Potential Projects for Flood Mitigation

Stream Monitoring

Identify Sites

Purchase Equipment

Install and Monitor

FLOOD WARNING SYSTEMS

A GUIDE TO UNDERSTANDING, IMPLEMENTING AND OPERATING FLOOD WARNING SYSTEMS

FONDRIEST ENVIRONMENTAL

WHAT'S INSIDE

WHY MONITORING MATTERS

While some areas are more prone to flooding than others, the establishment of flood warning systems near any major waterway or body of water provides critical information that can protect property and save lives. Of course, the most effective flood warning methods extend beyond the installation of gages and telemetry equipment, and employ qualified staff and carefully designed procedures to provide the earliest warning about whether a flood should be expected, when it will occur, and how severe it will be. This guide offers instruction to individuals, communities, and organizations interested in establishing and operating flood warning systems.

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FLOOD WARNING

Protecting Lives and Property from Floods

In the United States, the U.S. Geological Survey and the National Weather Service — part of the National Oceanic and Atmospheric Administration — work together to maintain flood warning systems across the country. Specifically, the USGS acts as the principal source on surface and groundwater data, and operates more than 85 percent of stream gaging stations in the U.S. The NWS uses those data and data from other sources to issue river forecasts and flood alerts.

Generally speaking, the NWS issues flood alerts either on a county basis, or for particular rivers and streams. Those alerts are divided into several basic categories:

Flood watches are issued when conditions suggest a possibility of flooding, or if flooding is anticipated within 12-48 hours.

Flood warnings are more severe, and are issued if widespread flooding is expected across a large region, or if flooding is imminent or actively taking place.

Flash flood watches and warnings follow the same protocol, but indicate potential for especially rapid flooding, usually from heavy rain or dam failure.

Flood statements are issued when flooding is expected along major streams where people and property are not threatened. They may also be issued as an update to previous warning and watch alerts.

In the U.S., these alerts are distributed in Specific Area Message Encoding through the Emergency Alert System and the NOAA Weather Radio network.

In communities that lack a flood warning program, but are interested in developing their own, the NWS can provide further guidance and technical support, as well as outreach and education to involved parties and community leadership. A flood warning system need not be expensive or overly complicated, and the benefits — protecting lives and property — far outweigh any potential complications or inconveniences.

When it comes to the installation and maintenance of gages, sensors, and other equipment, Fondriest Environmental can help you through every step of the process.

A REAL-TIME SOLUTION

An effective flood warning system should be based on the regular collection of local rainfall, stream level, and streamflow data. This can be done through routine monitoring, in which operating personnel make visits to stream gage and precipitation measuring sites, but a real-time monitoring system with telemetry can make data collection easier — and in many cases, more cost-effective — while allowing for the fastest possible response to a flood event. The NWS acknowledges that, even in areas where they provide flood warning coverage, a real-time, community-oriented flood warning system can reduce risks involved with flooding.

The NWS forecasts floods using complex mathematical models that predict how rivers and streams across the U.S. will respond to varying levels of rainfall and snowmelt. These models are based on records of stream stage and discharge, the calculations for which are outlined below. If you are interested in developing a responsive flood warning system without advanced forecasting capabilities, however, you can likely get by with a system based on Automated Local Evaluation in Real Time, or ALERT gages.

Automated Flood Warning System

Developing a flood warning system requires attention to three basic factors: Data collection via gaging, data processing, and the hardware and software required, and the dissemination of flood warning information. While automated flood warning systems are often surprisingly inexpensive to implement, the primary factor determining cost for any such system is the number of gage site locations. Additionally, the type of communications and telemetry capabilities at each site will contribute to costs.

ALERT Gages

There are a wide variety of automated stream gages that can transmit stream level data via telemetry, but gages developed according to the NWS ALERT protocol are among the most common and will be the focus of this guide. However, it's worth noting that many other gages designed to measure precipitation and water level operate under similar principles, and this guide may be applicable to certain aspects of other systems.

ALERT systems have the advantage of operating under a common standard of communications criteria, so although a wide array of manufacturers develop and produce ALERT hardware and software, most of those products are cross-compatible.

ALERT gages perform two primary tasks: sensing and communicating. An ALERT gage employs sensors to detect changes to a certain parameter, usually precipitation volume and/or water level. More advanced gages may also be equipped with temperature and wind speed sensors. Some ALERT gages can also provide site-specific information, or information regarding the health of the unit.

