An outdoor warning siren in San Marcos, Texas

# FLASH FLOOD WARNING SIREN GUIDE

TEXAS WATER
DEVELOPMENT BOARD

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# CONTENTS

# 1 OVERVIEW

## INTRODUCTION

Catastrophic flooding events impacted Texas in July 2025, prompting a series of state disaster declarations that covered 30 counties in Texas (see Figure 1-1). Later that year, the 89th Texas Legislature passed Senate Bill 3 (SB 3) and Senate Bill 5 (SB 5), establishing requirements for outdoor warning sirens in designated flash flood-prone areas within these 30 counties (see caption below for definitions). The requirements of SB 3 are codified in Texas Water Code Sections 16.051 and 16.052 (see caption below).

For the purposes of this guide, a siren refers to a "system that produces a sound designed to alert a person who is outdoors of an imminent disaster and encourage that person to immediately seek shelter or move to higher ground and includes sensors, gauges, and all other components essential to the function of the system" (§ 16.501(2), Texas Water Code).

Sirens support public safety by delivering timely, accurate, and actionable alerts during such public emergencies as flash flood events. Municipalities and counties (referred to in this guide as communities) located within flash flood-prone areas designated by the Texas Water Development Board (TWDB) must install, maintain, and operate sirens in accordance with the requirements set forth in this guide or document that their existing siren system meets the requirements identified herein.

This guide provides requirements and recommendations for implementing sirens in flash flood-prone areas based on best management practices and subject matter expertise, while considering the unique flash flood challenges in Texas.

Texas communities will find practical requirements and recommendations that aim to increase the likelihood of consistent, long-term successful implementation of sirens in flash flood-prone areas.

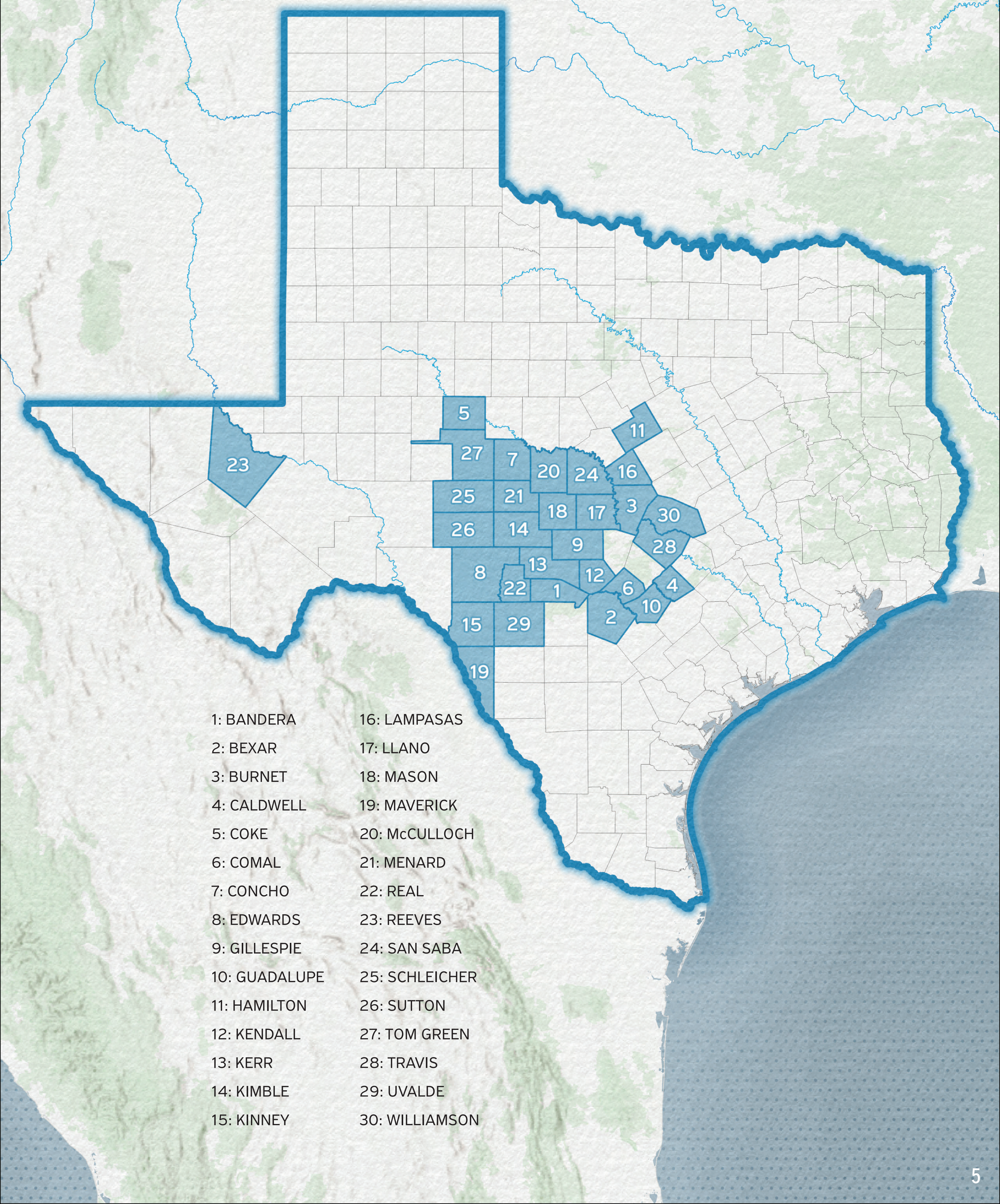
**Texas Water Code Excerpt**

**§ 16.501(1)** "Flash flood-prone area" means an area of this state included in the disaster declaration issued by the governor under Texas Government Code § 418.014 in response to the July 2025 floods.

**§ 16.501(2)** "Outdoor warning siren" means a system that produces a sound designed to alert a person who is outdoors of an imminent disaster and encourage that person to immediately seek shelter or move to higher ground and includes sensors, gauges, and all other components essential to the function of the system.

***Added by Acts 2025, 89th Leg., 2nd C.S., Ch. 4 (S.B. 3), § 2, eff. Sept. 5, 2025.***

## Figure 1-1. Counties Covered by 2025 Disaster Declarations



# HOW TO USE THIS GUIDE

The guide—which includes requirements and recommendations for flash flood warning sirens—is organized around planning, installation, operations, maintenance, and public education and outreach. Below are key questions that the guide aims to help answer.

## Overview

Who is this guide for, what is required of my community, and what is a siren system for flash flood warnings?

## Planning

What is a siren's lifecycle, cost, and implementation process? How do I set my community up for long-term success?

## Installation

How are sirens sited, what type(s) should be considered, and how should they be installed?

## Operations

How are sirens operated and alerts issued, and how is the system integrated with emergency response activities?

## Maintenance

How do I ensure our investment lasts and the system functions when it should?

## Public Education and Outreach

How do I foster public understanding of, support for, and responsiveness to siren alerts?

## Case Studies and Appendices

Where is a list of all requirements, references, and examples of siren systems used for flash flood warnings that I can learn from?

Please note that the TWDB does not endorse any products or services. Visuals and examples used in this guide are provided for reference only.

# WHO IS THIS GUIDE FOR?

This guide is intended for Texas communities responsible for planning, installing, operating, and maintaining sirens in flash flood-prone areas, as well as those involved in providing emergency warnings and public information regarding flash flood events. This guide includes requirements and recommendations for audiences that may have little or no experience with sirens.

This guide is not intended as an exhaustive technical reference for sirens. Each community is unique, with differing watershed conditions and populations. Communities will need to work with subject matter experts in Flood Early Warning Systems (FEWS) and sirens to conduct the required planning and design for installation and implementation. Communities should assess their needs and knowledge to determine what assistance they may need, if any, to support the implementation of a siren system.

Per SB 3, sirens referenced in this guide are intended to alert people located outdoors. Outdoor sirens may not be loud enough to be heard indoors in all areas, though they may be useful when operated in conjunction with other alerting methods to warn people who are indoors. Communities should consider how at-risk populations located indoors are notified prior to and during a flash flood.

While this guide focuses on flash flood-prone areas in Texas identified in SB 3, the requirements and recommendations are broadly applicable to sirens across Texas to promote safe responses to life-threatening flash floods. For the purposes of this guide, flash flooding is defined as riverine flooding that occurs rapidly (generally less than six hours) following a rain event.

Flash flood at Pedernales Falls State Park, Blanco County, Texas

# REGULATORY REQUIREMENTS

Communities in flash flood-prone areas designated by the TWDB must install, maintain, and operate sirens that comply with the Texas Water Code sections noted in the caption below as well as the requirements outlined in this guide and summarized in Appendix A.

**REQUIREMENTS**

Dark blue boxes correspond to TWDB requirements that municipalities and counties must follow. Recommendations not included in these boxes are optional but highly encouraged.

Communities impacted by SB 3 are not eligible for financial assistance from the TWDB, other than funding for sirens, until they comply with requirements in this guide (Texas Water Code § 16.502(j)). Note that some requirements in this guide are based on Federal Emergency Management Agency (FEMA) standards introduced in the FEMA 2006 Outdoor Warning Systems Technical Bulletin. For example, the bulletin required siren systems to include a backup power source within two years of publication.

**Texas Water Code Excerpts**

**§ 16.502 (c)** Except as provided by Subsection (d), for each area identified under Subsection (a)(2), the appropriate municipality or county shall install, maintain, and operate one or more outdoor warning sirens in accordance with the rules adopted by the TWDB under this section. If the site of the installation is:

(1) within the boundaries of a municipality, the municipality shall install, maintain, and operate the siren; or

(2) within the unincorporated area of a county, the county shall install, maintain, and operate the siren.

**§ 16.502 (f)** Each county or municipality with an outdoor warning siren required under this section or any other governmental entity with an outdoor warning siren in a flash flood-prone area shall regularly test the functionality of the outdoor warning siren and document the results of those tests.

