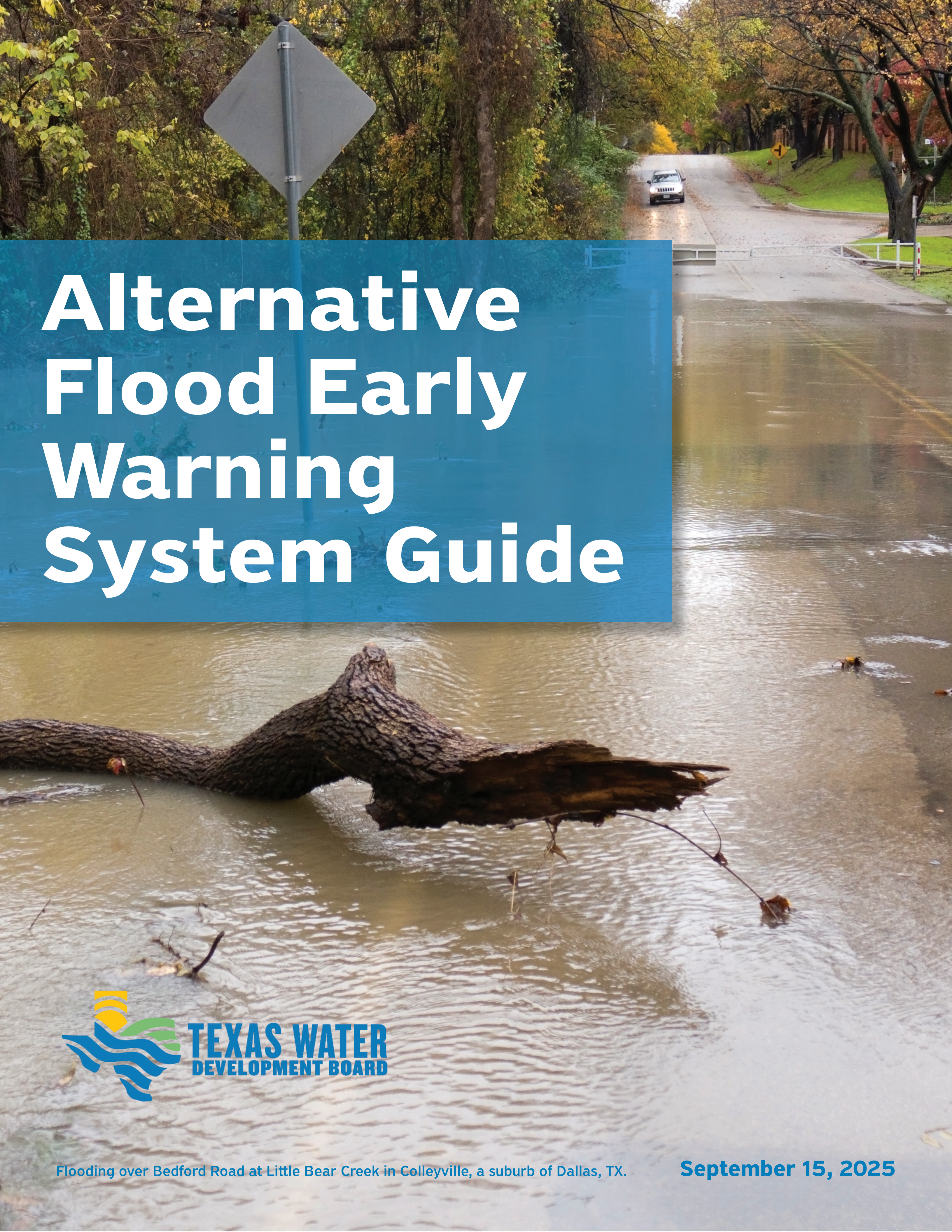
Alternative Flood Early Warning System Guide



TEXAS WATER DEVELOPMENT BOARD

Flooding over Bedford Road at Little Bear Creek in Colleyville, a suburb of Dallas, TX.

September 15, 2025

CONTENTS

EXECUTIVE SUMMARY

Flooding poses a persistent risk to communities across Texas and can occur within hours or days. Timely access to accurate flood information is essential for protecting lives, property, and infrastructure. Traditionally, Flood Early Warning Systems (FEWS) have been complex and expensive, limiting their use to larger agencies and well-funded jurisdictions. However, recent advances in technology have enabled a new generation of alternative FEWS that are simpler, more affordable, and easier to deploy.

This Alternative FEWS Guide was developed by the Texas Water Development Board (TWDB) to support communities seeking lower-cost options for monitoring flood conditions. Alternative FEWS focus on essential features—such as real-time water-level monitoring and online data access—while minimizing cost and complexity. Purchasing and installing an alternative FEWS to monitor water level at a single location typically costs between $2,000 and $10,000. Annual operation and maintenance costs per site range from $500 to $2,000, which includes a website to share information with users, including the public.

This guide provides an overview and practical guidance for selecting, installing, validating, and maintaining an alternative FEWS. It discusses components, such as water-level sensors, power supply, telemetry, data storage, and user dashboards, and outlines how system design affects performance and reliability.

The guide also provides takeaways to consider when evaluating alternative FEWS, such as:

- Define your goals early. Identify the range of end users and their individual needs.
- Select the right water-level sensor. Sensors offer different advantages based on site characteristics and monitoring needs.
- Plan for power and connectivity. Sun exposure is needed, and cell coverage may not always be reliable.
- Budget beyond installation. Ongoing maintenance and data validation are critical to long-term success.
- Communicate effectively. Make sure the website is user-friendly and meets user needs and expectations.
- Choose vendors carefully. Assess equipment durability, customer support, and system adaptability.

Real-world case studies from across Texas and beyond are also included to illustrate how a wide range of communities—from rural counties to urban centers—are adopting alternative FEWS to enhance flood preparedness.

While alternative FEWS can help improve public safety, **they must be supported by emergency action plans, effective communication during flood events, and relentless, continual public outreach**. Consult the comprehensive TWDB Flood Early Warning Systems Guide for more information on how to implement a successful FEWS. Download Here

PURPOSE

FEWS have traditionally included designs and features that are expensive and complex. This has typically limited the use of FEWS to large communities, river authorities, flood districts, and government agencies.

Recent advances in hardware and software have led to alternative FEWS that are simpler and lower cost. Alternative FEWS may allow owners to meet basic flood-monitoring goals and to expand existing flood warning systems.

To fulfill its mission to advance flood resiliency through public awareness, scientific data, and financial and technical assistance, the TWDB developed this Alternative FEWS Guide to provide basic information about alternative FEWS. For more information about FEWS in general, consult the TWDB's Flood Early Warning Systems Guide.
▸ Download Here

WHAT DISTINGUISHES AN ALTERNATIVE FEWS?

- Integrated design
- Compact size
- A focus on monitoring water levels for flood warning and emergency response
- $2,000-$10,000 average purchase and installation cost per site
- $500-$2,000 average annual operations and maintenance cost per site
- Basic but functional website to share flood information with users
- Limited customization, expandability, and redundancy

WHAT THIS GUIDE OFFERS

This guide offers a basic understanding of alternative FEWS to assist users in selecting the right system for their needs. It provides a list of considerations during purchase, installation, validation, and operations and maintenance, along with a summary of how system components relate to cost, performance, and reliability. Case studies offer insights and lessons from users.

This guide does not endorse specific approaches, products, or vendors and is based on information available up to the report release date. Users should define their goals and conduct their own due diligence before implementing any FEWS.

