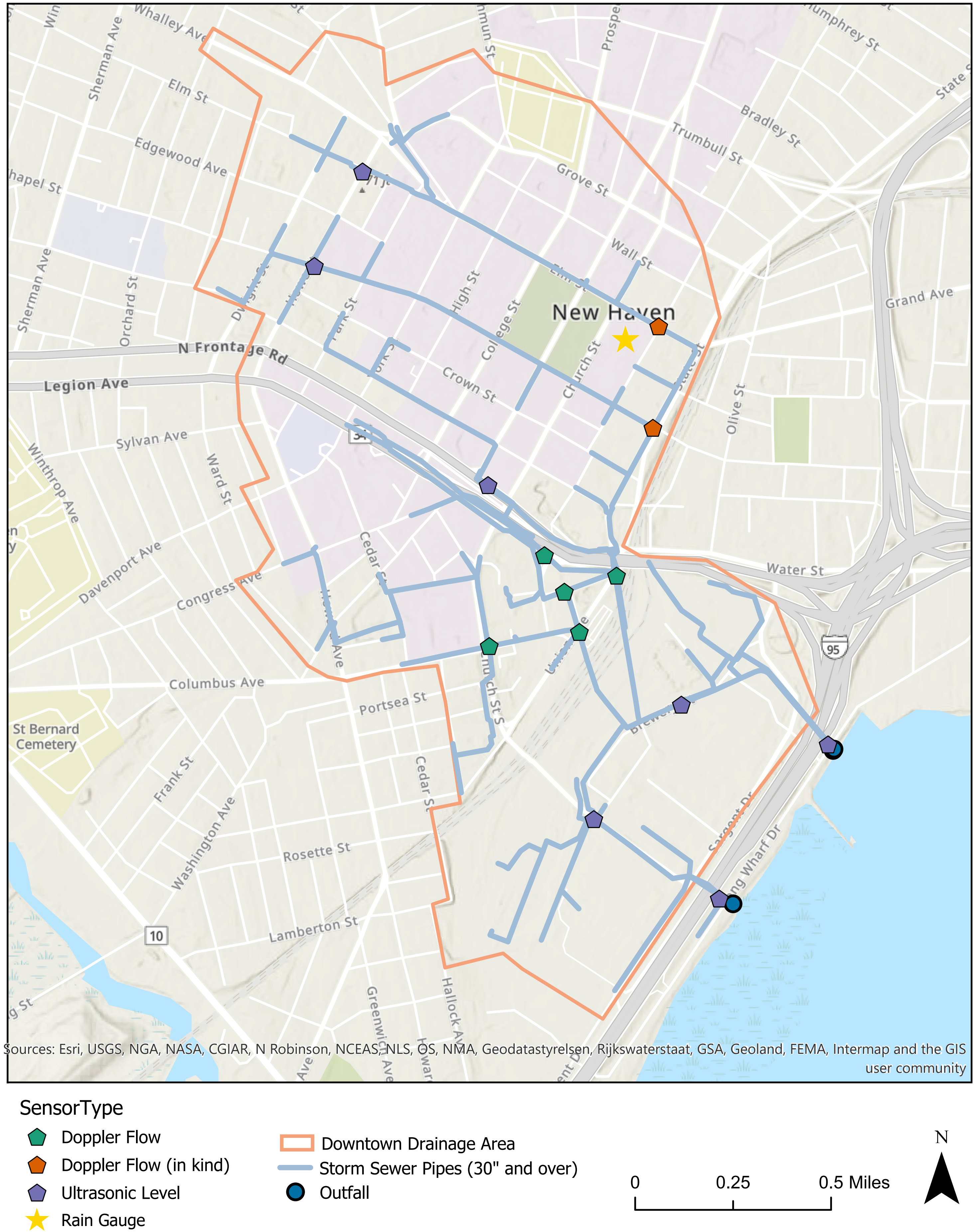
Budget Summary

The monitoring equipment purchased varied slightly from the proposed budget list based on the actual unit costs and immediate needs of the project. See table below.