**§ 16.502 (h)** The TWDB shall adopt rules and procedures to implement this section, including facilitating development of best management practices and guidance:

(1) for the operation of an outdoor warning siren in a flash flood-prone area of this state; and

(2) for an outdoor warning siren installed, maintained, or operated in a flash flood-prone area, including guidance that an outdoor warning siren be equipped with a backup power source that is different from the siren's primary power source.

**§ 16.502 (j)** The TWDB may not approve financial assistance, other than financial assistance for an outdoor warning siren, including assistance described by Texas Government Code § 418.027 for a county or municipality until the county or municipality certifies to the Board that it is in compliance with this section.

# THE SIREN SYSTEM LIFECYCLE

A successful siren system follows five interconnected phases, from planning through continuous improvement (see caption below). The typical lifespan of a siren is approximately 20-30 years but can vary widely depending on community growth, environmental conditions, technology advances, the type of siren, and how well maintenance is performed. With regular upkeep and upgrades, a siren should operate effectively for decades.

## PLAN

Planning is the foundation of any successful system or program. The planning process should identify challenges and opportunities while creating a blueprint for success. Discuss flood hazards, populations at risk, goals, and where sirens may be needed. Start talking about roles and responsibilities and coordination with stakeholders and authorities. Decisions made here will influence funding eligibility, system design and cost, and long-term success.

## FUND

Once planning is complete, communities move to secure resources for their siren system. This often includes applying for funding opportunities, such as FEMA Hazard Mitigation Assistance grants or financial assistance programs through the TWDB, and incorporating siren costs into capital improvement plans and maintenance budgets. Consider funding strategies during planning.

## INSTALL / UPGRADE

Installation involves selecting the right type(s) of sirens and optimal siting. Planning should anticipate such requirements as permitting, access, and integration with other warning systems so installation proceeds smoothly. A community may install new sirens, retrofit or upgrade sirens, and/or add sirens to an existing siren system.

## OPERATE AND MAINTAIN

After installation, a siren system must be managed effectively. This includes activating sirens during floods, conducting public outreach and education, performing routine tests, and maintaining the system. Planning should outline who will perform these tasks, how often tests will occur, how costs will be covered, and the required documentation.

## IMPROVE

Continuous improvement of siren systems will help them to remain effective as conditions change in the watershed and community. Establish these feedback loops early during the planning phase so that improvements become part of standard practice rather than reactive.

# WHAT IS A SIREN SYSTEM?

The audible, outdoor warning siren systems presented in this guide are used in flash flood-prone areas to alert people located outdoors of imminent or occurring life-threatening flood conditions. A siren is a fixed, high-powered audible device intended to warn people who are outdoors of an immediate or imminent hazard so they can take protective action. A siren system is the integrated network of one or more sirens plus the supporting systems required to operate the siren(s) (e.g., gauges, communications, power, and operating policies).

A siren system is one tool to notify the public of flash flood risk in addition to other methods like radio, TV, telephone, websites, and social media. A siren's audible alert is typically activated by local emergency management officials in combination with other public notification methods. Siren systems provide people extra time to move to safety during flash floods, where even 15 minutes of advance warning can save lives.

**A siren system is organized into components and functions that work together to monitor environmental conditions, rapidly communicate flood risk, and activate alerts to protect the public. Figure 1-2 on the following page illustrates typical siren system components.**

## Monitoring Network

Specialized sensors, such as river water level and rain gauges, are deployed at strategic locations near rivers, creeks, or flash flood-prone areas. These units continuously measure and transmit real time flood related data to a central location.

## Emergency Operations Center

Gauge data, National Weather Service (NWS) warnings, and other related information flows to a centralized location (e.g., an Emergency Operations Center), where emergency managers view conditions and manage alerts. Software analyzes gauge data, compares data against activation thresholds, and supports alert triggering.

## Siren Activation and Mass Notification

Upon reaching activation thresholds, sirens are activated and mass notifications are delivered through social media, cell phones, etc. Sirens produce a loud, highly recognizable signal — sometimes with varied tones or voices for different hazard levels—and may be paired with flashing lights. These signals are designed for quick, unambiguous warnings that prompt people to seek instructions, evacuate, or take protective action. Sirens can be activated manually (either onsite or remotely), semi-automatically, or fully automatically.

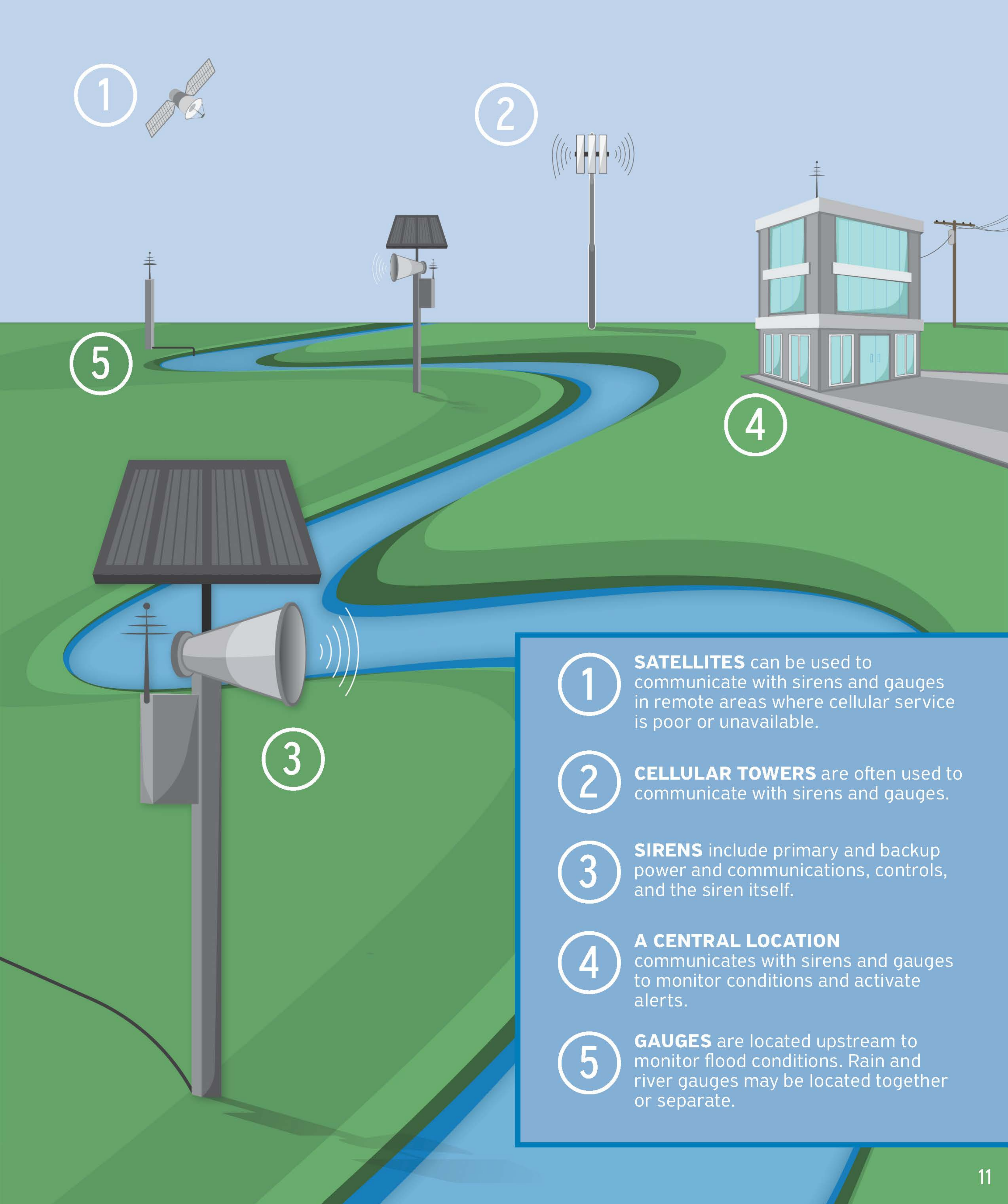
## Power and Communications

Siren systems, including gauges, must have power and the ability to communicate with centralized software. Power is often supplied by the grid or solar panels with batteries, while communications typically rely on radio, cellular towers, or satellites, unless broadband is accessible. Sirens must have backup power and communications to ensure functionality during severe weather.

## Public Education and Outreach

Siren alerts must be understood by the public in order for them to take effective action to reduce their flood risk during a flash flood. Relentless public education and outreach is needed to maintain public understanding and support for the siren system.

Figure 1-2. Siren System Components



# 2 PLANNING

Planning is the first step to achieving long-term success.

Planning is the foundation of any successful system or program. Sirens are not static infrastructure; they are living components of a community's emergency management system. Communities should plan to regularly evaluate their siren systems so they remain effective as populations grow, development expands, flood risk changes, and technology evolves.

This section introduces the siren system lifecycle and discusses how a clear plan answers the following key questions:

- Who will operate and maintain the sirens?
- How will funding be addressed?
- Where are sirens needed in our community?
- How will sirens integrate with existing emergency management systems?
- How should the sirens evolve over time?

A well-designed plan helps communities determine how sirens fit into broader flood warning strategies, secure resources for installation and maintenance, define roles and responsibilities across agencies for smoother operations, and establish a process for continuous improvement. Planning is the first phase of the siren lifecycle.

Garner State Park, Concan, Texas

# ROLES AND RESPONSIBILITIES

It is critical to determine roles and responsibilities (see Figure 2-1 on the following pages) for an effective siren system. The "who" depends on the size and capacity of the community. In small communities, an individual may take on several roles, or responsibilities may be shared with neighboring jurisdictions. In large communities, roles may be filled by multiple individuals or departments, and automated systems or contractors may assist them. The more complex the roles and responsibilities, the greater the need for documentation, so all parts of the siren system are managed well.

Communities must designate a primary and backup point of contact who will administer and be responsible for the siren system. A third person should also be designated as an additonal backup. The primary point of contact does not have to perform every function themselves, but they must coordinate with others who are delegated tasks, so they are aware and confident that the system is functioning.