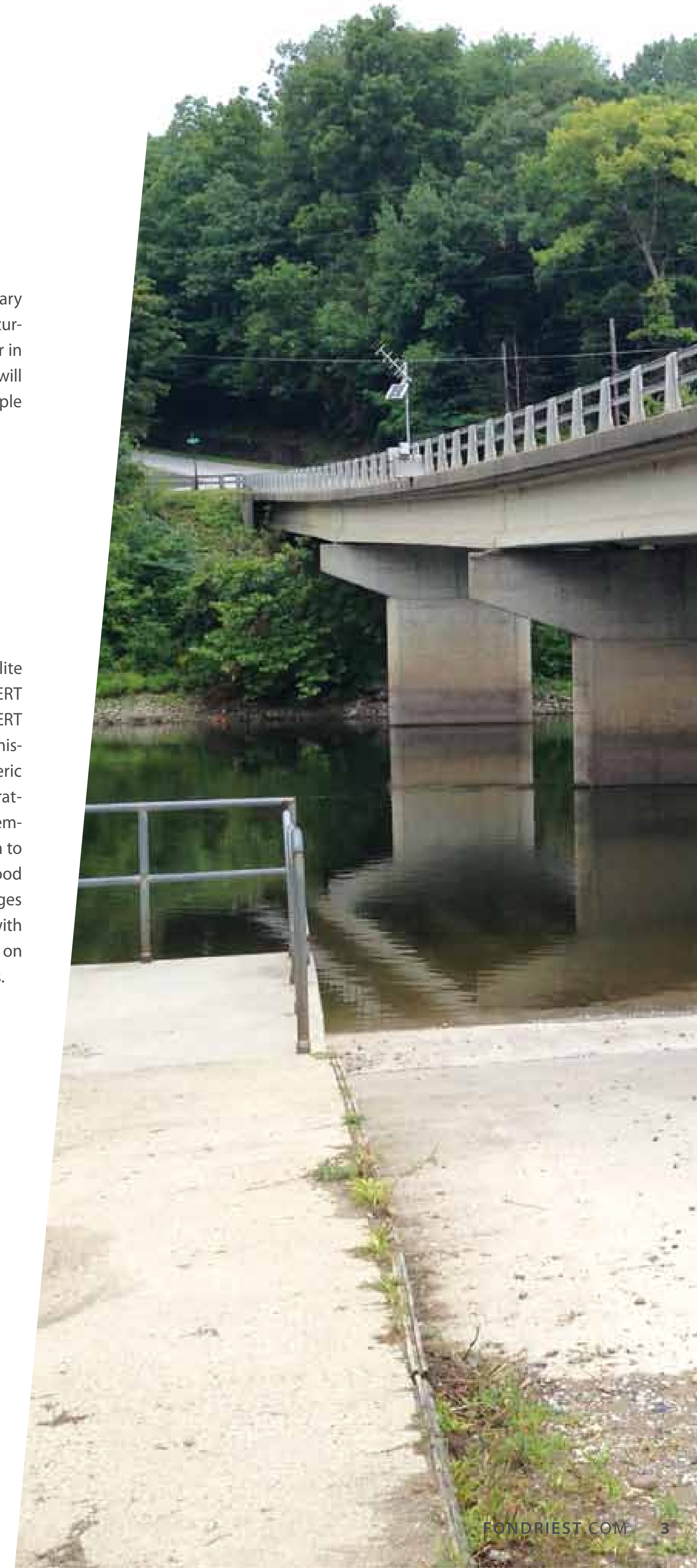
In the example of a precipitation-measuring ALERT system, the gage will be designed to detect a particular "event" — in a common case, 1 millimeter of rainwater entering the gage's tipping bucket through the top of its funnel. When the bucket tips, it pours out any water within, engaging a switch that transmits ALERT data and resetting the bucket. Any other sensors on the gage will also activate the ALERT data transmitter after detecting a specific event. On days without rain, ALERT gages will transmit a "no rain" report to show that the device is still working.

Data Processing

The software used to collect and process data from ALERT gages will vary based on the user's needs and preferences. Many ALERT gage manufacturers offer their own proprietary software to view data remotely, whether in a graphical or text format. The most useful ALERT processing software will permit multiple users to access the data simultaneously, and for multiple gages to be monitored at once.

Information Dissemination

Automated flood warning systems may utilize radio, cellular, or satellite telemetry to communicate with a host computer or network, but ALERT systems specifically operate using radio frequencies. Because of this, ALERT systems can suffer from some of the same issues as any other radio transmission device, including interference from electrical noise and atmospheric conditions. Interference may also occur if several ALERT systems operating in a close vicinity transmit simultaneously. Satellite and cellular telemetry tends to avoid these problems, but still require some consideration to site selection in order to maximize transmission quality. Automated flood warning systems of all sorts will also require a power supply. While gages installed near developed communities may be powered by connection with a commercial power grid, those located in remote areas generally rely on a combination of battery and solar power to run their telemetry devices.



STREAMFLOW MEASUREMENTS

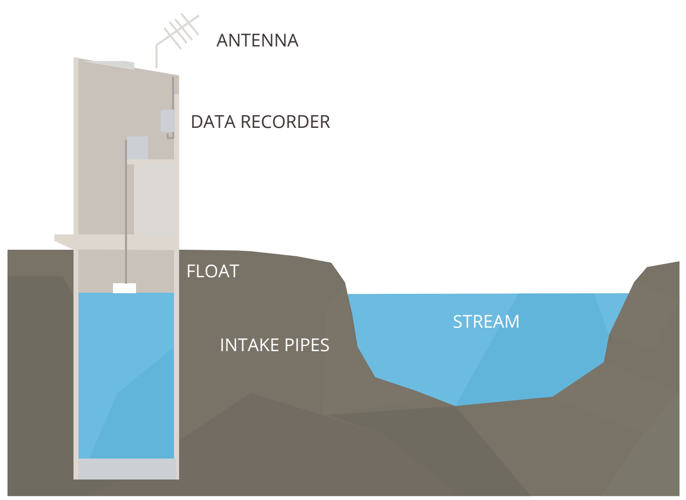
While streams and rivers may be monitored for many qualities and parameters that they share with lakes, ponds and basins, they possess one quality that sets them apart from other freshwater bodies: movement. Streamflow is a keystone parameter that impacts many other aspects of a river's hydrology and water quality. Although these other aspects may be just as vital to a river's health — or just as applicable to your particular project — they may be shared with other types of water bodies, and in many cases will be covered in other guides provided by Fondriest Environmental. For this reason, this application guide will focus primarily on establishing streamflow through stage discharge measurement.