Sensor Type	Budget Number Proposed	Budget Unit Cost	Actual Number Purchased	Actual Unit Cost	Equipment Model Info	Explanation for variation from proposed
Rain Gauge – tipping bucket style with real-time data logger	2	$1,500	1	$1,070 (including data logger)	Davis Wireless Vantage Pro2 with Fan plus data logger	This rain gauge was provided by the City in-kind to this project and therefore not included in this invoice.
Ultrasonic Level Sensor – mounts below manhole and measures distance to water, transmitting in real time	10	$2,000	8	$2,579	ADS Echo Monitor LTE-M	Monitors cost more than anticipated so lowered the number of units from 10 to 8.
Doppler Flow Meter – measures Doppler effect from particles in water and calculates water velocity	2	$4,200	5	$2,297	Unidata Starflow Model 6526J	Purchased more than anticipated because of lower actual cost, to replace the level sensors that weren't purchased and added value of this data to the project.
Tide Level Gauge – measures water level in harbor at the outfalls of the downtown stormwater systems	1	$1,800	0	N/A	N/A	Given installation and communications needs, this piece of equipment became too expensive. Similar information can be obtained in other ways.
Water Level Sensor – measures water level in monitoring well in GSI installations	5	$600	6	$685 (including cable)	Onset HOBO MX2001 Water Level Data Logger	Purchased an additional sensor to add to the data collected on bioswale performance
Communications – LoRA gateway	N/A	N/A	1	$350	The Things Gateway: 915Mhz Version PID: 3943	Purchased a LoRA gateway system to wirelessly communicate data from sensors to internet

Appendix A: Monitoring Locations Map

City of New Haven Downtown Monitoring Locations



Appendix B: Equipment Details

Weather Station including Rain Gauge

Equipment selection: Davis Instruments Wireless Vantage Pro2 with Fan

Cost: $850/each purchased through Davis Instruments Website

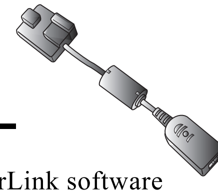
Datalogger for Weather Station with Rain Gauge

Equipment selection: Davis Instruments WeatherLinkIP Data Logger and Software for Vantage Weather Stations

Cost: $220/each purchased through Amazon.com

WeatherLinkIP™ for Vantage Pro® and Vantage Pro2™

6555



WeatherLinkIP

WeatherLinkIP™ for Vantage Pro® and Vantage Pro2™ consists of our WeatherLink software and a specialized data logger that connects to a Vantage Pro or Vantage Pro2 console or Weather Envoy to a ethernet connection. The software and data logger transfer your Vantage Pro or Vantage Pro2 weather data to your computer, allowing you to create a permanent weather database. Once stored in the database, your weather information can be used to generate a wide variety of reports and graphical displays.

In addition, the WeatherLinkIP data logger automatically uploads your console or Envoy information to a web server provided by Davis Instruments that lets you see your weather data via the Internet without having to set up your own web page. Your weather data is automatically saved to Davis's web servers which provide four times the storage of the data logger. Using the WeatherLinkIP data logger lets you become part of the WeatherLink Network, a collection of websites containing customer weather information that is stored on a server owned by Davis Instruments. Being part of the WeatherLink Network and having a site on WeatherLink.com means you are part of a community of weather enthusiasts who use the WeatherLink Network to view their own weather data and share that weather data with friends and people across the world quickly and easily.

WeatherLink Software Features

- Displays the current weather station data in a real-time "bulletin" on the computer.
- Allows you to set and clear data in the weather station console (time and date, highs and lows, alarm thresholds, calibration numbers, etc.) from the computer.
- Graphs archived weather data on an hourly, daily, weekly, monthly, or yearly basis.
- Generates Weather Watcher reports in the National Climatic Data Center (NOAA) format.
- Collects data from multiple weather stations on the same computer.
- Includes support for GLOBE, an international weather-related science program for students from elementary through high school. Visit www.globe.gov for more information.
- APRS data protocol allows volunteers in the Citizen Weather Observer Program (CWOP) to send real-time weather data to the National Weather Service. CWOP is data used for weather education and research projects. Visit www.wxqa.com for more information.
- Gives you multiple options for connecting to your WeatherLinkIP data logger.

WeatherLink Data Logger Features

- Archives weather data for subsequent transfer to the computer.
- Manages data communication between the weather station and the WeatherLink software.
- Information on WeatherLink communications protocols and data formatting can be found on the Software Support page at our website: (http://www.davisnet.com/support/weather/).
- Automatically sends data to Weatherlink.com without connection to a computer.
- Automatically uploads archive data to the Weatherlink.com website.

Weatherlink.com Website Features

- Gives you a real time summary of your station's current weather conditions.
- Sends daily summary and alarm e-mails.
- Stores archived record data for download to the WeatherLink software.
- Lets you view other weather stations in the WeatherLink Network.
- Lets you setup direct data uploads to other third-party applications and tools, such as CWOP and Globe.

Software Specifications

Software System Requirements

A network or ethernet connection. Computer running Windows™ 98 SE, Windows 2000, XP or Vista with Microsoft .NET 2.0 framework. The amount of disk space necessary for the data files depends on the archive interval. Each archive record in the database is 88 bytes. Every day in the database has an additional two records totalling 176 bytes that store daily summary information. A database containing data stored at a 30-minute archive interval requires 132 KB of disk space per month. The file size changes in a linear fashion depending on the archive interval. For example, data stored at a one-minute interval requires approximately 3.9 MB a month while the data stored at a two-hour interval requires approximately 33 KB a month.