Consider and assign other key roles and responsibilities with the following in mind:

- Who will monitor gauges, updates from the NWS, and other information during an event with flash flood potential?
- Who will activate the sirens and issue alerts?
- Who will oversee or perform maintenance?
- Who will maintain system components, such as communications networks (if relying on a local network like radio), servers/IT infrastructure, and gauges?
- Who will regularly test the sirens and maintain required testing documentation?
- Who will manage funding, including grants, budgets, and contracts?
- Who will coordinate and communicate with community leadership?
- Who will provide or support public education and outreach?

**Requirement 2.1**

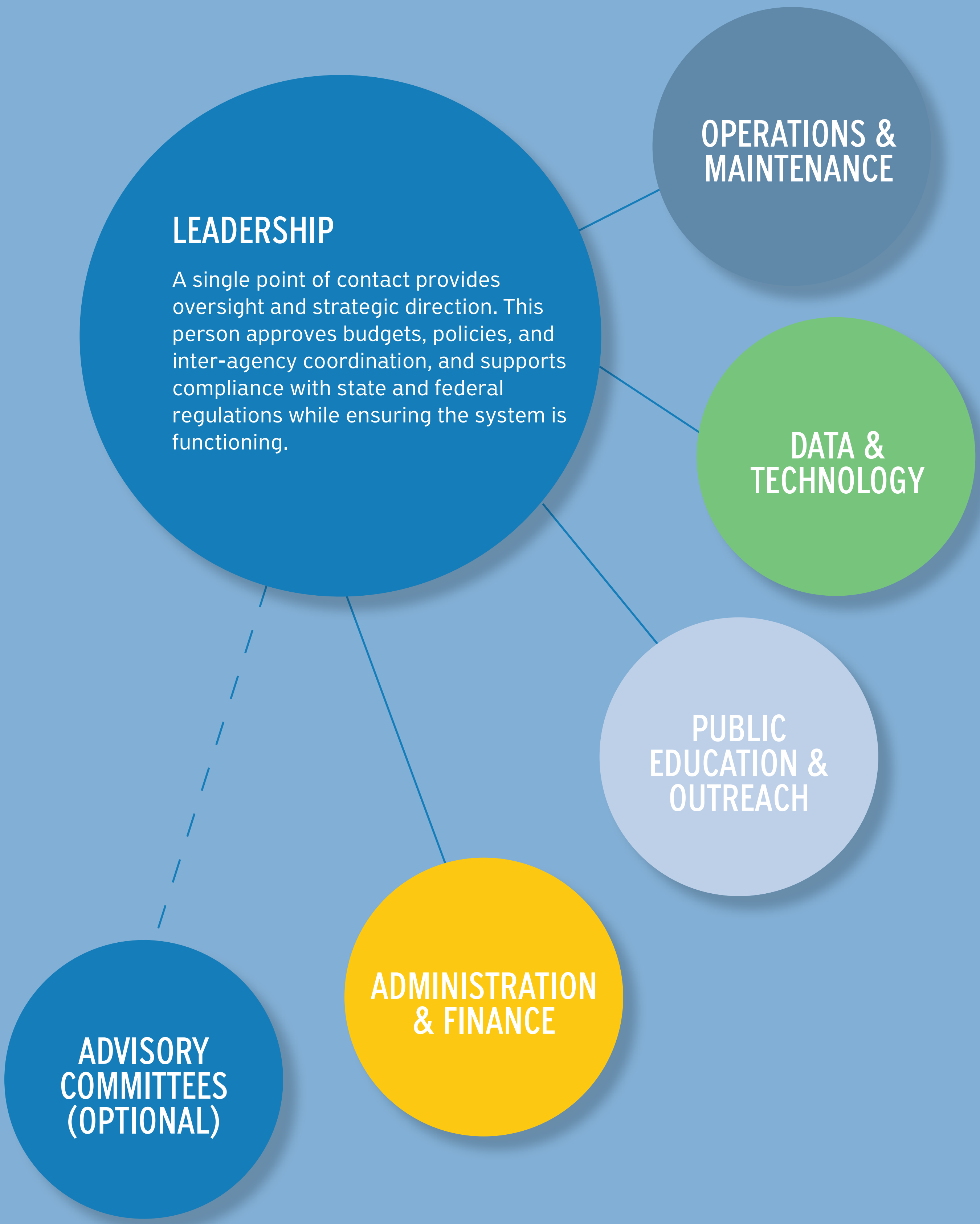
Communities must identify a primary and backup administrator responsible for their siren system with full oversight and awareness of the system and associated activities.

**Requirement 2.2**

Joint siren operations between municipalities, counties, and/or other government agencies must include a signed and/or adopted Memorandum of Understanding or similar written agreement with documented roles and responsibilities.

**Figure 2-1. Key Roles and Responsibilities**

See following page for an additional description of each group. Note that partnerships are important for data sharing, capacity building, and fulfilling these responsibilities.



### Flood Monitoring and Warning

Installs and maintains sensors, gauges, sirens, and communications systems. Promotes accurate and timely data collection.

### Emergency Communications

Issues audible alerts through sirens and other public notification channels (e.g. text, social media, and reverse 911). Coordinates with emergency response services.

### Hydrology and Forecasting

Analyzes meteorological and river conditions and, if warranted, develops predictive flood models.

### GIS and Mapping

Maintains floodplain inundation maps and real-time, flood-related dashboards. Supports analyses and access to data.

### IT and Cybersecurity

Manages system infrastructure, data integrity, and cybersecurity protocols.

### Public Education and Outreach

Conducts public education and outreach campaigns, workshops, and school programs to raise awareness of flood risk and siren alert protocols.

### Stakeholder Relations

Builds relationships with local governments, utilities, and community organizations.

### Grants and Compliance

Manages funding from federal, state, and other sources. Ensures regulatory compliance and reporting.

### Finance and HR

Handles budgeting, procurement, staffing, and internal administration.

### Technical Advisory Committee

Provides expert advice on related topics, such as flood risk, siren systems, FEWS, public education and outreach, and emergency operations.

### Community Advisory Committee

Offers feedback from residents and local leaders to ensure community needs are addressed.

Federal Signal Omni directional Modulator™ high-powered speaker array with anemometer, cameras, lights, and directional sirens

# COST AND FUNDING

Siren component costs include the initial capital investment, plus installation and ongoing operations and maintenance, with additional long-term costs for system expansion, interoperability, technology upgrades, and component replacement. Example ranges of typical costs below were obtained from subject matter experts and case study interviews in 2025; these are not exact prices and are provided as planning aids.

Capital and installation costs range from $24,000 to $70,000 per siren depending upon siren type and size. Depending on the control software used, additional annual licensing fees may apply; these can range from $10,000 to $30,000 annually and vary by system size and capabilities. Operating costs to consider include electrical service, cellular or satellite fees, and staff time for event detection, activation, notifi cations, routine testing, documentation, and system updates. Maintenance costs also vary by system type; a common annual maintenance budget estimate is 10 percent of installation costs. Many systems use battery banks for primary or backup power that consist of multiple batteries wired in series and/or parallel. In 2025, typical per-battery cost averaged $250 to $500. Batteries are typically replaced every two to five years, so consider the per-battery cost and the total sirens using batteries in your system when budgeting.

These costs exclude planning and siting studies, permitting, land acquisition or easements, site access, surveys, power installation, gauges, and integration with other flood warning systems. See the TWDB FEWS Guide and Alternative FEWS Guide (see References in Appendix E) for estimated costs for gauges.

Planning for the long-term costs required to operate and maintain a siren system is critical. Communities may qualify for financial assistance, including grant and loan programs. Recommended ways to position siren projects for federal, state, and local funding include:

- Strategically develop siren projects to be eligible for financial assistance programs funded through state and federal programs (i.e. FEMA Hazard Mitigation Grant Program Funding, TWDB Flood Infrastructure Fund, or similar).
- Look for partnerships (and think outside your jurisdiction) for funding system components. For example, a radio tower being funded and installed for a different purpose but usable for siren communications may be an opportunity for cost-sharing. Gauges located in watersheds upstream of your jurisdiction may be suitable for activation of your community's sirens. Connect with public works, regional planning districts, local school districts, river authorities, neighboring communities, or other potential partners to look for these opportunities.
- Include siren expansion costs in capital improvement plans and the regional flood planning process.
- Dedicate funding for maintenance. Annual or periodic maintenance costs are not always eligible for state or federal funding, so communities must plan for this. Years after the initial investment in sirens is made, your community will still be responsible for maintaining them. Siren systems that are not maintained, including the gauge components, will eventually fail.

# IMPLEMENTATION PHASES

The following provides a planning-level guide for implementing a siren system. Integration with mass notification systems, emergency response, and public education and outreach should be conducted in parallel and continue after installation. Construction times vary depending on selected equipment, site access, size of the siren system, permitting, authorization of funding, weather, labor and materials availability, or other factors.

## Phase 1: System Planning and Design

- Assess flood risk, affected populations, and site conditions
- Identify river corridors and develop siting strategy
- Identify existing gauges or plan for new ones to use as siren activation triggers
- Obtain permits, right-of-ways, access agreements, and/or land as needed

Assessing river corridors and individually placing sirens is the nexus between site-specific planning and performing the installation. Steps for identifying river segments, selecting appropriate equipment, and strategically placing sirens are covered in the Installation section of this guide.

## Phase 2: Equipment Selection and Authorization

- Request and review quotes from vendor(s) for siren and system components
- Select vendor and equipment
- Estimate and plan for the procurement and installation timeline
- Receive authorization for purchasing from community leadership

## Phase 3: Equipment Procurement and Delivery

- Place order
- Vendor manufactures and/or packages equipment
- Vendor ships equipment
- Receive and verify equipment

## Phase 4: Install and Test Equipment

- Confirm installation crew(s) schedules
- Mobilize installation crew(s)
- Prepare site for installation (grading, vegetation removal, traffic control, etc.)
- Install, test, and verify equipment

The City of Amarillo installs a gauge for monitoring the water level of a local playa lake.