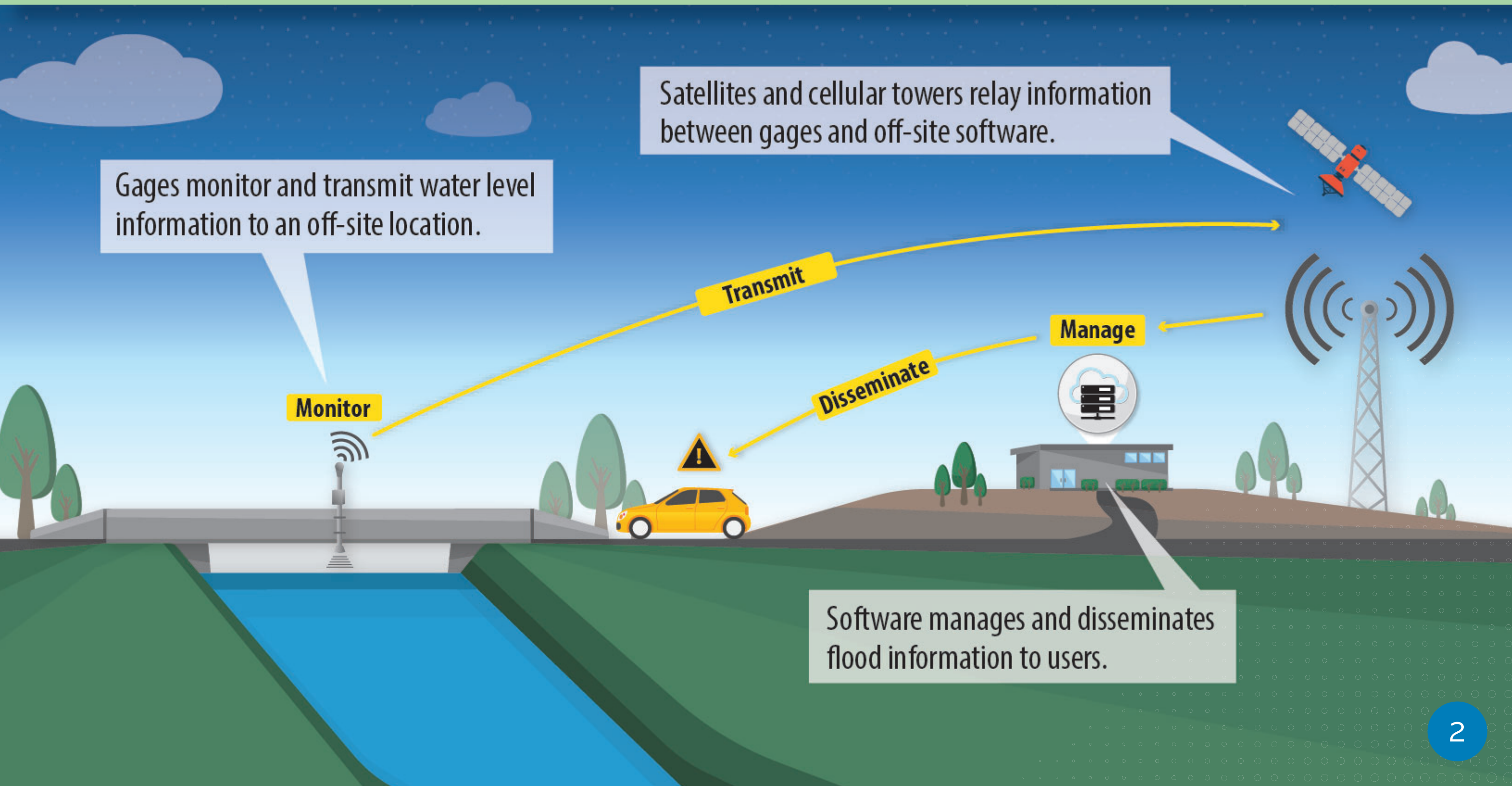
While alternative FEWS can help improve public safety, they must be supported by emergency action plans, effective communication during flood events, and relentless, continual public outreach. Consult the comprehensive TWDB Flood Early Warning Systems Guide for more information on how to implement a successful FEWS.

Flooding on the Canadian river north of Amarillo, National Weather Service, Rodney Bastow

FLOOD EARLY WARNING SYSTEMS

FEWS help reduce loss of life and property damage by monitoring flood conditions and providing early warning of impending flood events. They monitor, transmit, manage, and disseminate information about flooding conditions in real time using hardware (i.e., gages) that transmit water level information to locations where software manages and disseminates this information to users. Some FEWS include cameras to further provide situational awareness and additional sensors to monitor rain, snow, wind, sun, temperature, lightning, humidity, and soil moisture. FEWS enable government agencies and the public to take damage-reducing actions before flooding occurs.

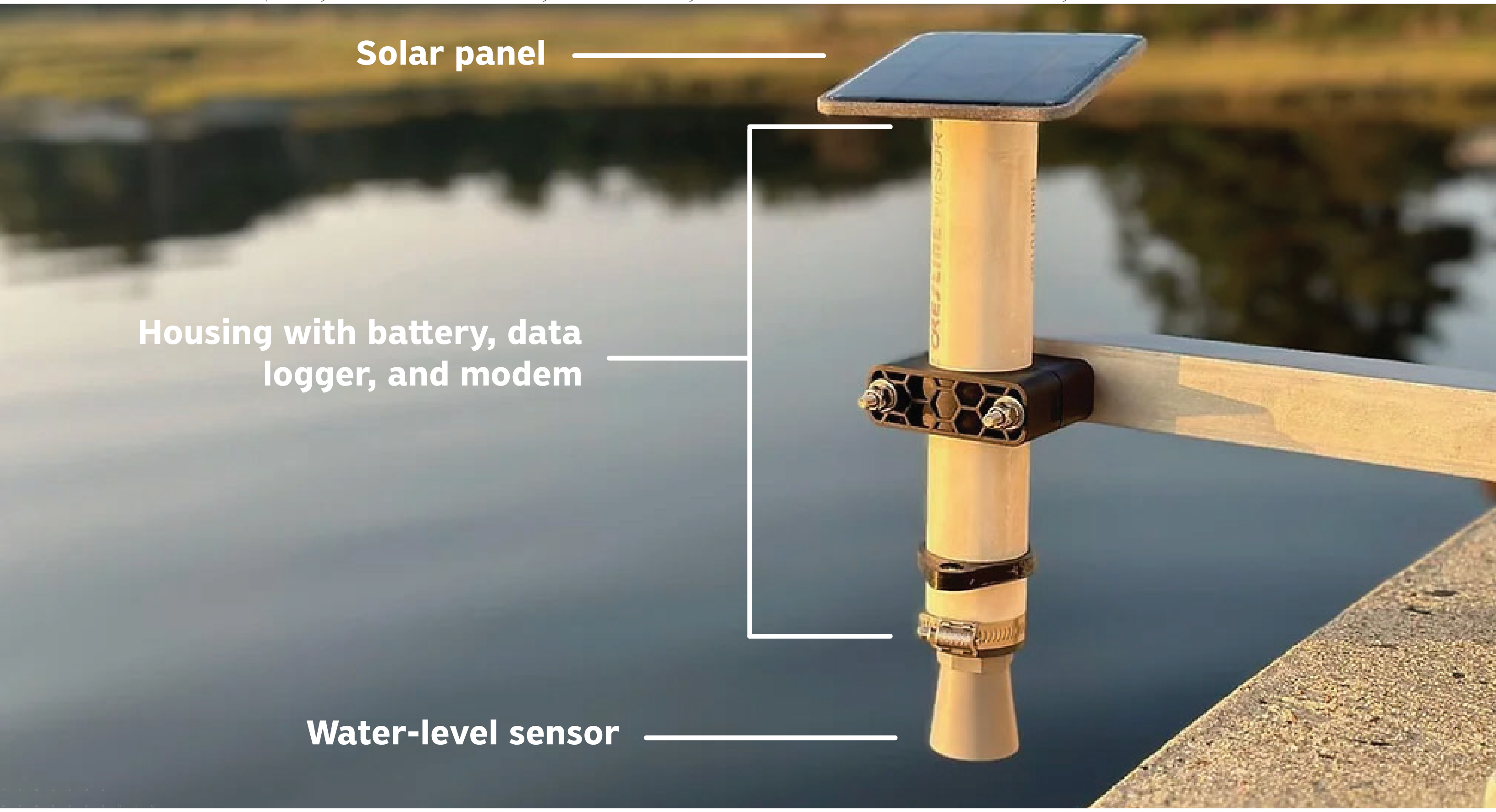
FEWS monitor, transmit, manage, and disseminate information about flooding conditions using hardware (i.e., gages) and software. Alternative FEWS focus on monitoring water levels.