Calculating Streamflow

Streamflow is a measurement of the amount of water flowing through a stream or river over a fixed period of time. Streamflow cannot be measured directly, say, by plunging an instrument into a river. Instead, it must be calculated in a process known as stream gaging. The USGS has been doing this since 1889, when it established its first stream gage on the Rio Grande River in New Mexico to determine how much water was available for irrigation as the nation expanded westward. Today, the USGS operates more than 7,000 stream gages across the U.S., which provides streamflow information used widely for flood prediction, water management, engineering and research, among other uses.

The USGS splits stream gaging into a three-step process: measuring stream stage, measuring discharge and determining the stage-discharge relation.

Measuring Stream Stage

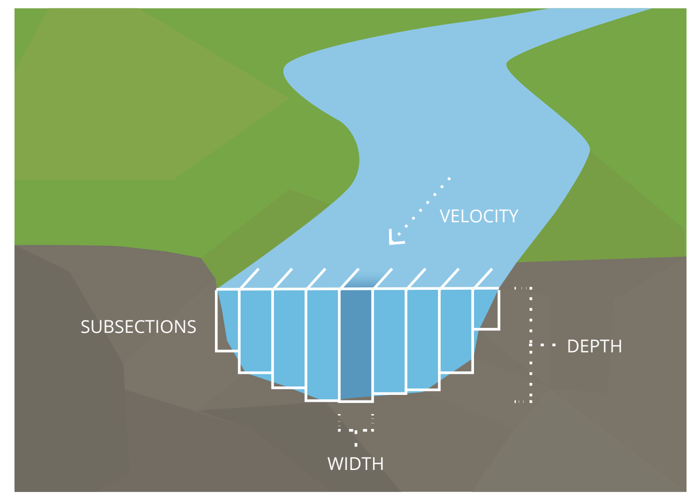


The first step in calculating streamflow involves measuring stage, which is the height of the water surface at a particular point in a stream or river. Stage is sometimes known as gage height, and can be measured several ways. Among the most common of these approaches uses a stilling well installed in the river bank or attached to a stationary structure such as a pier or bridge support. An underwater intake allows water into the stilling well at the same elevation of the river's surface. A float or a sensor — whether pressure, optical or acoustic — then measures the stage inside the well. An electronic recording device or data logger records stage measurements at regular intervals; in the case of the USGS, usually every 15 minutes. A telemetry system may also be present in a stilling well, allowing data to be transmitted remotely to a host computer in real time.

It may not always be cost-effective or space-efficient to install a stilling well where stream gaging is necessary. In these cases, stage can be measured with a vented pressure transducer installed within a PVC or metal pipe along the stream bank. In locations where a bridge or overhead structure is available for instrument mounting, a non-contact radar or ultrasonic water level sensor can also be used.

Stage must always be measured relative to a constant reference elevation, or datum. Depending on the duration of your project, it may be necessary to routinely survey the elevation of your stream gage structure and its datum, to ensure that elevations have not shifted due to settling or natural erosion.

Measuring Discharge



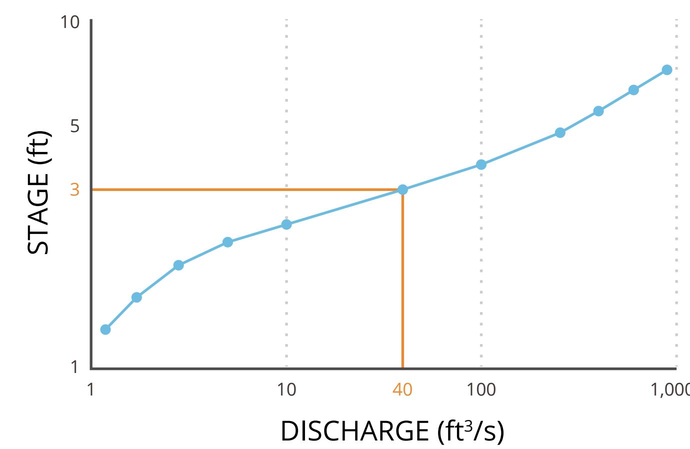
In addition to stage, discharge must also be established before streamflow information can be computed. Discharge is the volume of water moving down a waterway per unit of time. It is most commonly expressed in cubic feet per seconds or gallons per day. To calculate discharge, multiply the area of water in a channel cross section by the average velocity of water in that cross section. In short: discharge = area X velocity

The simplest way to measure discharge is to divide the channel cross section into vertical rectangular subsections. Once the area (width X depth) of each of these subsections is established and multiplied by velocity to determine subsection discharge, the results can be added together to calculate total discharge.

Subsection width is best measure with a cable or steel measuring tape, while depth can be measured by a wading rod in shallower channels and suspended sounding weights in deeper waters. Velocity, on the other hand, should be measured with a current meter. Many current meters rely on a wheel formed of several cups revolving around an axis. Each revolution generates an electronic signal that is counted and timed by the meter, which translates to water velocity.