# CONTINUOUS IMPROVEMENT

Siren systems should continually evolve and improve to serve the community.

Planning doesn't stop once sirens are installed. Plans should anticipate how the system will evolve over time. Communities change, technology advances, and lessons learned from real events or drills reveal opportunities for improvement. Building adaptability into your plan ensures the siren system remains effective and trusted for years to come.

## Anticipate and Respond to Growth

To keep pace with community growth and changing flood risk, include a strategy for when and how to assess and expand coverage. The recommended reassessment cycle is every five years. Communities experiencing rapid growth may want to use a more frequent cycle, such as every year or three years. Major development projects near the river corridor, new critical facilities (e.g., schools, hospitals, etc.) in siren-served areas, or population expansion are additional recommended triggers for siren system assessment.

## Assign Responsibility

Identify who will lead siren performance reviews, document when those will occur (e.g., annually and/or after flash flood events), and agree on how recommended improvements will be determined and implemented.

## Budget for Upgrades

Include potential costs for additions or technology improvements in long-term plans, in addition to costs for routine maintenance and replacement of worn or damaged parts.

## Define an Improvement Process

Decide how to identify and implement refinements to sirens when community conditions change, new technologies emerge, or lessons are learned from prior events. For example, document whether siren activation triggers are working or leading to false alarms. Are there ways to reduce false alarms?

Whelen WPS-2905 siren with solar panel and battery power supply

## Include the Siren System in Your Hazard Mitigation Plan

If your community has a hazard mitigation plan, document siren system goals, coverage maps, and maintenance schedules in your hazard mitigation plan, and include periodic siren coverage and system assessments as part of mitigation strategies. This shows sirens are part of a broader flood risk strategy and positions your community for funding opportunities.

## Connect to Development Regulations and Land Use Decisions

Monitor development within flash flood-prone areas. Use Geographic Information Systems or hazard maps to guide decisions and avoid unnecessary expansion of development in areas with high flash flood risk. Consider whether new development near or immediately adjacent to flash flood-prone areas could support costs for purchasing new sirens for the adjacent area.

Cypress trees line the banks of the Guadalupe River, Waring, Texas

# 3 INSTALLATION

Communities are required to determine how sirens are to be distributed in their area, the type(s) of sirens to install, and to ensure they are installed properly. The following sections discuss how to assess an area for siren coverage, the type(s) of sirens available, power and communications needs, and basic installation recommendations. Communities may undertake and document this process themselves or solicit assistance from siren and flood early warning system vendors and/or subject matter experts.

Whelen omni-directional WPS2906 siren being installed

**Requirement 3.1**

Communities must follow and document a process for siren site selection.

Cypress trees line the banks of the Guadalupe River, Waring, Texas

# RIVER CORRIDOR SEGMENTATION

The first step to install a siren system is site selection for the siren component. Note that a siren system requires additional components, such as river gauges, that may need to be placed elsewhere. To effectively warn the public of a flash flood, sirens must be positioned so they can be heard and activated in a relevant and suitable location.

Flood warning sirens specifically are designed to alert people that live, travel, and recreate along river corridors. So, the sound should primarily be directed upstream and downstream along the river corridor to ensure coverage. Additional propagation of sound should occur outward from the river into the floodplain.

To identify where to install sirens, river corridors can be divided into segments that match expected siren sound coverage patterns. Segmenting the corridor enables targeted alerts for areas at risk while avoiding coverage gaps and unnecessary alarms to low risk or unaffected zones. Segments are practical activation zones designed to balance flash flood hazards, where people are, and how sirens and communications work.

How far should a siren alert reach? In practice, a siren's range is often designed for one to two miles upstream and one to two miles downstream when used for flash flood warnings. Local conditions (e.g., vegetation, buildings, topography, wind, rain, etc.) influence the effective range. Different siren configurations also have different acoustical power that determine range. The following pages highlight common steps for identifying river corridor segments to support siren siting.

## What is a River Corridor Segment?

A river corridor segment refers to an area along the river that has common characteristics so that one or more sirens can serve the area in a coordinated manner.

**A segment is a stretch of river and adjacent flash flood-prone area(s) that**

- has similar flood arrival and lead-time characteristics from upstream trigger locations;
- contains a coherent outdoor population, if possible (e.g., parks, camps, and trails);
- can be covered by a logical cluster of sirens to provide effective and consistent alerting; and
- can be activated and managed as a unit without over- or under-alerting the area.

Figure 3-1 on the following page provides an example of how a hypothetical river corridor with different flood and population characteristics could be segmented. Communities should consider local factors and siren system design characteristics when defining their river corridor segments. Flash floods generally occur within a short time period after a rain event—typically six hours or less.

In addition, different warning zones within a segment may be needed for sub-areas where people must complete different protective actions before rising water makes movement unsafe. In these cases, tie each zone to a specific safety objective to understand how best to alert the population, such as time to reach high ground, time to clear campsites, time to close river access, etc.

## Information to Help Identify River Corridor Segments

**The following are examples of information that could be used to define river corridor segments and, if needed, unique warning zones. Basic to advanced data and methods can be used depending on community capacity and complexity.**

**Hydrology**: Rain and river gauge locations and metadata (e.g., what is being measured, how accurately, and how frequently), watershed boundaries, stream confluences, small dams and impoundments, flood risk and flood timing

**Terrain and Land Use**: LiDAR derived Digital Elevation Models, land cover, building footprints, parks, camps, trailheads, and low water crossing GIS data

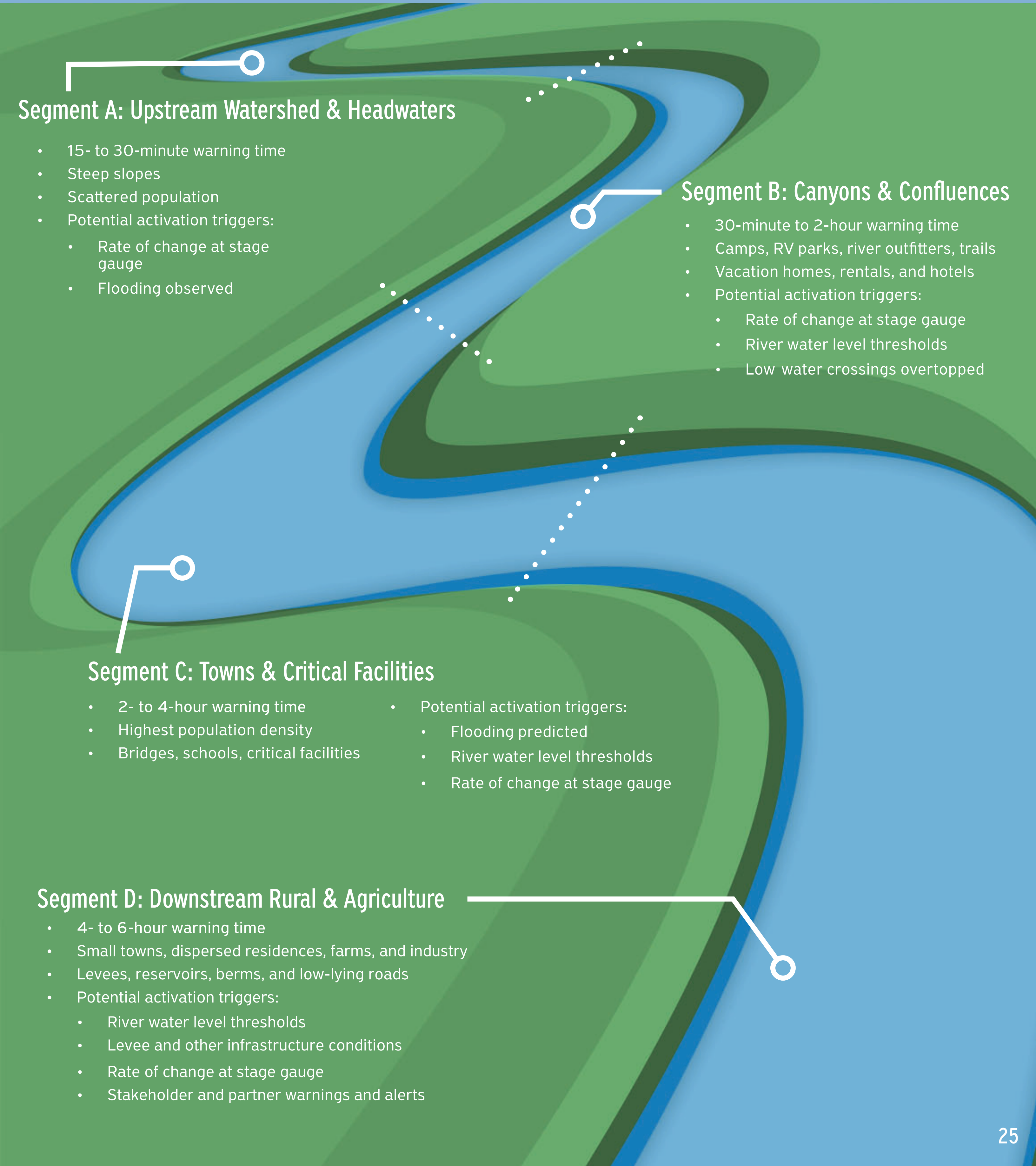
**Population and Use Patterns**: Population estimates (including population characteristics), seasonal camp locations, weekend recreation areas, such transient events as festivals and farmer's markets, and historic fatality data (i.e., National Oceanic and Atmospheric Administration FLASH database)

**Operations**: Administrative boundaries, cellular coverage maps, parcel boundaries, and ownership information

**Acoustics**: Preliminary siren propagation modeling and/or field testing, if available

## Figure 3-1. Example River Corridor Segments

**Example river corridor segments for a hypothetical river passing through areas with different topographic, geomorphic, and community characteristics are shown below.**



## Considerations When Creating River Corridor Segments

As you move from upstream to downstream in a system, segments you define will vary in size and in features. For example, upper basin segments tend to have the shortest flood travel times, so there are shorter warning time windows (e.g., 15-30 minutes) than downstream segments where over 1-2 hours of warning time is possible.