WHAT DISTINGUISHES ALTERNATIVE FLOOD EARLY WARNING SYSTEMS?

Alternative FEWS use compact, integrated gages and basic websites to monitor and report water levels. Components typically include a solar panel and battery for power, a sensor to measure water levels, and a data logger and modem to store and transmit data. This reduces complexity and cost, but limits customizability and redundancy. Alternative FEWS generally cost $2,000-$10,000 to purchase and instal, plus $500-$2,000 in annual costs per site. Traditional gages are larger, costlier, and more complex but offer greater customization and redundancy. They generally cost $30,000-$60,000 to purchase and install, plus $5,000-$20,000 in annual costs per site.

Examples of alternative FEWS products from various vendors.
Top image: Hohonu, Bottom images from left to right: Kisters, Dutch Water Prevention, OTT Hydromet, and AWARE



Flooding on County Road H, Hereford, TX, National Weather Service, Brady Kendrick

FEATURES AND COMPONENTS

An alternative FEWS gage includes components that provide power, measure water level, store data, and transmit information. Some alternative FEWS gages include cameras and sensors that record rainfall; however, these require more power and space. Monitoring rainfall can help increase warning time, particularly in flash flood areas where water levels can rise within hours or minutes, in some cases. For more information on cameras and rainfall sensors, refer to the TWDB FEWS Guide.

Alternative FEWS software, located off-site from the gage, includes a database and website that receive, manage, and disseminate information to users.

Understanding how each component contributes to system cost, performance, and reliability is critical when selecting a product. The following pages provide an overview of major components and key takeaways:

- Housing: The housing protects internal components from weather and vandalism. Its size and design affect capabilities, durability, maintenance, and expandability.
- Power Supply: Gages are often solar powered with a battery. Power limitations, such as a small battery and/or solar panel and limited sun exposure affect transmission frequencies and supported features.
- Monitoring Water Level: Water-level sensors include contact (i.e., submerged) and non-contact options. Each type of sensor has trade-offs in terms of cost, accuracy, reliability, installation, and maintenance.
- Storing Data: A data logger stores sensor measurements—which can be important for maintaining data if telemetry fails—but may not be included due to space constraints.
- Transmitting Data: Data is transmitted via cellular or satellite networks and the method determines how frequently and reliably data can be shared with users—the method also impacts long-term costs.
- Data Management & Dissemination: Websites and dashboards provide access to data, alerts, and visualizations but functionality varies by vendor.

Best practice for selecting an alternative FEWS is to consider how a given product fits your monitoring goals, site conditions, expertise, and budget based on the product's features. The following sections discuss how these features and components impact cost, performance, and reliability.

DEFINITIONS TO REMEMBER

Battery	Powers gage electronics, including data loggers, sensors, and other components
Camera	Captures video or still images
Contact Sensor	Measures water by physical contact (e.g., bubblers, pressure transducers)
Dashboard	Website that displays data collected from gages
Data Logger	Stores data collected by sensors
Datum	Vertical elevation reference (e.g., NGVD 29, NAVD 88)
FEWS	Flood Early Warning System
Gage	A system comprised of components used to monitor environmental conditions
Housing	Protective enclosure for electronics
Modem	Device that converts and transmits gage data
Non-Contact Sensor	Measures water without touching it (e.g., radar, ultrasonic)
Pressure Transducer	Submersible sensor that measures water level via hydrostatic pressure
Radar Sensor	Uses electromagnetic waves to measure the distance from the sensor to a water body
Satellite	Earth orbiting satellite used to relay data transmissions
Sensor	Device that measures data (e.g., water level)
Solar Panel	Charges the battery using solar energy
Solar Regulator	Manages solar charging of the battery
Submersible	Sensor designed for underwater use
Telemetry	Remote collection and transmission of data from a gage to a third-party
Ultrasonic Sensor	Uses sound waves to measure the distance from the sensor to a water body
Water Level	Height of the water surface (also known as stage, gage height, or water elevation)

Alternative gage housings typically integrate components in a small, compact unit.

Examples of alternative FEWS products from various vendors. From left to right: Campbell Scientific, Solinst, OTT Hydromet, and Onset

HOUSING

The gage housing protects sensitive components from wind, water, dirt, and vandalism. Alternative gages have smaller housings compared to traditional gages because they contain fewer and/or smaller components, and they typically cannot be expanded or modified. Alternative FEWS may integrate the sensor in the housing—which limits the user to the type and brand of sensor used by the vendor—or provide a connection that allows the owner to connect different sensors, if desired.

Housings typically have a weather rating that indicates their ability to withstand years of sun, rain, wind, dirt, pests, and floods. Alternative gages built to a high Ingress Protection (IP) rating, such as IP65 or IP67, can be fairly resistant to environmental conditions due to their simple design (i.e., fewer cables, antennas, and parts to be damaged). It's a good idea to ask the vendor how their housing will perform if submerged during a flood and consider whether an alternative approach is needed to prevent submergence.

Vandalism is another key consideration—alternative gages are easy to elevate because of their small size, which makes them less prone to vandalism. However, their small solar panels require greater sun exposure, which limits installation locations. With those factors in mind, users can proactively mitigate the chances of vandalism and theft during planning, installation, and operations.

A housing protects gage components

Housings are small, generally the size of a football

Basic components are integrated and not typically customizable

Verify real-world weather ratings with vendor

Vandalism is a common issue requiring proactive mitigation

Installation of solar panels in Amarillo, TX, WEST Consultants, Inc.

SUPPLYING POWER

Power is essential for all gages, though power requirements vary based on the gage components and how the gage is operated. The more measurements, transmissions, and functions performed, the more power consumed.

Power is typically supplied by batteries charged via solar panels. Alternative gages rely on small batteries that provide minimal power, which limits functionality. For example, alternative gages often measure in 15-minutes intervals, wheras traditional gages often take measurements every minute or less.

Solar panels on alternative gages are often integrated into the housing such that they cannot be expanded or their alignment adjusted. This can pose challenges if gages must be mounted where there is shading from vegetation, buildings, bridges, or weather. Be sure to ask the vendor to specify gage battery life when solar charging is unavailable (e.g., cloudy or shaded conditions). If a site does not allow for sufficient solar charging, consider a gage with a non-integrated solar panel that can be enlarged or moved.

Some alternative gages use small, replaceable batteries designed to last several years and do not include a solar panel. Although not common today, such gages present opportunities to further reduce costs and increase system reliability.

Alternative gages typically have not supported power-intensive features like large cameras, GOES satellite modems, water quality sensors, or rapid transmission frequencies. However, newer alternative gages have small cameras, rain gages, and modems for private satellite service. As battery and solar technology improves, additional functionality may become more common.