A faster, but more expensive method to measure velocity involves the use of an Acoustic Doppler Current Profiler (ADCP) which can be mounted in a small watercraft. The ADCP sends a pulse of sound into the water and measures changes in the pulse's frequency as it returns to the instrument. The ADCP speeds discharge calculations by measuring velocity and depth at the same time. Width is also measured as the boat-mounted ADCP is navigated across the channel. Though somewhat more limited in capability, rod-mounted Acoustic Doppler Velocimeters allow similar functions to be performed while wading through shallow streams.

Determining the Stage-Discharge Relation



Stage-discharge relation, or "rating," is a dynamic variable that is determined by comparing stage at a stream gage to discharge at the same point. Accurate stage-discharge relations can only be developed by measuring discharge across many ranges of stage. Furthermore, channels should be continually surveyed for changes caused by erosion, sediment deposition, vegetation growth and ice formation.

When discharge has been established across enough stages, stage-discharge relation can be visualized in the form of a graph. When this relation is properly maintained through periodic updates, it can provide useful streamflow information for a given stream or river.

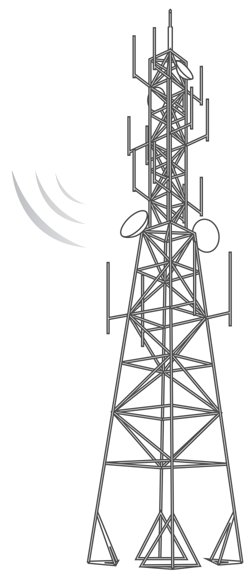
TYPICAL FLOOD WARNING SYSTEM

As discussed above, there are a number of ways to configure an automated flood warning system, but the needs of one system can differ widely from another. The number of gage sites, their locations, and the instruments and sensors used at each will vary based on the nature of your application and the size of the intended coverage area. If your warning system is intended to service an entire community, the number of gages necessary will depend on the location of nearby water bodies in relation to property and infrastructure. If only a small portion of your community is exposed to a jutting stretch of river, for instance, one gage may be sufficient.

In a single-gage system, installing a station on a riverbank or standing structure, such as a pier or bridge support, will likely provide the best results. Gages can also be built into stilling wells or standpipes, making it easier to include other instruments, such as multi-parameter sondes equipped with an array of sensors, as well as data loggers and telemetry systems. While radio transmission is the standard telemetry option for ALERT-based systems, satellite and cellular options may be more beneficial to your application, depending on its size and location. Nearly all telemetry options will provide continuous real-time data to any computer or mobile device, ensuring that your system runs smoothly, and any control measures or emergency actions can be implemented immediately if parameter limits are exceeded.