### Identify Flood Travel Times and Warning Time Needed

- Using past events or hydrologic and hydraulic analyses, consider floodwater travel time from the upstream gauge or trigger mechanism—how far does the flash-flood condition move downstream of the trigger in a given amount of time? Travel times are often much shorter for high flows than typical low flows.
- Target a warning time per siren zone from the upstream trigger—how much warning time is needed for the population at risk to respond? This should be no less than 15 minutes, and ideally longer.
- Farther downstream, more warning time is available because upstream gauges are already reflecting the rapid rate of rise and associated flows that will reach the downstream area.
- Aim for segment sizes such that the whole segment experiences the flash-flood impacts at similar times. This way, the warning time and required actions to be taken in a given segment are aligned.

### Identify Hydrologic and Hydraulic Control Points

- Place provisional boundaries at
    - major confluences,
    - dams and impoundments that slow or store water, and
    - notable channel slope or valley geometry changes.
- Associate segments with the most relevant upstream gauge(s) and/or other trigger mechanisms. Use information upstream to inform siren activation downstream.

Rio Vista Park, San Marcos River, San Marcos, Texas

City Tube Chute, Comal River, New Braunfels, Texas

### Overlay People and Places

- Identify population clusters by location and characteristics as noted in Figure 3-1. If possible, keep clusters with common populations (such as campgrounds, parks, or a town riverwalk) entirely within one segment.
- Use bridges and well-known landmarks for boundaries that are easy to explain to the public, are well known, and allow for signage to be installed.
- Keep segments activation-independent, if possible, to avoid designs where you are forced to activate two segments together.

### Check Acoustics

- During planning, perform acoustical testing and/or modeling to confirm siren sound coverage. Testing is typically offered by siren vendors using calibrated handheld sound meters in the field with a mobile siren. Modeling can also be performed by accoustic subject matter experts to confirm coverage in areas with complex terrain, vegetation, buildings, and wind.
- Identify features like terrain, dense vegetation, and buildings that may hinder effective sound coverage—consider splitting segments at such features. Aim for long, directional footprints along the river and minimize segments that would result in excessive alerting of neighborhoods away from the river that are not at risk.

### Align with Operations and Communications

- Try to keep a whole jurisdictionally-managed stretch (e.g., river parks/trail) within one or two segments for clear authority and routine testing.
- Place boundaries where your communication networks are strong on both sides.

### Validate Against Triggers and History

- Walk through past flash-flood timelines. Do the proposed segments get distinct, useful lead time from upstream gauges and warnings?

### Finalize and Document

- Assign each segment a name, upstream trigger gauge(s), typical lead time, activation rules, siren sites, and points of contact.
- Create a map with segment boundaries, notes, and signage/education plans.

# SITING STRATEGY

After determining segments, identify the types and locations of sirens to maximize coverage, reliability, and public safety. Consider soliciting vendors, acoustic engineers, and FEWS subject matter experts for siting and selection.

Since a siting strategy is extremely location specific, acoustical modeling is recommended (see following page for an example of an acoustic survey). General approaches to acoustical modeling include:

- Standards-based propagation models: ISO 9613-2, often with refinements from CONCAWE or Joule-type adjustments, are widely used to predict siren sound pressure levels over complex terrain and land use.
- Noise-mapping engines: General environmental-noise tools (e.g., Sound PLAN, Noise Modeling) compute sound pressure levels from point sources using using specific methods (e.g., ISO 9613) that can be adapted to sirens.
- Vendor-proprietary models: Several siren vendors and consultants use methodology developed in-house leveraging similar engineering models with calibration from field measurements.

## Siting Considerations

### FLOOD RISK MAPPING

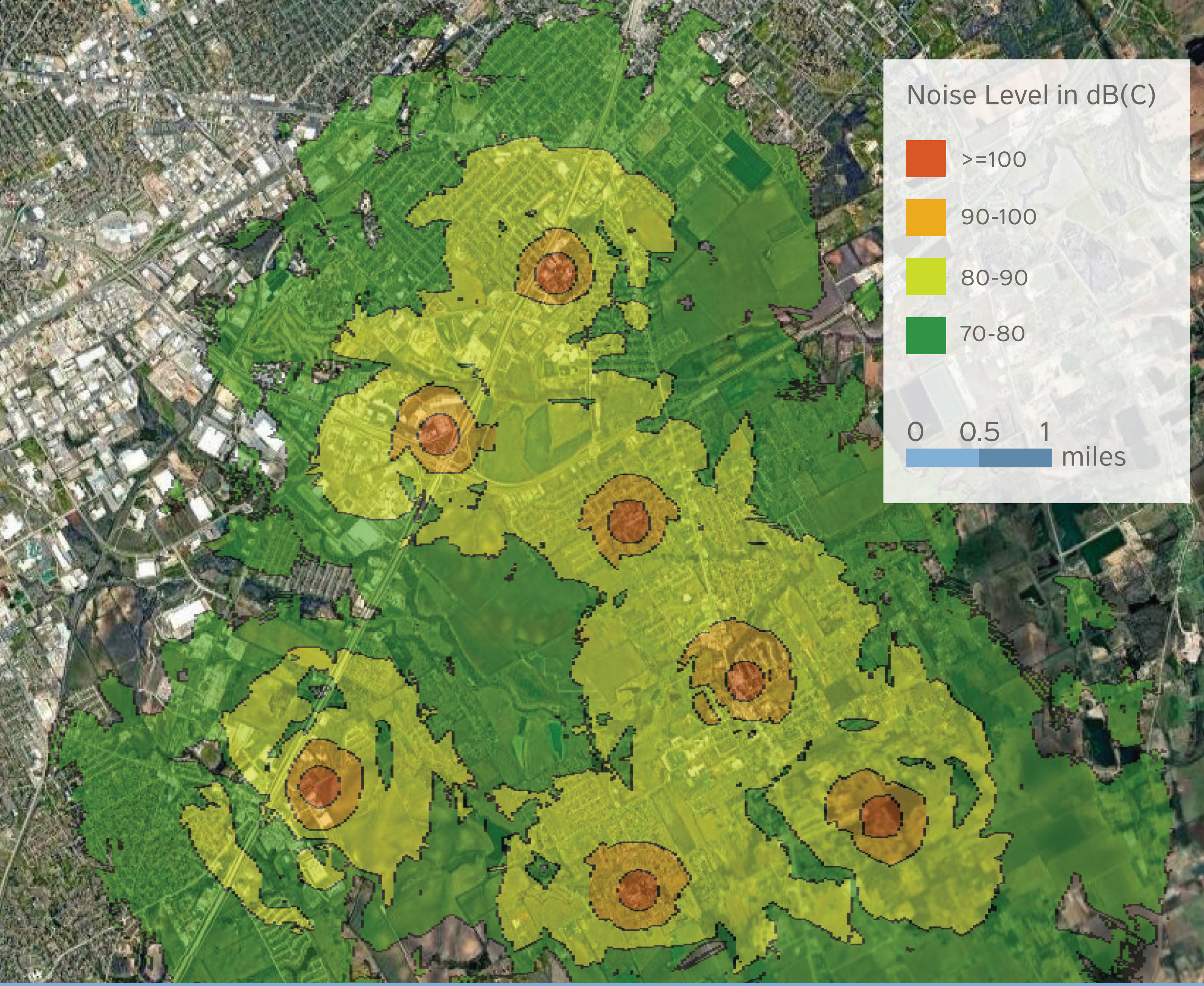
Use available flood risk products from FEMA, the TWDB, or local entities/community datasets. Conduct local flood risk assessments to identify and refine priority areas as needed.

### ACOUSTIC OBSTACLES

Account for terrain, buildings, vegetation, and ambient noise. Ensure targeted areas, such as parks, school playgrounds, and other public outdoor spaces, can clearly hear the siren.

### REDUNDANCY

Site sirens where edges overlap with critical infrastructure to ensure coverage redundancy where possible. Areas of overlap can be determined using GIS.




American Signal acoustic survey map illustrating noise level ranges for tornado sirens, with broad (not river focused) siren placement.

## LINE OF SIGHT AND ACCESSIBILITY

Place sirens with clear lines of sight that are elevated above obstructions but accessible for maintenance. Typical urban mounting locations for areas with limited line of sight include water towers and tall buildings. Access to the onsite manual trigger should not require specialized equipment (e.g., bucket truck, crane, etc.).

## REGULATORY CONSTRAINTS

Follow all local codes and regulations applicable to siren placement, such as zoning, land use, electrical, acoustic safety standards, or similar.

# SIREN SELECTION

There are a variety of sirens available that can support flash flood warning. Key selection criteria include siren types, acoustic output and effective range, power requirements, communication and activation methods, and costs related to operation and maintenance.

## Types of Sirens

Sentry omni-directional 40V2T siren

Whelen directional WPS4000 series siren

### Mechanical

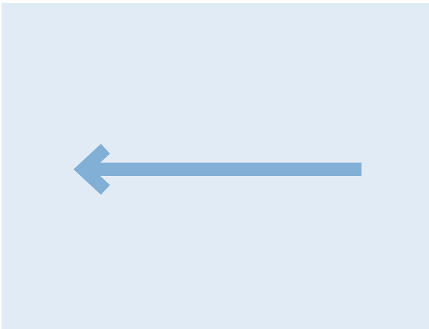
Mechanical sirens utilize a motor with modulated power to generate a distinctive "air raid" tone. Because of the motor, the power requirements (110V or 220V) can be higher than for electronic sirens. Routine maintenance on the motors is typically straightforward. The initial cost for this siren category will typically be less than electronic sirens, which have more features.