KEY POINTS

- **Power is required for the sensor, data logger, and modem**
- **A battery stores energy and delivers it to components**
- **Alternative gages typically use solar panels to charge a small battery**
- **Some alternative gages forgo solar power and use long-lasting, replaceable batteries**
- **Alternative gage functionality is limited by the minimal power provided by their batteries and solar panels**

MEASURING WATER LEVEL

Alternative FEWS gages use a sensor to measure water level. Sensors can be contact (i.e., physically touching the water) or non-contact (i.e., remotely measuring the water level). Most alternative gages use a non-contact sensor mounted to a bridge or structure overlooking the water. Contact sensors may be needed or preferred in some situations.

The suitability of a sensor for an application depends on environmental conditions, infrastructure, and goals. In arid regions, non-contact sensors may be warranted to avoid sediment deposition and wet-dry cycles. They may also be preferred in locations with a bridge, a clear view of the water, and where debris or objects are limited. Contact sensors may be needed if low-flow monitoring is important, if there are no suitable structures for mounting over the water, or if the structure could be overtopped during flooding.

In general, higher accuracy sensors are more costly. Achieving the desired balance of cost and accuracy requires understanding sensor characteristics and careful sensor selection.

It is critical to discuss with vendors how real-world sensor accuracy compares to stated accuracy. For example, ultrasonic sensors may have high accuracy in a laboratory, but have diminished real-world accuracy due to such environmental factors as rapidly changing temperature and humidity.

Also be aware that not all sensors of the same type have the same accuracy or features. Vendors typically purchase a sensor from a manufacturer and integrate it into their gages. As a result, two products that include a pressure transducer, for example, can vary in accuracy from 0.01 ft (0.12 in) to 0.04 ft (0.50 in). Talking with vendors ensures that sensor performance, characteristics, and features will meet user goals.

Selecting the right sensor for the user's application and goals is key. The following table and sections discuss the characteristics of sensors offered with alternative gages.

Water-Level Sensor Characteristics

	Pressure Transducer	Ultrasonic	Radar
Measurement Method	Water Pressure (Contact)	Sound Waves (Non-Contact)	Electromagnetic Waves (Non-Contact)
Installation	Routed via cable and conduit from the gage to the water body and installed underwater	Mounted on a bridge or structure overlooking the water	Mounted on a bridge or structure overlooking the water
Sensor Cost [1]	\$1,000–\$1,500 [1]	\$200–\$500 [1]	\$1,200–\$2,500 [1]
Accuracy	± 0.01 ft (± 0.1 in)	± 0.1 ft–0.2 ft (1–2 in)	± 0.01 ft (± 0.1 in)
Considerations	• Installation and maintenance can be difficult due to cable and conduit • Proven long-term performance • Affected by debris, sediment, ice, and algae	• Easy to install and maintain • Limited track record • Affected by debris and air temperature • Low power use • Smallest sensor	• Easy to install and maintain • Proven long-term performance • Not affected by wind and environmental factors but can be impacted by debris

[1] Sensor cost only. Total gage cost is greater. Based on quotes from vendors in 2024 USD.

Sensors | Pressure Transducer

A submersible pressure transducer (PT) measures the pressure exerted by water, converts it to depth, and transmits the data to the gage via cable. They are often used where a gage cannot be mounted over the water. In this case, the gage is located near the water body and the PT is run to the water via conduit and cable.

PTs typically cost $1,000-$1,500 for the sensor only, depending on cable length and accessories. They are popular for their relatively low cost but must be securely installed, especially in in rivers and creeks with high velocities and/or debris. Installation involves steel conduit, with angle iron driven into the ground to provide resistance, and proper positioning of the sensor in the water body.

Although PTs are reliable, they can be affected and damaged by sediment, debris, and drawdown—a condition where high velocities create a lower pressure zone, which leads to incorrect readings. Sites with high sediment loads, aquatic growth, or freezing conditions can also impact performance. Deep installations, such as reservoirs, can be challenging due to the difficulty of removing the sensor for maintenance or replacement.

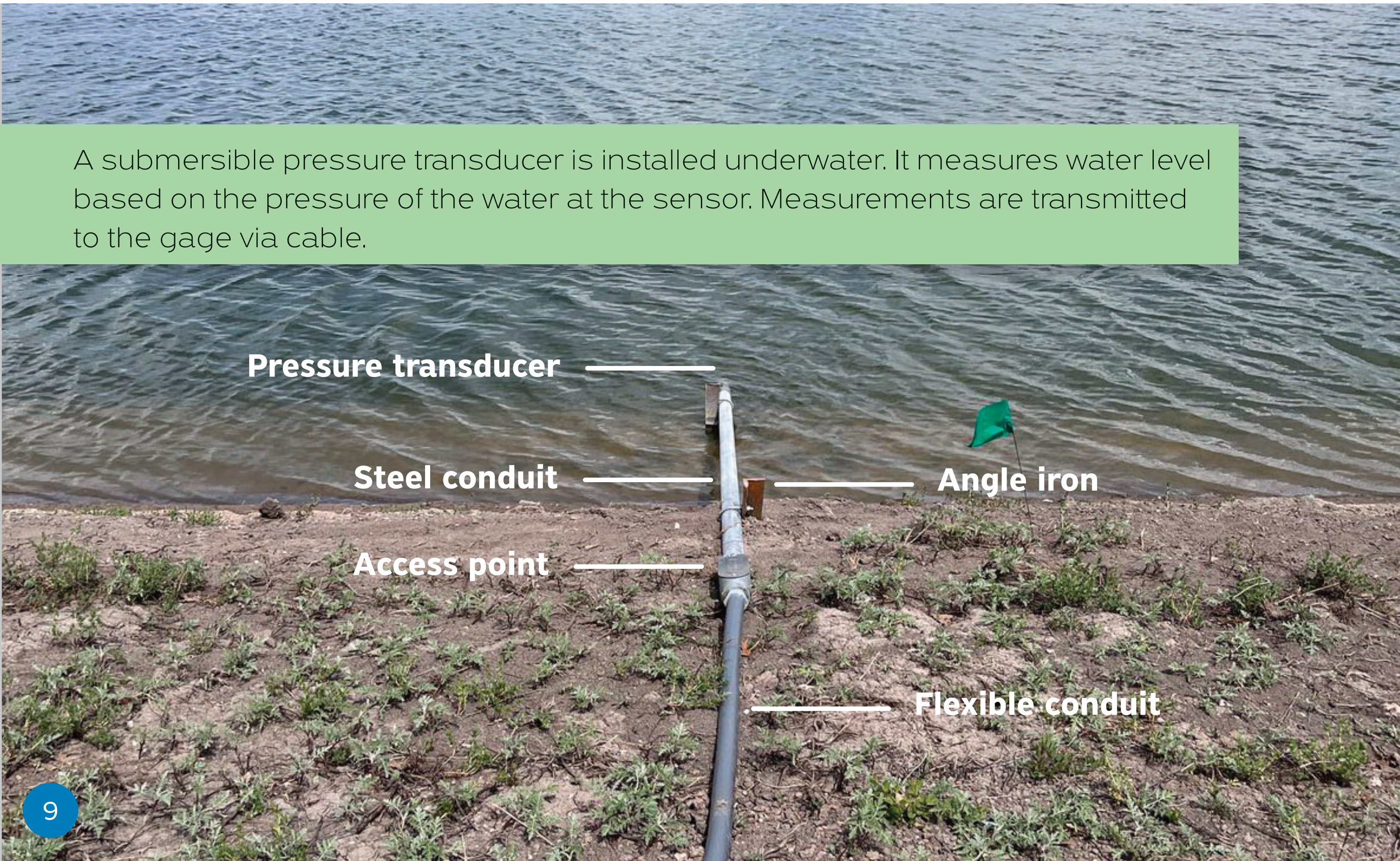
Discussing environmental conditions with vendors is necessary to understand how their PT will perform in each application.

Example Pressure Transducer[1]
Credit: Keller

Amarillo, TX, WEST Consultants, Inc.