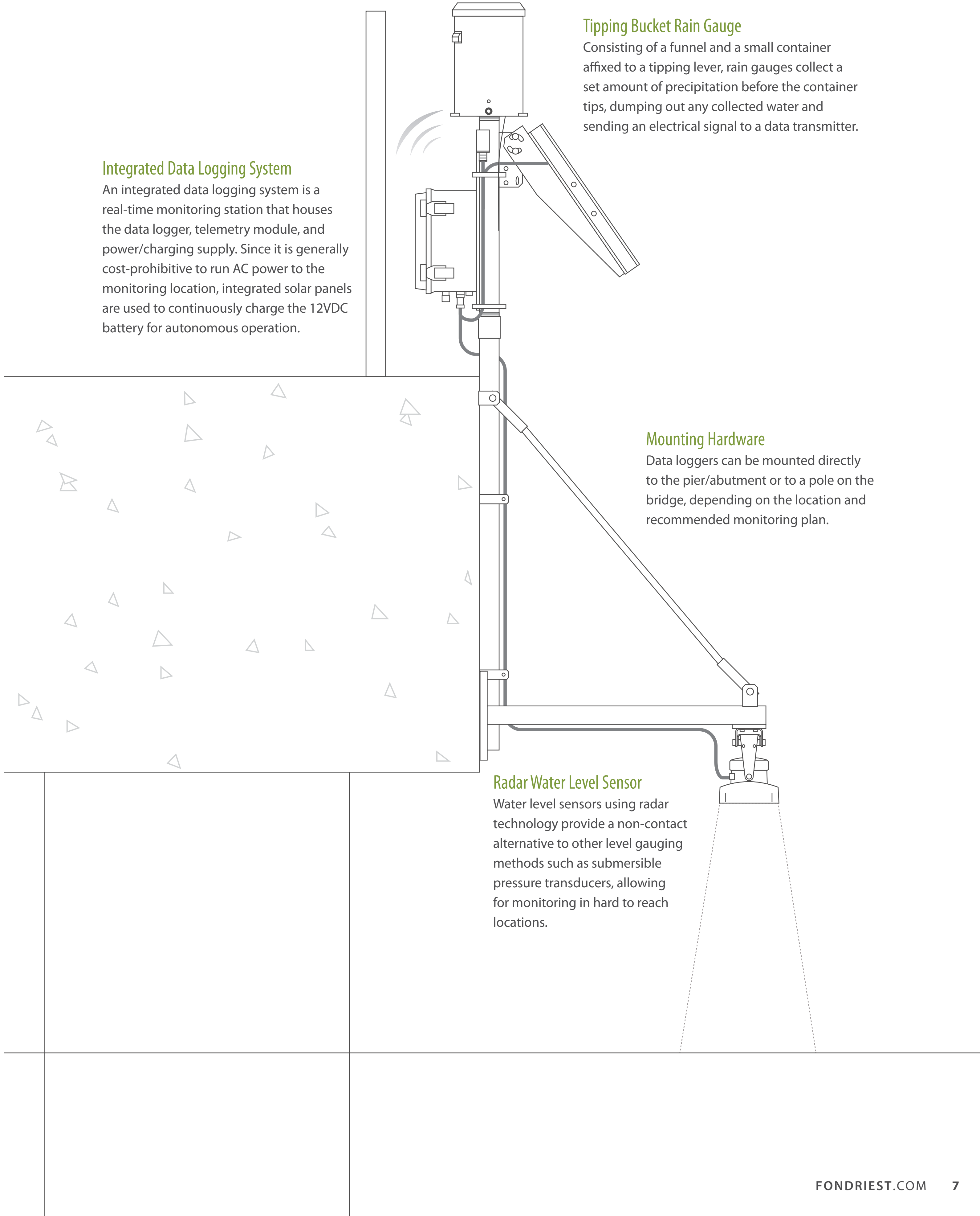
Telemetry

Telemetry provides access to data in real time. ALERT transmits wireless communications via radio frequencies, but cellular and satellite-based options are also available.



Live Data

Instant access to project data is available 24/7 through a cloud-based data center. Monitoring data can be viewed in real time, or as a graph to identify trends. Real-time automated alerts can be sent via text or email when specified parameters exceed predefined limits.



Integrated Data Logging System

An integrated data logging system is a real-time monitoring station that houses the data logger, telemetry module, and power/charging supply. Since it is generally cost-prohibitive to run AC power to the monitoring location, integrated solar panels are used to continuously charge the 12VDC battery for autonomous operation.

Tipping Bucket Rain Gauge

Consisting of a funnel and a small container affixed to a tipping lever, rain gauges collect a set amount of precipitation before the container tips, dumping out any collected water and sending an electrical signal to a data transmitter.

Mounting Hardware

Data loggers can be mounted directly to the pier/abutment or to a pole on the bridge, depending on the location and recommended monitoring plan.

Radar Water Level Sensor

Water level sensors using radar technology provide a non-contact alternative to other level gauging methods such as submersible pressure transducers, allowing for monitoring in hard to reach locations.

MONITORING LOCATION

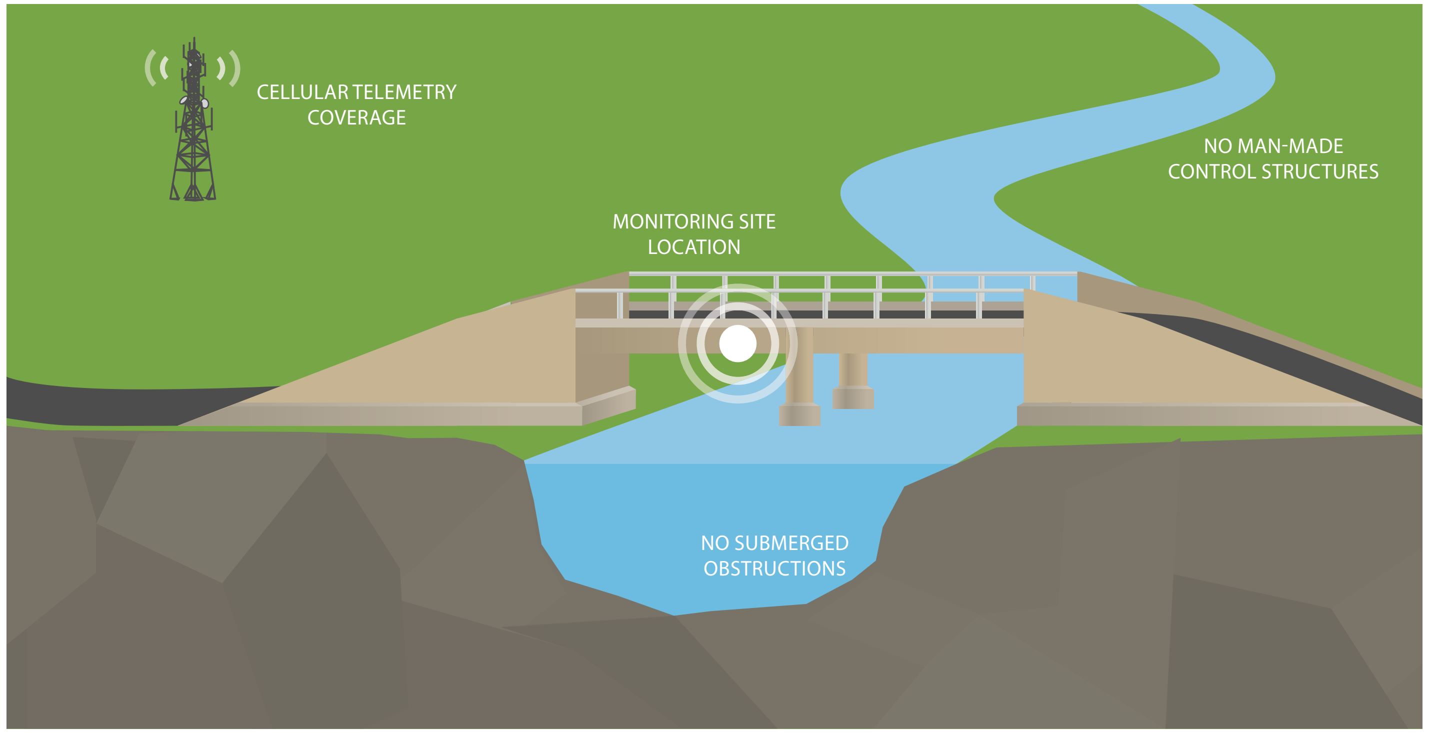
As mentioned before, the ideal placement for a flood warning gage will depend largely on the site considerations of the waterway where it is located. Careful planning is needed to select the location, determine substrate stability and water level fluctuation, and to design a housing solution that will effectively protect the gage from acts of nature or vandalism. Physical constraints of a site, the time required to reach the location, legal and physical access to a site, and safety issues must be considered when making site selections.