### Electronic

Electronic sirens utilize electronics to generate various tones and may also include a "voice" signal option. These newer sirens are more technologically advanced, and vendors could require that their trained technicians perform any repairs to proprietary components. Maintenance and inspection schedules should be similar to mechanical sirens. The power requirements for this category can vary from battery (48V) to AC (110V or 220V). The initial cost for this category is heavily dependent on the features and specifications of the siren.

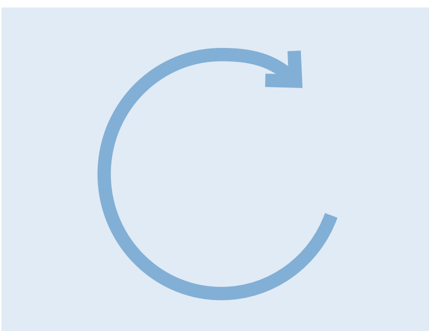
## Acoustic Directionality

The acoustic output and range of a siren will vary depending on the type and style of siren. The three common siren styles are fixed-directional, rotating, and omni-directional. Brief descriptions of each style are included below.



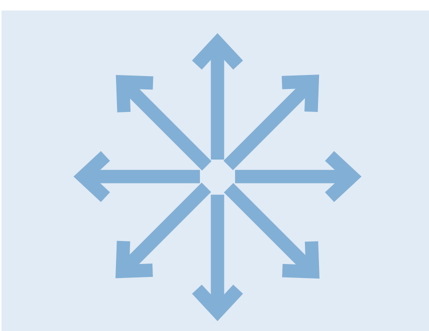
### Fixed-Direction

These sirens are affixed to a single point and pointed towards the area requiring coverage. They have a sound coverage pattern of a wedge and would be ideal for areas with numerous obstructions (e.g., heavily urbanized areas), where rotating and omni-directional sirens may be ineffective.



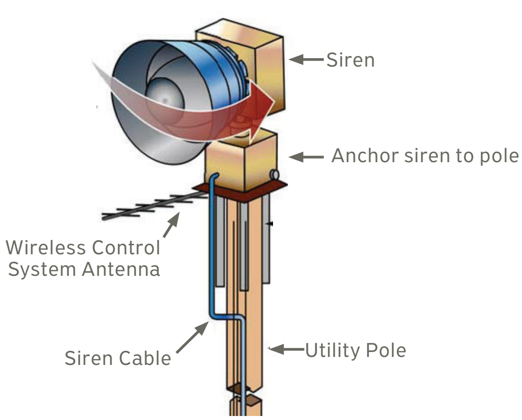
### Rotating

These sirens consist of a single speaker, positioned at the top of the pole, that rotates 360 degrees to create a coverage pattern of a circle. They can have a lower initial cost but may require routine maintenance on the motor that rotates the siren. Rotating or omni-directional sirens would be ideal for open areas, such as fields and pastures, and residential areas, such as neighborhoods and areas with one- to two-story apartment buildings.

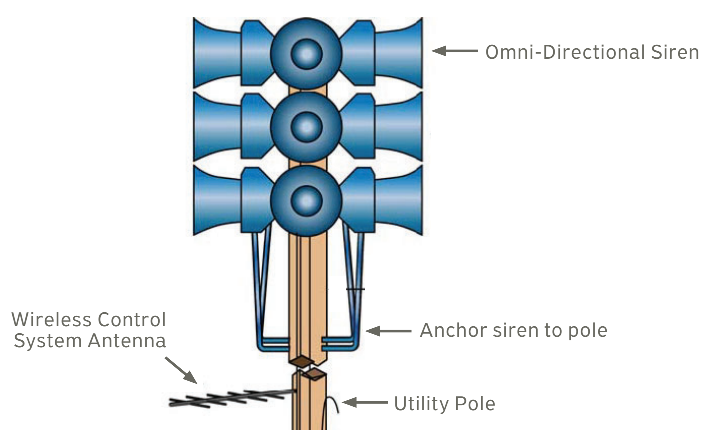


### Omni-Directional

These sirens consist of a stack of sirens that point in multiple directions to create a circular pattern of sound coverage. These sirens will range in initial cost depending on the number of stacks and type of sirens that are installed. Routine maintenance can require additional time due to the number of individual sirens installed. The benefit of these sirens is the scalability of the siren array and output, with the main limiting factor being power.




Rotating Siren (FEMA)




Omni-Directional Siren (FEMA)

## Acoustic Output and Ranges

Siren acoustic ratings are typically listed using dB, dB(A), or dB(C). See the caption below for definitions. When selecting a siren and assessing the required output, consider population density, terrain, and ambient noise—large areas and open corridors may require higher-powered, rotating models, while dense urban locations may benefit from omni-directional or multiple smaller fixed-directional units.

**Requirement 3.2**

Sirens must produce an audible alert of no more than 130 dB(C) at a distance of 100 feet from the siren. The siren's coverage area is defined as the area in which the audible alert is at least 70 dB.

## Multi-Signal Capability

Select sirens with programmable tones and/or voice message capability. For systems that are going to provide alerts during non-flash flood emergencies, it is imperative that the tones and/or messages are configured to distinguish flood alerts from alerts for other emergencies, such as tornados, severe weather, and fire. Alternatively, consider a tone based on the required action instead of the hazard.

## Integration

Select sirens that can integrate with gauge data from a local or regional FEWS that may be operated by other agencies. Discuss how gauge observations could be integrated through controlling software with vendors and FEWS operators.

## Other Considerations

Other considerations when selecting sirens include, but are not limited to, remote activation capability, two-way activation confirmation (to verify the siren received the activation command and is alerting), redundant methods for sending commands to the siren, and automatic system health monitoring.

## How is Sound Measured?

**dB** Decibel is the standard unit of measurement for sound.

**dB(A)** A decibel measurement of sound that has been adjusted to reflect the sensitivity of the human ear to different frequencies.

**dB(C)** A decibel measurement that is used to assess sound levels, particularly in contexts where the human ear is sensitive to certain frequencies. It is often used in noise assessments to measure impact noise, focusing on the peak sound levels that can cause hearing damage.

** An increase of around 3 dB is equivalent to doubling the intensity of the sound.*


Road closure due to flooding

Whelan WPS-2903 siren mounted on a roof

# POWER AND COMMUNICATION

Sirens are a critical line of defense in alerting communities to take action during a flash flood and must remain operational. Severe storms and flooding frequently damage electrical grids and communication networks, so without backup power and redundant communications, the siren can fail precisely when it is needed most. It is essential that the siren is equipped with backup power and communications so it continues functioning even if its primary power source or communication method fails.

This section details power and communications requirements, recommendations, and strategies to improve power and communications resilience—there are a variety of power and communications options available. Continuous and reliable power systems typically involve a combination of AC power, solar and battery, and/or onsite generators. Most commonly, AC power is used as a primary power source, with one of the other options listed above serving as a backup power supply. Communications systems typically leverage broadband, if available, and cellular or satellite services, but can also use radio.

Siren power and communications needs vary across communities and equipment choices. Consider working with vendors and FEWS subject matter experts to understand and meet requirements while addressing any unique site characteristics.

**Requirement 3.3**

Sirens must have the following:

- Both local and remote manual overrides for triggering the siren.
- A primary power source capable of operating the siren continuously and reliably.
- A backup power source different than the primary power source that is sufficient to operate the siren as designed in the absence of the primary power source (as detailed further below).
- Automatic transition between primary and backup power in the event of failure.

The backup power source must provide sufficient power for:

- 24 hours of standby.
  - "Standby" refers to the operational state where the system is waiting for a trigger signal and is capable of alert when a trigger signal is received.
- 30 minutes of alerting.
  - This requirement has been modified from the FEMA standard of 15 minutes to provide for a series of 10, three-minute audible alerts.

Batteries used for power supply must:

- Be automatically and fully recharged to at least 80 percent of maximum rated capacity from the fully discharged state in 24 hours or less.
- Be a low-maintenance design with a vendor-specified lifespan of at least five years. Note that this value has been modified from the FEMA standard of three years based on industry experience and advancements in battery technology.

"That's the good thing about the low-tech option... if we had an extended power loss and the batteries died just go to the local auto shop and buy a bunch of batteries."

- Assistant Emergency Management Coordinator, San Marcos, Texas

# Power

Sirens and their associated components require power to function. They are also required to have a backup power supply to support operations during severe weather. The following are available power supply options and associated pros and cons.

## AC

AC power refers to 120V power supplied by the grid. This is the best source of power, if available, and can be supplemented with off-grid power sources, such as a solar panel with batteries.

**PROS**

- Consistent power with minimal maintenance required once installed
- Low cost for sites with established electrical access nearby

**CONS**

- During severe weather, regional power blackouts could cause disruption
- Needs a connection to the grid, and if one is not available, it can be costly to install
- Maintenance poses a higher electrocution risk and needs special training

## Solar Panels with Batteries

Power can be supplied from batteries charged by solar panels. Size the solar panel and battery to ensure the daily recharge rate and capacity are adequate for maintaining continuous power to the siren. A second, independant set of panels and batteries can serve as a backup power source, but AC is recommended if available. Ask vendors if lithium iron phosphate (LiFePO4) batteries can be used, since they provide a longer lifespan and more stable power supply.