[1] A variety of sensors are offered by different vendors

A submersible pressure transducer is installed underwater. It measures water level based on the pressure of the water at the sensor. Measurements are transmitted to the gage via cable.



Sensors | Ultrasonic

Ultrasonic sensors measure water levels using sound waves. They must be installed with a clear view of the water surface and, ideally, above the highest anticipated water level. Ultrasonic sensors are inexpensive—a few hundred dollars for the sensor itself—and are generally accurate within +/- 0.1-0.2 ft (+/- 1-2 in). They are unaffected by high-velocity drawdown, are easy to install, and are safe from damage by debris and sedimentation.

Their accuracy can be significantly affected by large differences in air temperature and density between the sensor and water body. For example, if a rapid cool front creates a temperature gradient in the air column above the water body. Vendors may offer signal processing to reduce these errors, but their inaccuracy can still be significant. Ask the vendor for examples of real-world performance in similar climates and conditions.

Measurement accuracy can also be impacted by floating debris, vegetation, watercrafts, and interference from riverbanks and piers.

Example Ultrasonic Sensor[2]
Credit: Maxbotix

Sensors | Radar

Radars use electromagnetic waves to measure the distance from the sensor to the water surface. Typically, their accuracy is +/- 0.01 ft +/- 0. in), and they are unaffected by air temperature, air density, or weather conditions.

However, radars are more expensive than ultrasonic sensors, costing from $1,200 to $2,500 for the sensor itself. Like ultrasonic sensors, they must be installed on a structure with a clear view of the water below and ideally placed above the highest anticipated water level. Radars share advantages with ultrasonic sensors: no drawdown issues, easy installation, and safety from debris. They are more suitable for low-flow monitoring studies due to their higher accuracy, but aside from being more expensive and slightly larger, radars are equivalent to ultrasonics in their installation requirements and power demands. Some radar sensors even offer features that remove obstructions like piers or boulders from the signal, which could otherwise interfere with measurement accuracy.

Radar sensors are quickly replacing ultrasonic sensors as the sensor of choice for alternative FEWS gages due to their reasonable cost and higher accuracy and reliability.

Example Radar Sensor[2]
Credit: Campbell Scientific

[2] A variety of sensors are offered by different vendors

STORING DATA

A data logger is used to store sensor measurements locally at the gage. Unless data is stored locally, a loss in telemetry service can result in a loss of data that may be useful after a flood event. While most alternative gages include data loggers, some do not. Users should understand how data is managed at the gage before it is transmitted to an off-site database.

Accessing data on-site via Bluetooth, Wi-Fi, USB, or serial port can be useful, so confirm with vendors if this is possible. It is also important to know whether a gage offers remote access to change settings, restart the device, or update firmware.

KEY POINTS

- **A data logger stores sensor measurements on-site**
- **Not all alternative gages include a data logger, putting data at risk if telemetry fails**
- **Confirm whether on-site and/or remote access of data and system settings is possible**

TRANSMITTING DATA

Telemetry is the process of transmitting data from the gage to an off-site location. Although data is typically stored locally in the gage data logger, it must be shared in real-time with remote users to assist timely decision making prior to and during flood events. The telemetry method must also be reliable enough and of sufficient frequency to meet user expectations and needs.

Alternative gages use cellular or satellite telemetry while a few vendors offer dual telemetry for redundancy. Cellular telemetry uses terrestrial cell towers, while satellite telemetry relays data using orbital satellites. Alternative gages typically transmit data every 15–60 minutes or dynamically depending on the options offered. Alternative gages are less configurable than traditional gages, which can use multiple forms of telemetry for redundancy and transmit at higher frequencies. Combining cellular and satellite telemetry can benefit critical gage locations, but this option is not available with most alternative gages due to limited space and power.

Telemetry | Cellular

Cellular telemetry is widely used in alternative FEWS due to its low cost and power requirements. It uses a cellular modem and SIM card within the housing, paired with an antenna for data transmission.

Vendors offer services from most cellular providers. Some vendors offer SIM cards that allow users to switch between networks, which offers flexibility across a network of gages where service quality may vary. Signal coverage and quality should be evaluated, especially in rural areas where satellite telemetry may be more reliable. Cellular outages can occur during catastrophic events, but first responder networks offer priority service that may alleviate some of these issues.

Redundant telemetry combining cellular and satellite may benefit critical FEWS locations but is generally not available with alternative FEWS products. Costs are approximately $10–$20 per month per site, and often include two-way communication for remote updates and troubleshooting.

KEY POINTS

- **Cell towers relay information between a gage and off-site location**
- **$10-$20 per month**
- **Network-switching and first responder networks may improve reliability**
- **Confirm service availability, especially for critical locations**

Telemetry | Satellite

Satellite telemetry uses orbital satellites to relay data between a gage and an off-site location. The gage includes a modem and antenna within the housing that communicates to a specific satellite network.

Vendors of alternative gages may offer satellite service through private satellite networks. These services generally cost $30–$100 per month per site, transmit at rates up to every five minutes, support two-way communication, and can transmit camera images. Satellite service is suitable where cellular service is poor or unavailable, but the antenna needs a clear view of the sky to communicate with satellites.

GOES satellite telemetry, operated by the U.S. government, is commonly used by the United States Geological Survey (USGS) for its remote traditional-style gages and is available to private and public entities. However, GOES has a higher upfront cost, is power-intensive, transmits at up to 15-minute continuous intervals[3] only, and does not support two-way communication[4]. Partially due to these limitations, GOES is not currently offered with alternative gages.

KEY POINTS

- **Orbital satellites relay data from the gage to an off-site database**
- **$30-$100 per month**
- **Unaffected by local conditions such as power outages**
- **Ideal for remote areas with poor cellular service**

[3] 3-minute random intervals may be achieved based on event-triggered thresholds but are not guaranteed

[4] Two-way communication may be an option in the future

MANAGING & DISSEMINATING INFORMATION

Once data is transmitted from the gage, it must be received and managed off-site. Many alternative FEWS vendors provide basic websites and a cloud-hosted database to manage and disseminate information to users. Alternative FEWS websites generally display text, graphs, and images and have text message and email alert capabilities.