Software Data Display Options

Some of the weather data and reports listed below require optional sensors.

Real-Time Displays (these displays update in real-time):

Graphical Bulletin . . . . Inside Temperature, Outside Temperature, Wind Direction (0°- 360°), Wind Speed, Daily Rain Total, Monthly Rain Total, Year-to-Date Rain Total, Storm Total, Rain Rate, Inside Humidity, Outside Humidity, Barometer, Barometer 6-hour Plot, Evapotranspiration (ET) (day, month, year), Today's Highs and Lows, Forecast Icons, Forecast Text, and Illuminated Fraction of the Moon Disk.

Text-Based Summary . . . . Inside Temperature, Outside Temperature, Wind Direction (0°- 360°), Wind Speed, Daily Rain Total, Monthly Rain Total, Year-to-Date Rain Total, Storm Total, Rain Rate, Inside Humidity, Outside Humidity, Barometer, UV, Solar Radiation, ET (day, month, year), Today's Highs and Lows, Forecast Text, and Moon Phase.

Update Interval . . . . Two seconds (approximately)

Plotting Displays:

Plot Window . . . . Enables graphing of all database information (multiple variables may be plotted on a single graph) over any of the following spans (1 hr, 4 hr, 8 hr, 12 hr, 1 day, 3 days, Week, Month, Year). Multiple dates may also be plotted on the same graph.

Strip Charts . . . . Four stacked line graphs (multiple variables may be plotted on a single graph), which update at the time of each archive interval. Strip charts may use any of the following spans (1 hr, 4 hr, 8 hr, 12 hr, 1 day, 3 days, Week, Month, Year).

Reports:

NOAA Monthly Summary . . . . Based on the National Oceanic and Atmospheric Administration (NOAA) Monthly Weather Watcher report

NOAA Yearly Summary . . . . Based on the National Oceanic and Atmospheric Administration (NOAA) Yearly Weather Watcher report

Yearly Rainfall . . . . Calculates rainfall totals broken down by month and year. Rainfall data may be altered and added to reflect rainfall totals for months and years which are not contained in your weather database.

Degree-Days . . . . Tracks degree-days and progress towards development for an unlimited number of crops or pests; base and upper development thresholds and development totals entered by user.

Temperature/Humidity Hours . . . . Calculates the number of hours the temperature has been either above or below a given threshold, and that during which time the humidity was above a given threshold from a given start date. Typically used to track conditions for the development of agricultural pests and molds.

Soil Temperature Hours . . . . Calculates the time that soil temperature has been above freezing (or some other threshold). Typically used to determine a time to plant crops.

Chilling Requirements . . . . Calculates the number of hours spent below a specified temperature during a specified period of time. Typically used to determine if the coldness requirement for a fruit tree in dormancy has been met.

Bright Sunshine Hours . . . . Calculates amount of sunshine for a selected time period.

Leaf Wetness Hours . . . . Calculates the amount of leaf wetness hours over a time period.

Fuel Demand . . . . Estimates fuel usage based on past usage and outside temperatures.

Total ET . . . . Calculates ET for a selected time period.

Sunrise & Sunset Times . . . . Calculates sunrise and sunset times for any given latitude, longitude and date.

Data Logger Specifications

Network Interface

Network Interface	10Base-T half duplex
Connector	RJ45
Communication Standards	ARP, UDP, TCP, ICMP, TFTP, DHCP, HTTP
IP Address Configuration	DHCP/Manual Static IP Address Configuration

Hardware Specifications

Power	5VDC from console, 0.5 watts maximum consumption
Operating Temperature	+14° to 140° F (-10° to 60° C)
Console Communication Baud Rate	19200 serial connection

Data Logger Archived Data

The data logger stores up to 2560 archive records (one 52-byte record per archive interval) for later transfer to your computer. The archive records are stored in 128K of non-volatile memory; protecting the data even if the console loses power. Maxima, minima, averages, and totals are taken over the archive interval.