**PROS**

- Cost-effective long term
- No electrical grid connection provides for greater flexibility in site selection
- Maintenance on power circuit poses low electrocution risk

**CONS**

- Higher initial costs for batteries and solar panels
- Must have adequate access to sunlight and sufficient batteries to provide power during cloudy conditions

## Generators

Generators provide power using gasoline, propane, or natural gas but are complex and more prone to failure than solar power and batteries. They need monthly visits to ensure they are operating normally and cycle through fuel. If using a diesel generator, all fuel must generally be consumed or replaced every 6-12 months. They need to be appropriately weatherized and elevated. Follow the vendor's recommended maintenance schedule and verify generators are accessible for service. Consider whether propane generators are a viable alternative to diesel as they tend to be quieter and lower maintenance but are less fuel efficient.

| PROS | CONS |
|---|---|
| ✓ No electrical grid connection provides for greater flexibility in site selection | Large and requires additional space; difficult to elevate above flood waters ✗ |
| ✓ Maintenance on power circuit poses low electrocution risk | Point of mechanical failure that is more vulnerable compared to other options ✗ |
| ✓ Reliable power source | Regular visits needed for diesel engine maintenance and to refill fuel ✗ |
| | Higher costs for fueling and maintenance of generator; needs trained staff ✗ |

## Power System Resilience Strategies

In addition to implementing backup power supply options, the design of siren sites should plan for worst-case scenarios. The following recommended strategies can be used to enhance power resilience so that alerts reach communities in a timely manner:

- Deploy portable or permanent generators for critical locations (e.g., communication relays, central control, or other failure points). Have a cover or enclosure that protects them from the elements while not in use.
- Select batteries that can maintain power supply standards at the siren's operating temperature extremes for their entire life cycle.
- House power components in waterproof, corrosion resistant enclosures.
- Employ measures to protect equipment from vandalism or theft (padlocks, fencing, or security cameras) where warranted.
- Maintain service contracts or agreements for rapid generator refueling and replacement in the wake of extreme weather events.
- Provide annual training to key staff that covers how to switch to and operate sites manually during emergency situations.

# Communications

Siren systems depend on maintaining communication between sirens and a central location. Using communications backups minimizes the likelihood of system failure during an emergency, so redundant communications pathways are a requirement. This is an area of rapidly evolving technology, so work with a siren vendor to identify the best communications options for each site, depending on coverage, budget, and compatibility. Common communications systems are listed below.

## Cellular

Cellular networks utilize cellular towers to relay information. This is a common communication method for FEWS. Perform onsite signal strength testing to verify if cell coverage is sufficient. If using a SIM failover protocol for communication redundancy, confirm connection to multiple towers in case a tower fails.

**PROS**

- ✓ Low cost if the necessary infrastructure (i.e., cell towers) is already in place
- ✓ Low latency allows for near real-time monitoring and communications
- ✓ Minimal repair and maintenance

**CONS**

- ✗ Coverage can be spotty in remote areas
- ✗ Lower degree of security than other options
- ✗ Cell traffic increases during severe weather, which can reduce the reliability of transmission

## Satellite

Satellites offer a more expensive but reliable way of communicating where cellular service is not available. It can also serve as an excellent backup form of communication. Ensure that both primary and backup power sources can meet the power requirements of the satellite components (e.g., the modem and antenna) and monitor and remove potential signal obstructions (e.g., trees) as they can degrade the signal quality.

**PROS**

- ✓ Dedicated network availability increases system reliability
- ✓ Less vulnerable to ground-based infrastructure damage
- ✓ Works well in remote areas

**CONS**

- ✗ Most expensive wireless option with highest power supply requirements
- ✗ Needs a clear view of the sky
- ✗ Higher latency means system is less immediately available than other options

**Requirement 3.4**

Sirens must have a backup communications method that is sufficient to operate the siren as designed in the absence of the primary communication method.

The siren must provide automatic transition between primary and backup communication methods in the event of failure.

## Radio

Radio communication provides a reliable way to communicate with the system but is more complex to implement and operate. Radio repeaters may also be required to maintain line-of-site communication, which is not an issue with cellular and satellite. If using radio, be sure to use two-way radio communication wherever possible for remote monitoring of site and equipment conditions.

**PROS**

- Cost-effective long term with no annual fees
- Tend to be more reliable during natural disasters, making it a solid backup option

**CONS**

- Higher initial costs, especially if repeaters are required
- Limited range compared to other options and dependent on terrain, obstacles, and line-of-site distances
- One-way radio communication does not allow for real-time system monitoring

## Broadband

Broadband corresponds to traditional internet lines and is an ideal primary communications method; however, it is often not available in areas where sirens are needed. Even broadband must be supplemented with wireless communication for redundancy.

**PROS**

- Fast, reliable data transmission

**CONS**

- Can have high costs and maintenance; not feasible at all sites

## Communications Resiliency

Focus on identifying potential single points of failure and add redundant equipment or protocols wherever possible. The more flexible a system is, the more likely it is to continue to operate continuously through extreme weather. Some general strategies include the following:

- Select equipment that is compatible with multiple forms of communications.
- Install redundant repeaters and/or additional transmitters if using radio.
- Source Subscriber Identity Modules (SIMs) through third-party Internet of Things vendors, which provides flexibility in connecting to the strongest available network signal.

## Remote Monitoring

In addition to the regular testing and maintenance outlined in this document, siren systems with two-way communication should be remotely monitored by emergency management personnel to check that all components are operating as expected and address issues as they arise. Remote monitoring activities could include:

- User-initiated checks to review and quality control data.
- Diagnostic “self-testing” to continually verify system functionality.
- Status monitoring with a user-facing dashboard that provides an alert when a site experiences an outage or has maintenance needs.

## Stream Gauges for Siren Activation

When used as a siren activation trigger, stream gauges should be installed upstream far enough to provide sufficient lead time for the population serviced by the siren. Stream gauges should have sensors capable of measuring water levels with 0.10 foot accuracy or better.  A minimum transmission interval of 15 minutes is required, and a five-minute transmission interval is recommended during an event. Check with vendors to confirm if their systems are capable of increasing transmission rates when rapid flood conditions occur to reduce telemetry costs.

A backup form of telemetry is also strongly recommended when possible. Note that stream gauges do not typically have backup power due to their lower power requirements and are not required to do so. See the TWDB FEWS Guide and Alternative FEWS Guide (see References in Appendix E) for more information.

**Requirement 3.5**

When used as a siren activation trigger, gauges must use at least one form of telemetry capable of transmitting data to a central location at a minimum of every 15 minutes.

“Our standard practice would be AC power and fiber as your primary for power and communication, [and] solar and cellular would be secondary.”

- County Engineer, Comal County, Texas


Sentry Siren omni directional electro mechanical 14V B siren

# SITE INSTALLATION

Adhere to manufacturer recommendations for detailed installation needs for specific sirens and components.

A siren must include at least one stream gauge as an activation trigger. This gauge may already exist, may be operated by a separate agency, or may need to be installed at the same time as the siren. Note that multiple sirens can be activated by a single gauge.

**Requirement 3.6**

Sirens must be tested immediately after installation and the results must be documented.

**Requirement 3.7**

Sirens must include at least one stream gauge as an activation trigger. One gauge may serve as a trigger for multiple sirens.

## Mounting and Placement

Federal Signal fixed-directional Informer 15 Series C 15W siren

### Sirens

Mount sirens on sturdy poles or other structures (e.g., water towers or buildings) at the manufacturer's recommended height (typically 20–50 feet), with clear line-of-sight that is free of nearby vegetation and buildings. Poles should be designed to withstand high-velocity floodwaters and debris or placed where lower water velocities are expected. The siren control box should be secure yet accessible for manual override and troubleshooting. All electronic components must be elevated to or above the 500-year, 24-hour maximum water surface elevation.

Installation of river gauge on a roadway

### Gauges

Gauges include many components, such as rain or water level sensors, dataloggers, batteries, and communications modules. Securely mount sensors and components for accurate measurements and to withstand severe weather, flooding, and debris. The datalogger, battery, and communications module should be mounted within a secure weatherproof enclosure above the 100-year, 24-hour maximum water surface elevation. For more information on gauges, consult the TWDB FEWS Guide and Alternative FEWS Guide (see References in Appendix E).

**Requirement 3.8**

All siren electronic components must be elevated to or above the 500-year, 24-hour maximum water surface elevation.

## Connectivity

Confirm connectivity prior to and after installation and protect broadband, if applicable, with resilient conduit. Antennas should be mounted securely to withstand severe winds.

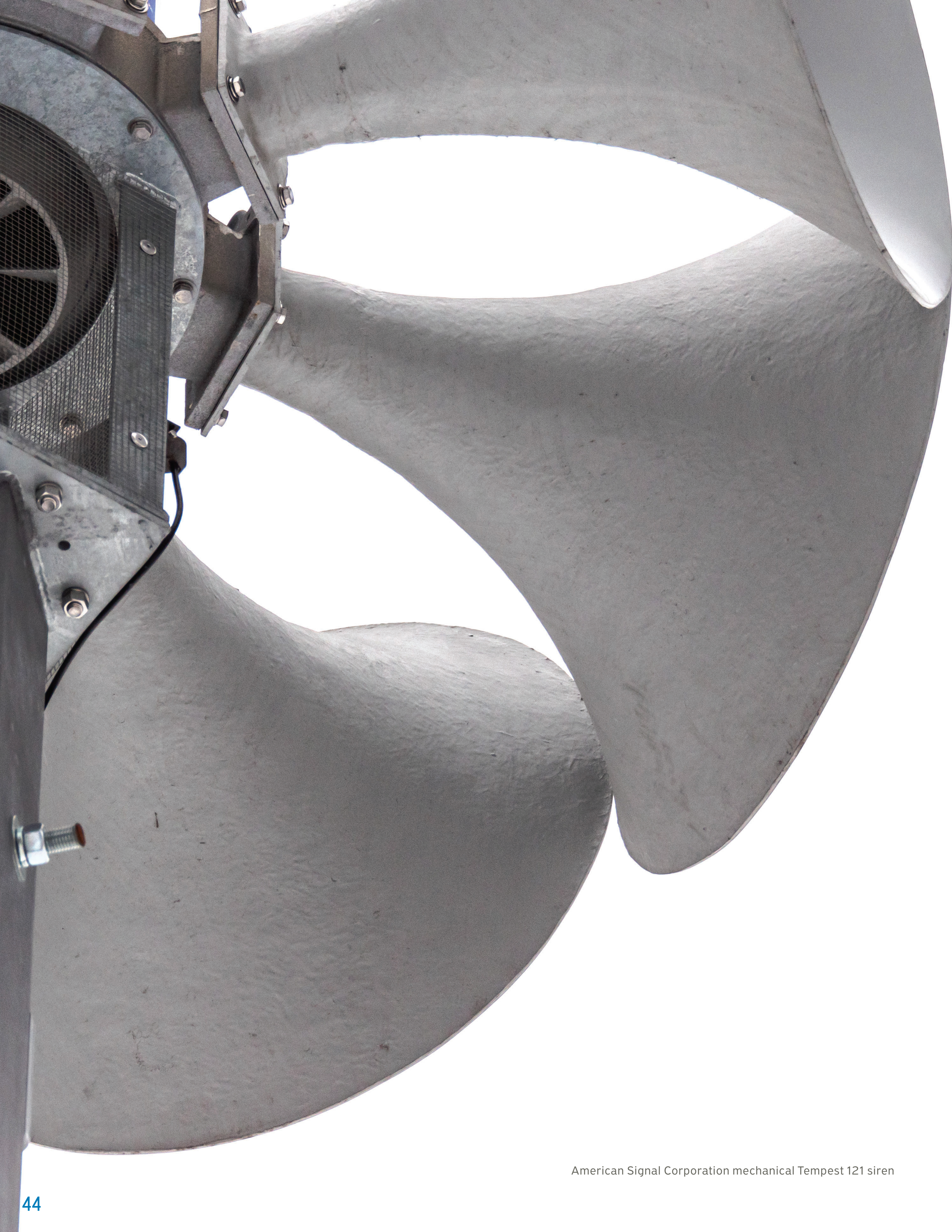
## Testing

Perform initial acoustic and operations tests post-installation, and document results to establish baselines for routine operational testing.