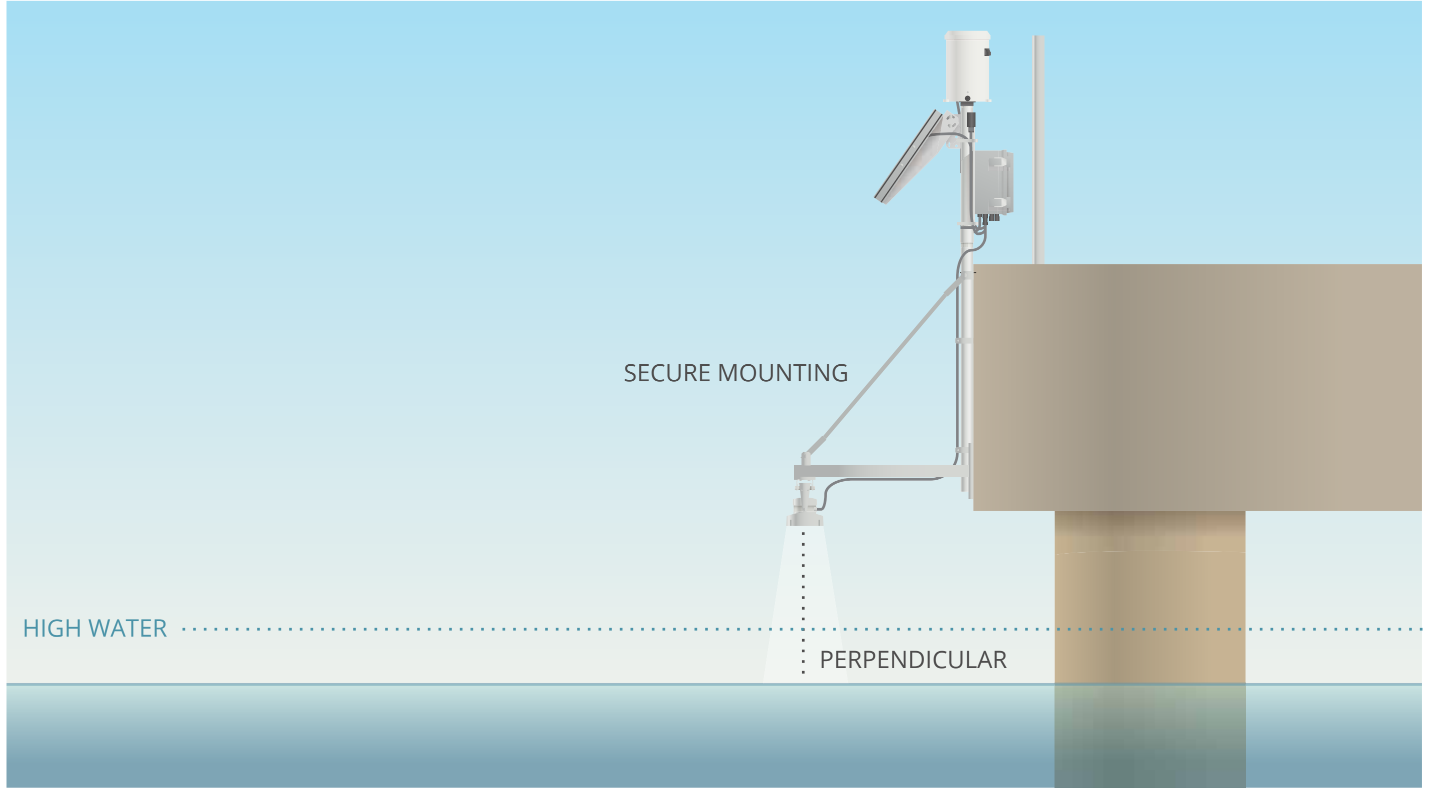
Site Considerations

- The monitoring location should have access to a bridge or overhead structure for securely mounting the radar sensor. There should be a clear path between the sensor and the water to avoid false reflections.
- If using telemetry, determine whether there is sufficient cellular coverage to get a signal at the site. If not, satellite telemetry will likely be required.
- Avoid submerged obstructions such as rocks or bridge piers that disturb or influence the water level. Check for such obstructions when the water is at the lowest anticipated level.
- The mounting location should also avoid horizontal structural surfaces such as beams, brackets, and side wall joints, these surfaces tend to reflect a strong false signal.
- Avoid man-made control/flow structures upstream or downstream of the site that may change flow profiles erratically, as this will making rating development difficult.

Installation Considerations

- Make sure data logging and telemetry equipment will be installed sufficiently above the high water mark to prevent it from being flooded or otherwise damaged by high water.
- The radar sensor should be mounted directly above the water surface, such that the radar beam is perpendicular to the water.
- The radar sensors should be securely mounted to prevent vertical displacement by wind or vibration. Any movement can disturb measurements and result in vertical alignment errors.
- Make certain the radar sensor is mounted high enough to avoid being submerged during high water or flood conditions.
- Any potentially exposed sensor cables near the ground should be run through a conduit to the data logger box to protect from animals.