Archive Record Data	Time/Date of Record, Inside Temperature (last or avg.), Outside Temperature (last or avg.), Maximum Air Temperature, Minimum Air Temperature, Wind Direction (dominant), Wind Speed (average), Maximum Wind Speed, Rainfall (total), Rain Rate, Inside Humidity (last), Outside Humidity (last), Barometric Pressure (last), Solar Radiation, Hi Solar Radiation, UV, Hi UV, Evapotranspiration, Forecast, Leaf Temperature (2), Leaf Wetness (2), Extra Humidity (2), Extra Temperature (2), Soil Temperature (4), Soil Moisture (4), Wind Samples, Wind Tx, Length of Archive Interval, ISS Reception
Archive Interval	User-selectable from the following intervals (in minutes): 1, 5, 10, 15, 30, 60, or 120

Archive Storage Capacity (the amount of time before the archive is completely filled):

1 Minute Archive Interval	42 hours
5 Minute Archive Interval	8 days
10 Minute Archive Interval	17 days
15 Minute Archive Interval	26 days
30 Minute Archive Interval	53 days
60 Minute Archive Interval	106 days
120 Minute Archive Interval	213 days

Download	Data is automatically uploaded to WeatherLink.com (see below for details). Using the WeatherLink software, data may be transferred automatically from the data logger to your computer up to once an hour using the Auto Download command. Data can be transferred more frequently, from once a minute to once every two hours, to support Internet uploading and other data sharing features. Only new archive data is transferred during the download.

Data Logger Auto Uploads to WeatherLink.com

Current Conditions Upload Interval	Every 60 seconds
Archive Record Upload Interval	Every 60 minutes
Website Archive Record Storage Capacity	10240 archive records (4 times the storage capacity of the data logger)

Note: The data logger storage capacity is not affected by the IP upload interval. The data logger still stores the same amount of data for download into the WeatherLink software. If network communication is interrupted and the current conditions and archive records are not being uploaded to WeatherLink.com, the data is still archived on the data logger. When communication is reestablished, all the records not uploaded due to communication loss are automatically uploaded to the website.

WeatherLink.com Specifications

WeatherLink Data Display Options

See WeatherLink.com for updated details of the data display options available.

Package Dimensions

Product #	Package Dimensions (Width x Height x Depth)	Package Weight	UPC Codes
6555	6.00" x 9.00" x 1.63" (152 mm x 229 mm x 42 mm)	9.0 oz. (0.26 kg)	011698 00893 3

Ultrasonic Level Sensor

Equipment Selected: ADS ECHO Level Monitor

Cost: Bid breakdown of unit costs

Exhibit A - Equipment and Service Pricing - Variation

PART NUMBER	QTY	EQUIPMENT	UNIT PRICE	TOTAL PRICE
9000-ECHO-4VZ KIT	8	**ECHO Monitor, Intrinsically Safe** - LTE-M, Mounting, and Antenna	$2,195.00	$17,560.00
9000-0061	2	**Bluetooth Dongle** - Enables onsite connection with the monitor	$100.00	$200.00
8000-0460	2	**Magnet, Blue** - For Modem initiation	$15.00	$30.00
9000-ECHO-INS	1	**Onsite Installation** - Physical setup and software initiation	$1,000.00	$1,000.00
9000-ECHO-FV Setup	0	**FLOWVIEW Setup** - Initial web-hosting site configuration	$0.00	$0.00
9000-SiteConnect	8	**FLOWVIEW Web-Hosting & Wireless Service** - SIM Card connection (1 Year) - 24/7 Data Access (1 Year)	$384.00	$3,072.00
			Total	$21,862.00

ADS® LEVEL MONITOR

The new ADS ECHO monitor provides utilities with an economical level monitoring solution to provide early warning of preventable blockages, such as FOGs, root intrusion, silt/sediment, and debris. ECHO is a cost effective, easy-to-use monitoring system for overflow prevention. ECHO technology is designed for ultra low power consumption, yielding up to a five-year battery life based on modem and data delivery rate configuration.

ECHO™

- Continuous collection system monitoring, from the earliest detection of blockages to overflow notification
- Deploy a fleet of dozens or hundreds of level monitors with the flexibility to move units to multiple locations, such as problem sites where overflows occur or areas that require regular cleaning and maintenance
- Easy installation in less than 10 minutes with no manhole descent required
- Intrinsically safe (IS) certification under ATEX, IECEx and CSA for use in Zone 0 (equivalent to Class I, Division 1, Groups C & D) hazardous areas