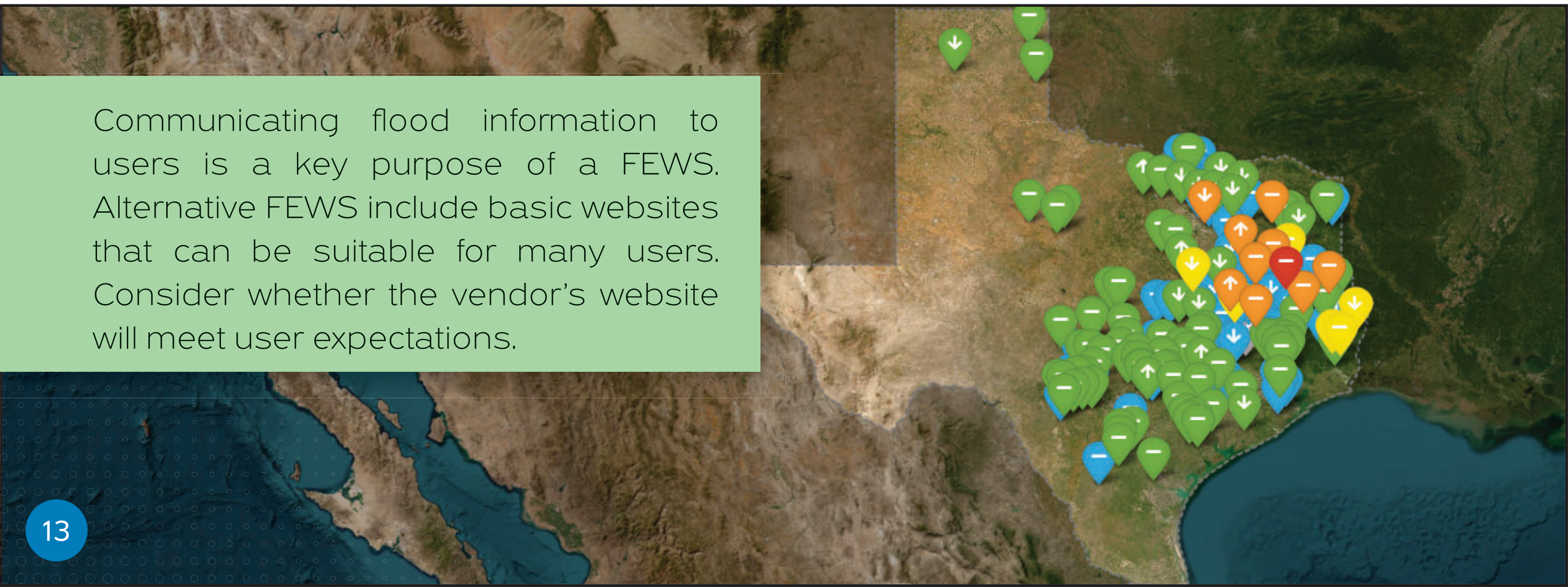
Alternative FEWS websites do not typically ingest data from other vendors, so users may need multiple websites or a third-party site to consolidate data if they operate systems from multiple vendors. Third-party websites offer more features, such as data editing, custom plotting, and flood mapping but are more expensive. Users should confirm with the vendor how much data can be stored on the website and whether local backups are needed to preserve historic data. Websites included with most alternative FEWS provide reasonable value at $200–$1,000 per year (including telemetry fees) but users should confirm that they are sufficient for their needs.

Leveraging FEWS data to help users make good decisions during a flood event requires intuitive and clear methods. Consider how a vendor's website will help achieve this goal and review the TWDB FEWS Guide for more insights into leveraging flood data.

KEY POINTS

- **Vendor fees are $200-$1,000 per year per gage, including telemetry fees**
- **Gage data is stored off-site**
- **A website allows users to view and share gage data**
- **Confirm that the website offered by a vendor meets user expectations**
- **Confirm interoperability with other FEWS**
- **Backup gage data and confirm what happens if the vendor goes out of business**
- **Check if the vendor offers text message or email alert functionality**

An example of a public flood information viewer developed for Texas > View Dashboard Here



Communicating flood information to users is a key purpose of a FEWS. Alternative FEWS include basic websites that can be suitable for many users. Consider whether the vendor's website will meet user expectations.

Flooding on Interstate 2 from the Arroyo Colorado River near La Feria, TX

UNDERSTANDING COSTS

FEWS include a range of capital, installation, and operations and maintenance costs. Although purchase costs are less than traditional systems, users must still plan for long-term operations and maintenance costs that can cumulatively exceed initial costs within five years. Gages designed for high performance, flexibility, and reliability generally come with higher price tags compared to those with more limited functionality, accuracy, and reliability. Labor for gage installation and maintenance is also a major cost that is mainly determined by site accessibility and who is doing the work.

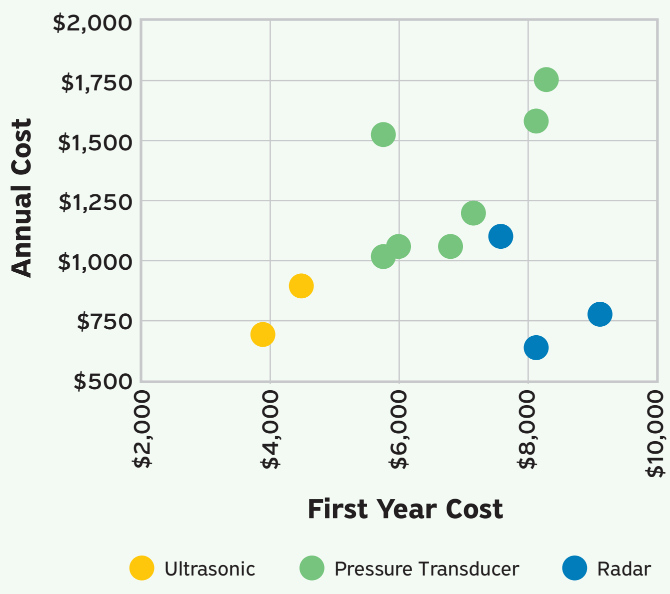
The table and figure below summarize alternative FEWS costs. Estimates are based on installation and operation at a typical site with reasonable access and assume labor is performed by the owner at a rate of $50 per hour. If vendor or consultant labor is required, costs will be higher. Hardware refers to miscellaneous materials needed to mount and install the gage.

Estimated Range of Costs

Capital & Installation	Low Cost	High Cost
Equipment	$1,000	$7,000
Labor	$500	$2,000
Hardware	$500	$1,000
Sub-Total	**$2,000**	**$10,000**
Annual O&M		
Website & Telemetry	$200	$1,000
Labor	$300	$900
Hardware	$0	$100
Sub-Total	**$500**	**$2,000**

Based on estimates in 2024 USD. Assumes cellular telemetry.

Estimated Costs by Sensor Type



Flooding along Buffalo Bayou in Houston, TX

THINGS TO CONSIDER

Consider the following during equipment selection, installation, validation, and operations and maintenance. These lists are not exhaustive, so consult the TWDB Flood Early Warning System Guide for additional information and best practices. Download Here

EQUIPMENT SELECTION

When choosing a vendor and equipment, select the tools best suited to the project's specific needs while considering whether the company will provide reliable support throughout the project's lifespan.

Important considerations when selecting a product and vendor:

- What is your budget for purchase, installation, and maintenance?
- How many sites do you want or can you afford to install and maintain?
- How much spare equipment do you want to keep on-hand?
- What is the recommended maintenance and expected lifespan of the equipment?
- Do the gage durability specifications meet your needs?
- Does the vendor offer a warranty?
- How long will it take to deliver the equipment after ordering?
- Can the vendor provide references and share who else uses their equipment?
- What are the impacts on your operations if the vendor goes out of business?
- Do you want data logging capabilities to store data locally on-site?
- Do you want to backup data on your servers? Does the vendor offer this option?
- Is cellular service available and reliable or do you need a satellite option?
- Do you want email and/or text message alerts?
- Ask to see the website dashboards used by the vendor's clients.
- What are your end user's expectations in a website? Does the website meet those needs?
- Will the vendor's website share data with other vendor websites?
- How accurate do you need your sensor to be in real-world conditions?
- Will a non-contact or contact water-level sensor work best for your site(s)? Are you willing to accept lower accuracy to reduce costs?
- Is solar exposure at the site sufficient for the gage's power needs?
- Would camera images be useful?
- Do you want the option to add a rain gage or a different sensor?

INSTALLATION

After selecting and procuring a system, the next step is installation. Installation varies by vendor and can take anywhere from a few hours to several days. Installation requirements are site- and system-specific; for example, non-contact gage installations differ significantly from contact gage installations. Gage housings and sensors should be securely mounted according to manufacturer recommendations—additional effort and hardware are typically required, even for the simplest gage. For example, gages with pressure transducers require installation secure enough to withstand stream conditions using durable materials like galvanized or stainless steel for long-term operation. Although alternative gages may appear "plug-and-play," considerable care and planning are still necessary for proper installation.