DATA MANAGEMENT

A major part of any monitoring project is collecting and accessing the data. While it is possible to simply record measurements onsite, the ability to log, send and view monitoring data in real time is far more efficient.

Data Logger

As the name implies, a data logger is an instrument that stores data. In environmental monitoring applications, data loggers can be used not only to collect data from sensors and sondes, but to control sampling rates and transmit data to a central location in real time.

While some water monitoring instruments have the ability to log their own data, a separate, dedicated data logger can gather all data from any and all attached sensors ensuring that no data are lost. If telemetry (wireless communication) is available, the logger can remotely control sensor sampling rates and transmit collected data to a central project computer. Data loggers with telemetry technology can provide real-time hydrological profile data and remote access via a cellular modem, radio transmission or satellite modem.

When housed in a data buoy, a data logger is charged by the buoy's solar power system. If a solar panel system or external battery is not available, the logger can be self-powered using alkaline batteries. Data loggers can be configured with a number of sensor ports for connection to industry-standard digital and analog interfaces, including RS-485, SDI-12 or 0-2.5 VDC. A data logger can also support water quality sensors and sondes, weather stations, and other instruments to complement the hydrological profile data.

Telemetry

Telemetry, or wireless communication, is a useful tool for monitoring rivers and streams in real time. Common telemetry options are cellular and radio, though satellite telemetry can be used in more remote locations. The deciding factor when determining the most cost-effective telemetry option should be the local site conditions and proximity to a project computer. All three of these options permit real-time updates for temperature profiles.

Radio telemetry is recommended when all equipment is in close proximity. If equipped with a license-free spread-spectrum radio, a data logger can communicate with a shore-side or dam-mounted radio base station. This range may vary depending on the logger and base station used. Spread-spectrum radio technology may allow a range as far as five miles (line-of-sight) or a few hundred feet (non-line-of-sight). The radio base station serves as a central hub for any compatible data logger in range, with the ability to send the collected data to a project computer.

Cellular telemetry offers more geographic flexibility than radio, though it does require a cellular data plan. This small, additional cost permits data transmissions from anywhere that receives a cellular signal. With cellular telemetry, monitoring stations do not need to be in close proximity, nor is a base station required. If multiple monitoring stations are required, each data logger can send information individually to a central database. All the data can then be accessed wirelessly from any computer via the Internet. Data loggers may be equipped with cellular modems from different providers, including AT&T, Verizon and Sprint.

For remote applications where radio and cellular telemetry are not feasible, satellite telemetry can be used. The Iridium communications network maintains a dynamic, cross-linked constellation of Low Earth Orbiting (LEO) satellites, providing coverage all over the world. This means that data loggers with an Iridium satellite modem can transmit data in real time from anywhere on Earth. As with cellular networks, the data are sent to a central gateway, which then transfers the data over the Internet to any project computer or cell phone.

Real-Time Online Datacenter

The easiest way to share and view river and stream monitoring data is through a web-based datacenter. An online datacenter offers 24/7 instant access to project data via any web browser. Water pressure and other data can be exported into the datacenter directly from the data logger, or through the project software.

This project management service can be password protected or public, and allows users access to the collected data in real time. In addition to any profile-specific information, the online interface can provide dynamic area maps, overlaid with weather information, recent and historical data, time series graphs and statistical summaries. Visitors can interact with the project maps and view real-time monitoring data or trends over time.

But these cloud-based datacenters are more than just a pretty face. Many can be programmed to send out automated alarm notifications when parameters exceed pre-defined limits. Once an allowable range has been set, the data are entered into the online database. If levels exceed or fall below these recommended ranges, the datacenter will immediately issue an alert (text and/or email) to the appropriate project manager or interested party.

With the availability of real-time data and the datacenter's auto-alert system, project managers can be notified immediately when interesting or action-oriented events may exist. This can be nutrient pollution, algal blooms, turbidity, eutrophication, etc. The online datacenter can also transmit this alert back to the data logger in order to respond to the exceeded temperature, conductivity, pH or any other range. Automated responses may include taking more frequent readings high or low temperature periods, then resuming regular log intervals when levels return to normal.

QUALITY ASSURANCE

To maintain accuracy and keep equipment functioning within specifications, best practice recommends cleaning and calibrating the instruments at regular intervals. It is also recommended to cross-check sensor accuracy against a separate instrument. Projects may even require the use of a Quality Assurance Plan (QAP) that provides a detailed outline of maintenance, calibration and QA/QC requirements.

System Maintenance

Radar sensors are nearly maintenance free. There are is no calibration frequency or consumable parts to be concerned with. That said, it is still important to periodically visit the site to check for potential problems.

Check the sensor for dirt, spider webs, insect nests, etc. that can lead to impairment of the measurement. If obstructions are observed, carefully clean the sensor using a non-abrasive cleaner and soft sponge.

It is also important to check for obstructions in the measurement beam. This can include flotsam or branches of trees and bushes growing in the water. Remove any beam obstructions.

Performance Verification

In addition to visually checking the sensor and measurement beam, it's also important to periodically verify that the sensor is providing accurate data. This can be accomplished using a portable distance sensor or nearby staff gauge.