Mounting Options

Installation Bar

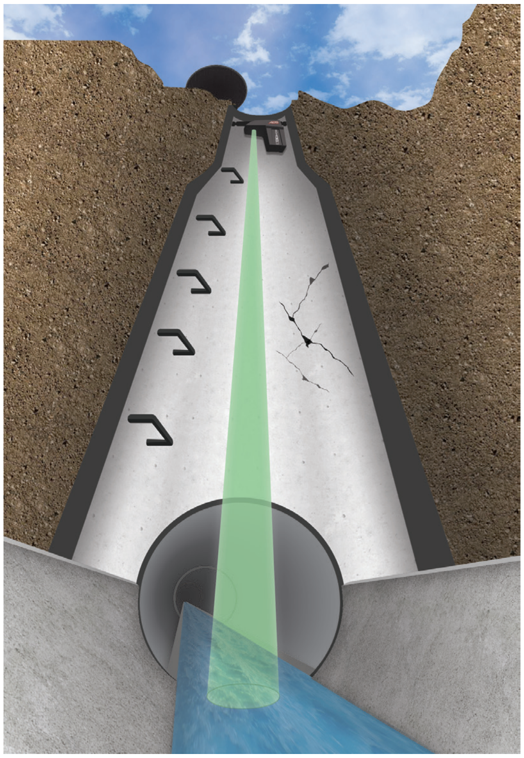
Wall-Mount Bar

ECHO with installation bar attached

ECHO with installation bar mounted on manhole frame

Typical Manhole Installation

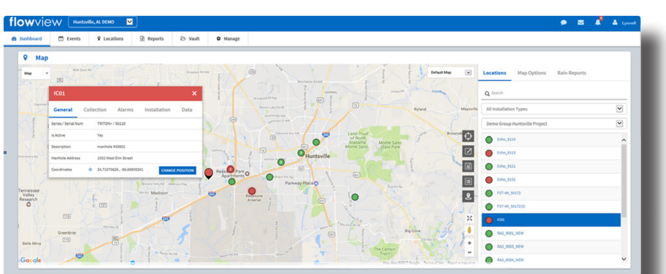
The ECHO features ultrasonic sensing technology with advanced digital signal processing. A single high-power transducer housed inside a tuned parabolic reflector reliably reads up to 20 feet (6.1m).



Applications

The ADS ECHO monitor is designed for use in many applications, including:

- Comprehensive Sewer Performance Monitoring
- Early warning and notification of sewer blockages and impending overflows
- Combined Sewer Overflow (CSO) monitoring
- Sanitary Sewer Overflow (SSO) monitoring
- Sewer Capacity Studies



FlowView Software Interface

The intuitive, graphical interface replicates client system maps for quick identification of system assets and provides drill-down functionality.

Learn more at www.adsenv.com/flowview

Specifications

Enclosure
Single piece, injection-molded, glass-filled polycarbonate meeting IP68 standards. Measuring sensor is an integral part of the monitor enclosure.

Weight (including battery)
11.5 pounds (5.21kg)

Dimensions
6 inches (152 mm) wide x 17 inches (432 mm) high x 15 inches (380 mm) long

Operating Temperature
-4 to 140 degrees F (-20 to 60 degrees C)

Mounting
Mounts to an expandable bar which requires no tools for installation or manhole descent. Optional wall mount hardware is available.

Measurement Detail
ULTRASONIC Sensor
Dead Band: 0.00 inches (0 mm)
Range: 0.00 inches from the bottom of the sensor housing to 240 inches (6.1m)
Resolution: 0.01 inches (0.25 mm)
Drift: 0.00 inches (0 mm)
Temperature Compensation: Actual sensor temperature is used in combination with the seasonal manhole temperature to obtain the best depth accuracy and precision

PRESSURE Sensor
Overflow Detection: A sealed gauge pressure sensor detects when surcharge depths exceed the depth of the manhole causing the monitor to initiate an alarm notification. Begins measuring when flow depths reach the bottom of the parabolic reflector and can measure depths up to 100 inches (2540 mm) above the sensor.

Data Storage
At a 5-minute Sample Rate:
3,784,704 bytes, 630,784 storage locations
Approximately 540 days for three stored entities

Clock
Battery-backed real-time clock module (synchronized to the nearest cell tower)

Power
Replaceable 9V 60Ah alkaline battery pack with up to 5-years battery life depending on modem and data delivery rate configuration

Communications
Cellular Modem: Third-party, FCC/IC/EC and carrier approved, global coverage, commercial UMTA/HSPA+/GSM modem. FCC ID: R17HE910.
Local: On-Site, local wireless connection (Bluetooth® technology)

Antenna
SMA connector on enclosure housing supports external antenna provided by ADS or customer. Antenna may be installed in or outside the manhole depending on wireless signal strength in the area.

Firmware Upgrades
Remotely via wireless connection or locally using on-site wireless connection

Diagnostics
Two primary options for monitoring and acting on diagnostic information:
- Daily Check-In messages delivered automatically to user via text message or email that provide battery status and wireless signal strength as well as additional diagnostic information through an email attachment
- Direct Call to the monitor through ADS ***Qstart***™ software for reading the latest monitor status and test firing the ultrasonic sensor

Intrinsically Safe
- CSA certified to CLASS – C225803 – Process Control Equipment – Intrinsically Safe – For Hazardous Locations – Certified to Canadian Standards
- CLASS – C225883 – Process Control Equipment – Intrinsically Safe – For Hazardous Locations – Certified to US Standards
- Class I, Division 1, Groups C and D, T3 (152°C); Ex ia IIB T3 (152°C) Ga; Class I Zone 0 AEx ia T3 (152°C) Ga.