Consider the following when planning and installing gages:

- Can you install the housing where solar exposure is sufficient for continuous operation?
- What is the highest anticipated water level, and can you install the housing above that elevation?
- Are there critical locations where a second, backup gage may be worthwhile?
- Who owns the property or structure where you want to install the gage?
- What methods and materials will you use to install components?
- How long do you need the gage to last? Build the mounting hardware accordingly
- Do you have the necessary tools and skills for installation?
- What is the risk of vandalism? Can you mitigate those risks?
- Do you need any permits or drawings signed and sealed by a professional engineer?

Installing an AWARE gage with a Geolux radar sensor on the Farrington Highway (Hwy 930) above Kaukonahua Stream, Wailua, Hawaii, WEST Consultants, Inc.

Validation of water levels on the North Santiam River using a Topcon Hiper VR RTK GNSS, Stayton, Oregon, WEST Consultants, Inc.

VALIDATION

Validation of sensor water-level measurements is important to ensure the gage is operating as expected. Without validating the results, how do you know if the readings are accurate?

Sensor measurements can be validated using separate reference gages; however, these are not provided by the vendor when purchasing an alternative FEWS gage. Reference gages typically must be purchased and installed separately by the user, although some vendors may offer these at additional cost. A common example of a reference gage is a staff gage, which are vertical rulers installed in the water. These are easy to use and provide a clear indication of water level. Although simple, they are generally expensive to install and maintain.

The simplest and lowest cost solution for many users of alternative FEWS is to define reference points. Reference points—as opposed to reference gages—are inexpensive, identifiable points with a known elevation that are used to measure water level. For example, reference points may include surveyed paint marks, fenceposts, or rebar.

Lastly, sensor measurements can be validated by surveying the water level on an as-needed basis. Verification by survey is a practical and affordable approach if the user is trained and owns the equipment, the site is easily accessible, and continuous validation is not needed.

Consider the following to ensure sensor measurements are accurate:

- How will you validate sensor water-level readings?
- Can you forgo a reference gage by using reference points or surveying the water surface?
- What datum will you use (e.g., NAVD 88)?
- Would a crest-stage gage—which uses a floating cork to mark high water during an event—help verify peak water levels? Would it provide a useful backup if the sensor fails during an event?
- Will you have a camera to validate readings?
- How important is long-term accuracy? (This answer will help determine the importance of validation and the appropriate validation method.)

Inspecting an AWARE gage with a Geolux radar sensor in Hawaii, WEST Consultants, Inc.

OPERATIONS & MAINTENANCE

Proper operations and maintenance (O&M) are essential for reliable performance and should be budgeted for prior to purchasing equipment. Traditional gages, operated by the USGS, typically require site visits every 6–8 weeks, with daily or weekly data checks. Alternative gages generally need less frequent maintenance but still require routine system checks, basic upkeep, and emergency repairs. An O&M plan is vital to ensure long-term performance.

Operators should work with the vendor to estimate annual O&M hours and to develop a budget. Office-based activities include routine system checks, data review, software updates, and timely payment of website and telemetry fees to avoid service disruptions. Field-based activities include following vendor-recommended maintenance, cleaning sensors and solar panels, maintaining vegetation, validating sensor measurements, troubleshooting, and performing site repairs due to accidents and vandalism. The frequency of activities depends on the gage components, the importance of the data, available funding, vendor recommendations, and overall project goals.

While component lifespan is hard to predict, replacement equipment is often needed over a 10-year operational period. Unlike traditional gages, alternative gages generally require complete replacement and/or returning equipment to the vendor if they become non-operational. Depending upon the number of gages and the importance of each gage, consider keeping spare gages on-hand to swap if a gage becomes non-operational.

Consider the following when planning your O&M:

- What routine maintenance does the vendor recommend?
- How often will the site be visited?
- How much time does a site visit require?
- How frequently will the website be reviewed to identify potential equipment issues?
- How are potential issues identified using the website? For example, does the vendor report battery health or provide automated data quality checks?
- Is there enough staff and expertise for the required maintenance or will the vendor provide maintenance services?
- If equipment fails, how quickly must it be repaired or replaced?
- Where will backup copies of the data be stored?
- Is there a dedicated O&M budget?

NEXT STEPS

Alternative FEWS provide a practical and cost-effective option for improving flood awareness, especially for communities seeking simpler, lower-cost solutions. While these systems may not offer the full range of features available in traditional FEWS, they can play a critical role in enhancing preparedness and public safety.

For additional insights, the case studies that follow highlight real-world examples of how agencies across Texas and beyond are successfully implementing alternative FEWS. These examples demonstrate the importance of clear goals, reliable vendors, thoughtful planning, and sustained maintenance.

Users seeking more general information about all aspects of FEWS are encouraged to consult the TWDB FEWS Guide, available on the TWDB website. This resource complements this guide and is particularly valuable for developing a broader understanding of FEWS. ▸ Download Here

Looking ahead, the flood warning industry is rapidly evolving. Emerging technologies, such as artificial-intelligence-enhanced cameras, weather, and flood models, high-resolution satellite imagery, and crowd-sourced, real-time data are just a few examples being used to supplement traditional sensors. With new ways to envision and operate FEWS, this may offer new possibilities for communities of all sizes in the years to come.

Overtopping of a low water crossing at Slippery Creek in the Texas Hill Country.

Alternative Flood Early Warning System Guide

CASE STUDIES

SOUTHEAST TEXAS FLOOD COORDINATION STUDY

A collaborative, regional approach

The Southeast Texas Flood Coordination Study (SETx), managed by Lamar University's Civil and Environmental Engineering department, is a collaborative effort among eight southeast Texas counties via the SETx Flood Control District (SETx FCD) to address increasing flood risks. SETx aims to develop an alternative FEWS tailored to regional needs that will be initially operated and maintained by SETx FCD. The SETx FCD does not have taxing authority but provides a platform for counties to coordinate flood management strategies.

KEY LESSONS

- **Partnerships with universities, communities, and agencies helped reduce the burden**
- **Clear communication is vital to success**
- **Maintenance is necessary for system longevity**
- **The FEWS was adaptable to a range of conditions across multiple counties**

Lamar University serves as project manager working with SETx FCD, government agencies, and the FEWS vendor. Rather than relying on local agency or grant funding, SETx leveraged support from the Department of Homeland Security Science and Technology Directorate (DHS S&T), which sponsored the deployment and monitoring of a previously tested alternative FEWS. Through this partnership, 73 AWARE Systems Inc. (previously Intellisense Systems, Inc.) alternative FEWS gages were installed across the region. Each site included a gage with cellular telemetry, a pressure transducer, and a waterproof camera, with a unit cost of about $4,000 each (2021 USD prices). Data is transmitted via a third-party cellular plan at roughly $40 per year per gage (2023 USD prices) and hosted on a third-party website by AEM that was already licensed and operated by the Sabine River Authority.

Installation was efficient—teams of two to three graduate students installed two to four sites per day. The estimated system lifespan is 10 years, depending upon the battery, solar panel, and operations and maintenance. Lamar found the FEWS reliable, with accuracy within 0.05 ft (0.6 in), and suitable for general flood monitoring, though periodic calibration of the pressure transducer was needed.

Maintenance is an ongoing requirement and was recommended every two to three months. Sensor repairs or replacements took from a few days to a few weeks depending upon location, staff availability, and sensor. Most FEWS were installed at bridge crossings or roads known to overtop, but the large network also includes ditches and drainage outfalls—which highlights the flexibility of alternative FEWS to adapt to community needs across a diverse, multi-county region.

This project illustrates the value of regional collaboration and university partnerships. By pooling resources, agencies reduced upfront and ongoing costs, and clear documentation of roles and responsibilities proved essential for smooth operations and long-term system success.

KITTITAS COUNTY

Starting small

Implementing a FEWS can be challenging for small communities with limited experience. Kittitas County, Washington, faced this situation. The Kittitas County Flood Control Zone District (KCFCZD), formed in 2014 with a small staff, initially relied on a few traditional FEWS operated by the USGS and U.S. Bureau of Reclamation. Seeking more real-time data for their agency and the public, KCFCZD hired a consultant to review FEWS options.