RECOMMENDED EQUIPMENT

When it comes to developing an automated flood management warning system, there are many pre-made ALERT systems available for purchase, but customizing a system to your specific needs may provide the best results. Fondriest Environmental has selected these products as the best in their field for their quality, reliability and value. Together, they provide an advanced and powerful real-time monitoring system for any river or stream prone to flooding. The RLS Radar Water Level Sensor from OTT is uses radar pulse technology to measure depth in areas unsuitable for contact-based depth sensors. The HSA TB3 Tipping Bucket Rain Gauge offers reliable precipitation data with less than 3 percent margin of error for rainfall intensities from 0 to 500 millimeters per hour. The NexSens 3100-MAST Wireless Telemetry System features a mast-mounted data logging system with cellular modem telemetry and solar charging to keep your data up to date, eliminating the need to routinely visit a gage site. Additionally, the WQData LIVE web data-center allows 24/7 remote access to collected data from any computer or mobile device, while incorporating instant alarm notifications and trend tracking.

OTT RLS Radar Water Level Sensor

The RLS non-contact radar level sensor with pulse radar technology is ideal for monitoring in remote areas and applications where conventional measuring systems are not suitable. The RLS accurately and efficiently measures surface water level With a non-contact distance range of up to 115 feet above water. The sensor is IP67 waterproof and has extremely low power consumption, making it ideal for solar-charged monitoring systems.

The radar level sensor uses a revolutionary level measurement technology, meeting the USGS accuracy requirement of +/-0.01 feet. Two antennas are enclosed in a compact housing and transmit pulses toward the water surface. The time delay from transmission to receipt is proportional to the distance between sensor and water surface. A sampling rate of 16 Hz (16 measurements/second) with 20 second averaging minimizes water surface conditions such as waves and turbulence. The RLS does not require calibration and is unaffected by air temperature, humidity, flood events, floating debris, or contaminated water.

HSA TB3 Tipping Bucket Rain Gauge

The Hydrological Services TB3 Tipping Bucket Rain Gauge incorporates a syphon mechanism to deliver high levels of accuracy across a wide range of rainfall intensities. This rain gauge has 5 tipping bucket capacity options: 0.1mm, 0.2mm, 0.5mm, 1.0mm and 0.01 in. The TB3 also offers the choice of bucket materials: a synthetic ceramic coated brass tipping bucket or an injection molded ABS chrome plated tipping bucket, both of which are balanced to +/-0.05 gms.

Each unit consists of a collector funnel with leaf filter, an integrated syphon control mechanism, an outer enclosure with quick release fasteners, and base which houses the tipping bucket mechanism. The rain gauge also includes dual output reed switches with varistor protection that senses the pulse from each tip and logs it in an internal or external data logger. The dual reed switch can also transmit the tipping bucket pulse from the rain gauge to a telemetry system.

NexSens MAST Data Logging System

The iSIC-MAST system includes the data logger and solar panel pre-mounted to a 2" diameter pole to create a truly plug-and-play data collection and sensor interface platform. The system integrates a NexSens iSIC data logger and 20-watt solar power kit - all in a compact, pre-configured package. Simply thread the system to any 2" NPT male pipe thread, connect the solar panel & battery, wire the sensors, and setup a project using iChart software - it's that simple!

The iSIC data logger arrives ready for long-term deployment. All electronics are housed in a rugged, NEMA 4X enclosure constructed of heavy-duty fiberglass. The built-in 8.5 amp-hour sealed lead acid battery provides 12 volt power to the system, and the battery is continuously charged using solar power. Polymer-coated circuit boards, sealed connectors, corrosion-resistant stainless steel hardware and built-in lightning protection ensure reliable performance in the harshest conditions. All sensors are cabled through Sealcon gland fittings to ensure protection from the elements.

NexSens iChart Software is a Windows-based program for interfacing to an iSIC data logger or network of data loggers. The iChart Setup Device Wizard includes built-in drivers and a step-by-step interface for setting up and configuring remote monitoring sensors and systems. When connected, the user can quickly configure sample & log intervals, upload data, or troubleshoot communications.

NexSens WQData LIVE Web Datacenter

WQData LIVE is a web-based project management service that allows users 24/7 instant access to data collected from NexSens remote environmental data logging & telemetry systems. More than just an online database, WQData LIVE offers the ability to generate automated reports, configure alarms to notify project personnel when data values exceed threshold limits, create FieldBooks to store calibration forms, notes and media and much more. Projects are password protected with the ability to configure a public portal or presentation view to share data with the general public. Project Administrators have the ability to edit project descriptions and information, while users given Collaborator access are limited to data viewing and form entry.

The Google Maps view shows all project sites on a map with zoom, scroll and drag capability. Mousing over a site on the map displays the most recent data values, and clicking on the site navigates to a display showing the last reading or tabular data that can be downloaded to Excel and sent via email or FTP. FieldBooks can be created to store notes recorded during field visits, including forms to store calibration data, which can be submitted from the WQData LIVE mobile app. This eliminates the need for conventional field-books while keeping critical project information in a single, easy-to-access location. Site photos can even be placed onto FieldBook pages or uploaded into the project's Media page.

The WQData LIVE report feature allows data to be shown both graphically and in a tabular format. Report templates can be saved so that specific information can quickly be referenced. Project alarms send email or text messages to project staff for immediate notification of critical conditions. With this unique set of features, WQData LIVE provides everything needed to effectively manage an environmental monitoring application.