ADS LLC
340 The Bridge Street, Suite 204, Huntsville, AL 35806
Phone: 256.430.3366/ Fax: 256.430.6333
Toll Free: 1.800.633.7246, www.adsenv.com

Doppler Flow Meter

Equipment Selected: Unidata Starflow Ultrasonic Doppler Velocity, Depth, and Flow Meter, Model J, 5 meter

Cost: $2,297/each ordered directly from Unidata

6526

STARFLOW ULTRASONIC DOPPLER VELOCITY, DEPTH AND FLOW INSTRUMENT

MODEL J

Unidata ultrasonic Doppler instrument is a compact, easy-to-use system for measuring the velocity and depth of water in rivers and streams, open drainage channels, and large pipes. It is suitable for use in a wide range of water qualities ranging from sewage and wastewater to clean streams, potable water and even sea water. This model incorporates a backup lithium battery for the RAM which allows for logged data to be stored for some months / years until power is restored.

The instrument measures forward and reverse flow conditions and may be programmed to computer flow rate and total flow in pipes and open channels.

The ultrasonic transducer assembly is profiled to reduce flow disturbance. It is designed to be placed at (or near) the bottom of the water channel for upstream measurement. A single cable connects the instrument to a 12V DC power source.

Water velocity is measured by the ultrasonic Doppler principle which relies on suspended particles or small air bubbles in the water to reflect the ultrasonic detector signal. The instrument will not operate in very clean, degassed water. Water depth is gauged by a hydrostatic pressure sensor, referenced to atmospheric pressure through the vented power and signal cable.

SPECIFICATIONS

PHYSICAL SPECIFICATIONS	
MATERIAL:	PVC body, Marine Grade 316 Stainless Steel Mounting Bracket
SIZE:	290mm x 70mm x 30mm (LxWxH)
WEIGHT:	2kg with 15m of Cable
OPERATING TEMPERATURE:	0°C to 60°C water temperature
VELOCITY RANGE:	21mm/s to 4500mm/s bi-directional
VELOCITY ACCURACY:	2% of measured velocity
VELOCITY RESOLUTION:	1mm/s
DEPTH RANGE:	0m to 2.0m and 0m to 5.0m
DEPTH ACCURACY:	Typical ± 0.25%
TEMPERATURE:	-17°C to 60°C
TEMPERATURE RESOLUTION:	0.1°C
FLOW COMPUTATION:	Flow rate, totalised flow
CHANNEL TYPE:	Pipe, open channel, natural stream
CABLE:	15 metre, 9 way vented <<SQL>> compatible
CABLE OPTIONS:	User specified up to 50 metres

ELECTRICAL SPECIFICATIONS	
POWER SOURCE:	External Battery 12V DC
POWER USAGE:	11.5V to 15V DC, 50μA standby, 200mA active, 90mA communications
CONTROL:	1 x CMOS output trigger – water sampler
COMMUNICATION:	1 x RS232C Baud rates: 300/1200/2400/4800/9600/19200/38400
SDI-12:	SDI-12V 1.3 recorder (1200 baud smart instrument channel)
INTEGRATED LOGGER SPECIFICATIONS	
STORAGE MEMORY:	Low power CMOS RAM 512k standard
RAM BACK UP BATTERY:	Lithium Battery 3V, 950mAh
TIME CLOCK:	Crystal regulated, +/- 10 seconds/month
SCAN RATES:	Programmable from 5 seconds to 5 minutes
LOG INTERVALS:	Programmable from 5 seconds to 24 hours
CPU:	80C552 microcontroller, 14.7456 MHz

AVAILABLE FROM: **Unidata Pty Ltd** | 40 Ladner Street, O'Connor, 6163 Western Australia | Tel: +61 8 9331 8600 | info@unidata.com.au | **www.unidata.com.au**

Water Level Data Logger

Equipment Selected: Onset MX2001 HOBO Bluetooth Low Energy Water Level Data Logger (4m range with 5m cable)

Cost: $685 ($595/sensor + $90/cable) ordered directly from Onset

HOBO® MX2001 Data Logger

Bluetooth Low Energy Water Level Data Logger

The HOBO® MX2001 is the industry's first water level data logger designed for convenient wireless setup and download from mobile devices via Bluetooth Low Energy. The logger dramatically simplifies and lowers the cost of field data collection by providing wireless access to high-accuracy water level and temperature measurements right from a mobile phone or tablet. The MX2001 logger consists of a top-end unit and a water level sensor which are sold as a set, plus a direct read cable to connect them. Cables can be ordered in lengths from 0.2 to 500m for deployment in a wide range of wells.