Based on the review, KCFCZD pilot tested ToltHawk's alternative FEWS. This pilot test allowed KCFCZD to assess capabilities and select the best FEWS for their needs. After the pilot, KCFCZD chose to install four ToltHawk FEWS gages, as no other all-in-one package matched their budget at that time. The alternative FEWS was lower cost, easier to deploy, and simpler to maintain than traditional FEWS.

KEY LESSONS

- **Accessible to small teams with minimal or no FEWS experience**
- **Costs can be affordable for small, rural communities**
- **Local tax funding can support the minimal capital and operations and maintenance costs**
- **Starting with a pilot study and one or more vendors can help identify the best FEWS for a community**

Installation required KCFCZD to create custom mounts to reduce vandalism and theft while improving staff access, but the rest of the process was straightforward. Minor issues—such as software updates, solar panel performance, and data transmission delays—were resolved with vendor support. The small solar panels sometimes struggled to keep batteries charged in Washington's winter and remote locations occasionally caused data delays due to poor cellular service. Funding for the system was secured through a county tax levy, which ensured stable financial support for the purchase and operations and maintenance.

This case study shows that small communities can successfully implement affordable, simple-to-maintain alternative FEWS by leveraging expert advice and pilot testing. Custom solutions and strong vendor support can help address site-specific challenges, while stable funding ensures ongoing operations and maintenance.

CITY OF AMARILLO

When a traditional FEWS is needed

The City of Amarillo, located in the Texas Panhandle between the Canadian and Red river basins, manages stormwater primarily through a network of playa lakes—natural, shallow basins that have been dredged up to 65 feet deep for flood storage. The lakes do not drain naturally and require pumping to draw levels down after heavy rain. Historically, lake levels were reported to the public via a city website, which was manually updated after staff visually confirmed water levels.

In May 2023, heavy rainfall caused several playa lakes to flood, resulting in significant damage to homes and businesses. The city pumped over one billion gallons of water from six lakes.

KEY LESSONS

- **Project needs drive equipment selection**
- **Site conditions must be considered when choosing equipment**
- **The lowest cost option isn't always best**
- **Proven performance and vendor support add valuable peace of mind**
- **Additional sensors and cameras add value**

In response to the 2023 flooding, Amarillo installed a real-time water-level monitoring system at eight playa lakes to automatically report water levels to staff and the public. A consultant conducted field reconnaissance to identify the best monitoring technology. The city and consultant determined that a traditional FEWS, featuring bubbler water-level sensors with traditional, cellular-enabled data loggers, would best meet their needs due to such factors as reliability, resistance to fouling, ease of installation, and straightforward maintenance. This setup also allows for rain gages and cameras at each lake. Alternative FEWS were considered, but they lacked key features that were important to the city. Specifically, alternative FEWS were not compatible with bubbler sensors, which were recommended due to the lake depth and potential for freezing and algae growth.

Data from the new gages will be transmitted to a public website operated by AEM, and the FEWS equipment is purchased from OTT Hydromet. The total project cost is about $400,000, or $50,000 per lake, which covers equipment, installation, training, and support. Cost was not a major factor for the City of Amarillo, so paying for a traditional FEWS was within their budget. The city is assisting with installation and will handle operations and maintenance in the future.

Amarillo's project shows that traditional FEWS may be necessary when specific sensors like bubblers are required and if rain gages and high-quality cameras are desired. However, the cost of traditional FEWS quickly exceeds that of alternative FEWS. This project also demonstrates that input from consultants can help communities with limited experience to select the right technology. Stable funding, training, and documented operations and maintenance plans are also required for long-term success.

WISE COUNTY

Taking decisive action and building regional support.

Wise County, though part of the Dallas-Fort Worth-Arlington metropolitan area, is predominantly rural. Flooding is a significant concern, especially in the community of Bridgeport, which sits downstream of a lake. Historically, the county relied on local knowledge and one river gage to determine when roads would be overtopped. Seeking a more proactive approach, the county invested in alternative FEWS.

Selecting the right FEWS was critical. The county's criteria included the ability to purchase single gages without a minimum order, being able to add different types of sensors at each site, keeping costs low, using its own cellular SIM cards, and monitoring all sites through a unified dashboard.

KEY LESSONS

- **Increasing the number and diversity of users strengthens overall system support**
- **Funding can come from non-traditional sources**
- **Some vendors may be willing to customize products**
- **Emergency managers can take the lead in promoting and implementing FEWS**

Led by the county office of emergency management, Wise County reviewed a range of FEWS. The county considered a traditional FEWS in partnership with the USGS, but this proved too expensive. Ultimately, they selected the AWARE (formerly Intellisense Systems, Inc.) product, which met all other requirements but required a minimum initial purchase of five gages.

The county established an agreement with AWARE, allowing gages purchased by communities in the county to be added under the same annual plan and website. This arrangement will enable communities to purchase their own AWARE gages, cover upfront costs, and join the Wise County network—benefiting both the county and individual users by expanding coverage while reducing costs.

In addition to monitoring water levels, the county is considering monitoring lightning strikes and soil moisture. Some areas of the county have poor cellular coverage, so they are also researching whether Starlink can be used for connectivity in the most rural locations. The county continues working closely with the vendor in a hands-on manner to tailor the system to their needs.

Funding remains the largest barrier, but the county is testing unique strategies. One example includes partnering with the county's seven schools. All schools require lightning detection for safety and could implement AWARE weather stations with real-time lightning detection, then add water-level sensors to the same units. This would allow schools to monitor bus routes for flooding while fulfilling state requirements for lightning monitoring and potentially unlocking additional funding. Creative partnerships like these may be useful for expanding a FEWS in rural areas.

To manage costs and increase control, the county uses its own SIM cards through FirstNet's Internet of Things platform. This data-only system allows the county to monitor and adjust data usage in real-time. For example, during a flood event, data limits can be increased or decreased on-demand to achieve optimal reporting.

The county has worked to develop a FEWS suited specifically to their needs. They are still looking for partnership opportunities and solutions for their rural communities, but they have developed a network that is able to provide real-time monitoring to increase knowledge and safety.

ACKNOWLEDGEMENTS

Project Team

Texas Water Development Board

Nathan Brock
Srikanth Koka
Tatum Lauten
Saul Nuccitelli
Jenna Rao
Cody Ransone

AtkinsRéalis

Seth Ahrens
Kaleb McClellan
Rebecca Purvis

WEST Consultants

Jeff Budnick
Ramesh Chintala
David Curtis
Liberty Smith
Lee von Gynz-Guethle

Independent Review Panel

Nefi Garza | Tetra Tech
Jeremy Justice | Harris County Flood Control District
Jacob Torres | Torres & Associates, LLC
June Wolfe | Texas A&M AgriLife

Interviewees

Dutch Water Prevention, In-Situ, Kittitas County, Queensland Reconstruction Authority, United States Geological Survey, Distinctive AFWSD, University of Bonn, Green Stream, AWARE, Intellisense Systems, Xylem, University of Iowa, University of South Carolina, Campbell Scientific, AEM, OTT Hydromet, Simplicity Integration, Harris County Flood Control District, Lamar University, University of Texas at Austin, Wise County, Bastrop County, City of Austin, Fort Bend County Drainage District, Tarrant Regional Water District, City of Fort Worth, San Antonio River Authority, and Bexar County

TEXAS WATER DEVELOPMENT BOARD

AtkinsRéalis

WEST CONSULTANTS

WATER | ENVIRONMENTAL | SEDIMENTATION | TECHNOLOGY

Credit: Hohonu, Boston, MA