Supported Measurements:

Absolute Pressure, Barometric Pressure, Differential Pressure, Temperature, Water Level and Water Temperature

Key Advantages:

- Wireless data offload to mobile devices using Bluetooth Low Energy
- Integrated barometric pressure sensor enables direct water level readout
- Direct read cable connects sensor to top-end logger/transmitter
    - The cable includes Kevlar strength member
    - Cables are interchangeable so loggers are easy to redeploy in future applications
    - The logger and sensor add 0.39 meters to the length of the cable
    - Cable length can vary up to 3% from the length ordered
    - The 1, 5, 10, 15, 30 and 60 meter cable lengths are in stock; custom cable lengths have a 2 to 4 week lead time
- Reference water level can be entered at the start of the deployment
- Use HOBOmobile for setup, data viewing and data sharing
- Powered by two user-replaceable AA batteries in the top-end unit
- Several logging modes: normal, multi-rate logging and event-triggered burst-logging
- Durable ceramic sensor
- Available with stainless steel or titanium sensor ends
- 3-point NIST-traceable calibration certificate included for the water pressure sensor

HOBO MX2001 Data Logger Specifications

Pressure (Absolute) and Water Level Measurements MX2001-01-S and MX2001-01-Ti-S - 9 Meter (30') range	
Operation Range	0 to 207 kPa (0 to 30 psia); approximately 0 to 9 m (0 to 30 ft) of water depth at sea level, or 0 to 12 m (0 to 40 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 207 kPa (10 to 30 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 0.5 cm (0.015 ft) water Maximum error: ±0.1% FS, 1.0 cm (0.03 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.62 kPa (0.09 psi) maximum error
Resolution	<0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water
Pressure Response Time (90%)***	1 second at a stable temperature

Pressure (Absolute) and Water Level Measurements MX2001-02-S - 30 Meter (100') range	
Operation Range	0 to 400 kPa (0 to 58 psia); approximately 0 to 30.6 m (0 to 100 ft) of water depth at sea level, or 0 to 33.6 m (0 to 111 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 400 kPa (10 to 58 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	500 kPa (72.5 psia) or 40.8 m (134 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 1.5 cm (0.05 ft) water Maximum error: ±0.1% FS, 3.0 cm (0.1 ft) water
Raw Pressure Accuracy**	±0.3% FS, 1.20 kPa (0.17 psi) maximum error
Resolution	0.04 kPa (0.006 psi), 0.41 cm (0.013 ft) water
Pressure Response Time (90%)***	1 second at a stable temperature

Pressure (Absolute) and Water Level Measurements MX2001-03-S - 76 Meter (250') range	
Operation Range	0 to 850 kPa (0 to 123.3 psia); approximately 0 to 76.5 m (0 to 251 ft) of water depth at sea level, or 0 to 79.5 m (0 to 262 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 850 kPa (10 to 123.3 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	1,200 kPa (174 psia) or 112 m (368 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 3.8 cm (0.125 ft) water Maximum error: ±0.1% FS, 7.6 cm (0.25 ft) water
Raw Pressure Accuracy**	±0.3% FS, 2.55 kPa (0.37 psi) maximum error
Resolution	<0.085 kPa (0.012 psi), 0.87 cm (0.028 ft) water
Pressure Response Time (90%)***	1 second at a stable temperature

Pressure (Absolute) and Water Level Measurements MX2001-04-S and MX2001-04-Ti-S - 4 Meter (13') range	
Operation Range	0 to 145 kPa (0 to 21 psia); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level, or 0 to 7 m (0 to 23 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 145 kPa (10 to 21 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.075% FS, 0.3 cm (0.01 ft) water Maximum error: ±0.15% FS, 0.6 cm (0.02 ft) water

Raw Pressure Accuracy**	±0.3% FS, 0.43 kPa (0.063 psi) maximum error
Resolution	<0.014 kPa (0.002 psi), 0.14 cm (0.005 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature

Barometric Pressure (MX2001-TOP)	
Operation and Calibrated Range	66 to 107 kPa (9.57 to 15.52 psia); -20° to 50°C (-4° to 122°F)
Accuracy	±0.2 kPa (±0.029 psi) over full temperature range at fixed pressure; maximum error ±0.5% FS
Water Level Accuracy*	Typical error: ±0.075% FS, 0.3 cm (0.01 ft) water Maximum error: ±0.15% FS, 0.6 cm (0.02 ft) water
Resolution	0.01 kPa (0.0015 psi)
Response Time	1 second at stable temperature
Stability (Drift)	0.01 kPa (0.0015 psi) per year

Temperature Measurements (All Sensor End Models MX2001-0x-S and MX2001-0x-Ti-S)	
Operation Range	-20° to 50°C (-4° to 122°F)
Accuracy	±0.44°C from 0° to 50°C (±0.79°F from 32° to 122°F), see Plot A
Resolution	0.1°C at 25°C (0.18°F at 77°F), see Plot A in manual
Response Time (90%)	5 minutes in water (typical)
Stability (Drift)	0.1°C (0.18°F) per year

Logger	
Operation Range	-20° to 50°C (-4° to 122°F)
Radio Power	1 mW (0 dBm)
Transmission Range	Approximately 30.5 m (100 ft) line-of-sight
Wireless Data Standard	Bluetooth Low Energy (Bluetooth Smart)
Logging Rate	1 second to 18 hours
Logging Modes	Fixed interval, multiple intervals with up to 8 user-defined logging intervals and durations, or event-triggered burst
Memory Modes	Wrap when full or stop when full
Start Modes	Immediate, date & time, or next interval
Stop Modes	When memory full, stop with HOBOmobile, date & time, or after a set logging period
Time Accuracy	±1 minute per month 0° to 50°C (32° to 122°F)
Battery	Two AA, 1.5 V alkaline batteries, user replaceable
Battery Life	1 year, typical with logging interval of 1 minute. Faster logging and/or statistics sampling intervals, entering burst logging mode, excessive readouts, checking of Full Status Details, and remaining connected with HOBOmobile will impact battery life.
Memory	256 KB memory (30,000 sets of measurements)
Full Memory Download Time	Approximately 2 minutes; may take longer the further the device is from the top end of the logger

Dimensions	Top end (MX2001-TOP): 2.54 cm (1.0 inches) diameter, 28.9 cm (11.4 inches) length; mounting hole 7.6 mm (0.3 inches) diameter Sensor end (MX2001-0x-S and MX2001-0x-Ti-S: 2.54 cm (1.0 inches) diameter, 9.91 cm (3.9 inches) length **Note:** The length of the water level logger cable (CABLE-DR-xxx) can vary -0% to +3% +10 cm (3.9 inches) from the length ordered. The logger adds 38.8 cm (15.3 inches) to the length of the cable ordered.
Weight	Top end (MX2001-TOP): Approximately 136 g (4.78 oz) in air Stainless sensor end (MX2001-0x-S): Approximately 106 g (3.74 oz) in air; approximately 53.9 g (1.9 oz) in fresh water Titanium sensor end (MX2001-0x-Ti-S): Approximately 80 g (2.83 oz) in air; approximately 37 g (1.3 oz) in fresh water
Wetted Materials	Top end (MX2001-TOP): Acetal housing, Polycarbonate end caps, Polycarbonate collar nut; Viton and Buna-N O-rings Stainless sensor end (MX2001-0x-S): Acetal housing, PVC end cap, Polycarbonate collar nut; Viton and Buna-N O-rings; ceramic sensor in stainless steel end cap Titanium sensor end (MX2001-0x-Ti-S): Acetal housing, PVC end cap, Polycarbonate collar nut; Viton and Buna-N O-rings; ceramic sensor in Titanium end cap
Environmental Rating	Top end: NEMA 6, IP67 Sensor end: IP68
The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).	

*Water Level Accuracy: With accurate reference water level measurement, known water density, and a stable temperature environment. System Water Level Accuracy equals the sum of the Barometric Water Level Accuracy plus the selected sensor end Water Level Accuracy.

**Raw Pressure Accuracy: Absolute pressure sensor accuracy includes all sensor drift, temperature, and hysteresis-induced errors.

***Changes in Temperature: Allow 20 minutes in water to achieve full temperature compensation of the pressure sensor. There can be up to 0.5% of additional error due to rapid temperature changes. Measurement accuracy also depends on temperature response time.

Contact Us

Sales (8am to 5pm ET, Monday through Friday)
- Email sales@onsetcomp.com
- Call 1-508-759-9500
- In U.S. toll free 1-800-564-4377
- Fax 1-508-759-9100

Technical Support (8am to 8pm ET, Monday through Friday)
- Contact Product Support www.onsetcomp.com/support/contact
- Call 1-508-759-9500
- In U.S. toll free 1-877-564-4377

Onset Computer Corporation
470 MacArthur Boulevard
Bourne, MA 02532

Flow Meter Communications Equipment

Equipment Selected: The Things Network

Cost: $350 ordered on amazon.com

For more information and specifications, go to https://www.thethingsnetwork.org/docs/gateways/gateway/