## Documentation

Document installation dates, personnel, latitude and longitude locations, and deviations from design due to field conditions. Adopt a consistent, logical naming convention and descriptions for siren components.

Sentry Siren omni-directional 14v siren installed at the Comfort, Texas fire department



American Signal Corporation mechanical Tempest 121 siren

# 4 OPERATIONS

The role of a siren is to provide immediate notification of impending flash floods. The period of operations for sirens is 24 hours a day, seven days a week. This section provides requirements and recommendations for operating sirens, including event detection, siren activation, and notification, as well as routine operations.

## Operational Phases

Primary operational phases are illustrated below with associated key activities.

| ROUTINE | DETECTION | ACTIVATION | NOTIFICATION |
|---|---|---|---|
| • Routine, normal conditions<br>• Silent, daily tests to confirm status<br>• Audible weekly or monthly tests to confirm functions<br>• Yearly validation of entire system | • A trigger or threshold is reached<br>• Manual verification of conditions<br>• Decision by authorized personnel to activate siren(s) | • Siren(s) issue alert<br>• Tone and/or voice based on conditions<br>• Confirmation that siren(s) operated, if possible<br>• Activation event documented | • Activation verification sent to officials<br>• Message(s) disseminated with instructions and additional information<br>• Notification via multiple channels |

**Requirement 4.1**

An operations plan must be assessed annually and include, at minimum,

- roles and responsibilities, including who is responsible for authorizing activation;
- detection protocols (i.e., trigger(s), threshold(s), etc.);
- activation protocols (i.e., how and when a siren is activated);
- notification protocols for officials, emergency managers, and the general public;
- testing protocols; and
- a false alarm policy.

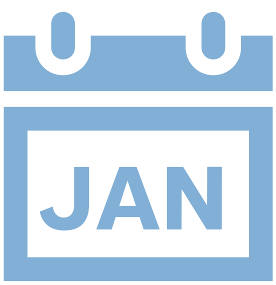
# ROUTINE OPERATIONS

Routine siren operations include testing and reviewing system performance. Regarding testing, the Texas Water Code § 16.502 requires that "each county or municipality ... or any other governmental entity with an outdoor warning siren in a flash flood-prone area shall regularly test the functionality of the outdoor warning siren and document the results of those tests."

Daily

**Daily silent tests** verify if sirens are receiving communications and are operational. Tests are typically performed as follows:

- Ping each siren controller remotely each morning to verify connectivity, battery status, and diagnostics. Silently means without sounding.
- Review test results and respond to faults immediately.
- Some sirens have a diagnostic "self-testing" feature to automatically verify system functionality.




Monthly

**Monthly audible tests** verify if siren activation and alerting is functional. Tests are typically performed as follows:

- Sirens are tested on a fixed day and time schedule (e.g., first Wednesday or Saturday of each month at noon).
- Activate each siren for 30 seconds to one minute with the standard flash flood alert. The duration should be less than the standard duration for an actual flash flood emergency.
- During tests with voice protocol, clearly state: "This is a test of the flash flood warning siren. No action is required."
- Cancel the test if severe weather is present or forecasted. Reschedule for the next non-severe weather period, as soon as the next day.

**Requirement 4.2**

Sirens must be tested daily using silent tests and monthly using audible activation to verify sirens are receiving communications and are operational. Primary and backup systems must be tested. The monthly audible activation can be cancelled if severe weather is present or forecasted. All tests must be conducted on a fixed, documented schedule, and test results must be documented.

If a test fails, corrective action(s) must be initiated within 72 hours and retesting performed after corrective action(s) are completed. Corrective action(s) and retesting must be documented.

## Yearly

Annual activities include testing along with other actions to assess system performance. The following are some examples of annual recommendations that depend on the type of siren, location, community, etc.

- Review documentation, procedures, and maintenance and testing logs to confirm siren status and condition.
- Update documentation to reflect any changes to system architecture, workflow, roles, and responsibilities.
- Review siren acoustic output and range and review site conditions that could affect siren performance.
- Review siren protocols, evacuation plans, etc. and update as necessary.
- Perform training and exercises that include activation of the system and the notification procedures for a flash flood event. The objective is to identify any potential weak links so that mitigation measures can be employed.
- Consider coordinating with river outfitters, campgrounds, and seasonal facilities before camping season. This could include running short audible signals to confirm coverage, providing outreach, and conducting exercises.
- Conduct regular public education and outreach so residents recognize alerts and understand what actions to take.

"We'll do a wet test. We'll actually put a column of water on the PT [pressure transducer] and make sure everything's working properly."

- County Engineer, Comal County, Texas

# Sample Test Documentation

Documentation must be maintained showing that testing was completed while noting the timing and results of the tests. The following checklist provides items to consider when logging daily, monthly, and yearly tests. The checklist should be updated based on equipment type, manufacturer recommendations, and any other considerations based on the siren system.

**Table 1:**

| | Daily | Monthly | Yearly |
|---|---|---|---|
| Date | ✓ | ✓ | ✓ |
| Time | ✓ | ✓ | ✓ |
| Siren locations | ✓ | ✓ | ✓ |
| Tester name | ✓ | ✓ | ✓ |
| Activation method | ✓ | ✓ | ✓ |
| Signal strength* | ✓ | ✓ | ✓ |
| Type of system activation | | ✓ | ✓ |
| Battery status | ✓ | ✓ | ✓ |
| Results and findings | ✓ | ✓ | ✓ |
| Review system documentation and procedures | | | ✓ |
| Review siren acoustic output and range based on equipment recommended by the manufacturer | | | ✓ |
| Review site conditions that could affect siren performance | | | ✓ |
| Review protocols, evacuation plans, etc. that reference the siren system | | | ✓ |
| Follow-up needed | ✓ | ✓ | ✓ |

- ** Note: Signal strength refers to system connectivity and applicable parameters including primary and backup power source voltages, etc., and varies with system components.*


Sentry Siren omni directional 7v8 siren

# DETECTION

Detecting a flash flood for which a siren should be activated is a critical component of a siren system. The siren system operations plan must identify at least one stream gauge as an activation trigger and the threshold(s) that will be used. The community should strongly consider incorporating more than one trigger to activate the system to minimize false alarms. Below are examples of other triggers, although this is not an exhaustive list as local conditions must be considered.

## Stage Gauge

Threshold values for gauges can be based on water elevation (stage) and/or rate of change in water elevation. Identify which siren(s) correspond to which gauge(s) to link specific siren activations. Automated gauge systems can analyze data and notify decision makers when set threshold values are exceeded. Gauge data quality should be confirmed prior to activation. Whether to automate siren activations is a local decision.

## Direct Observation

Public safety officials observing that a flash flood is imminent or occurring (e.g., flood waters rapidly rising, overflowing a roadway or structure, indications from rain gauge network paired with local interpretation of readings, etc.) may warrant siren activation.

## National Weather Service

NWS warnings may be considered for triggering sirens. Discuss with your NWS River Forecast Center and/or Forecast Office to determine whether to incorporate NWS warnings in a siren system.

# ACTIVATION

Activation of the siren is when the siren is physically activated and an alert is sounded. The operations plan must identify how the system is activated and who is responsible for activation. The siren must have the capability to be manually activated by authorized personnel. An automatic trigger for the system may be used to activate sirens and minimize the delays and lapses in the process. This can be especially helpful after normal working hours or on holidays when manual activations would take longer. Without manual review, however, false alarms may occur more frequently. Communities may activate sirens using automatic and/or manual methods.

Consider the following recommendations as well:

- Enable authorized personnel from fire and police departments to also manually activate sirens during local flash flood emergencies when warranted.
- Coordinate siren activation as part of the unified emergency command operations (see Appendix D for more information).
- Document all activations, including location, date and time, reason, storm event description, and authorizing personnel.

> "If you're doing voice [messaging] and siren, you need to make sure that you have good acoustics around that. Otherwise, you can run into some problems with understanding it [the voice alert]."
>
> Director of Office of Disaster Management for the City of Boulder and Boulder County, CO

# SIREN TONE AND VOICE ALERTS

A siren must provide a clear and standardized alert tone. Where practical, use a secondary voice alert with simple instructions to maximize attention and understanding.

## Primary Alert

- A siren must produce a sound per Texas Water Code § 16.502. The operations plan must document protocols regarding the tone used for a flash flood emergency. Tones for flash flood emergencies should not be confused with other hazard or non-emergency tones. Alternatively, a hazard-agnostic tone indicating the action to take, regardless of the hazard, can be used. Public education and outreach is also required and should increase public understanding.
- Alert tone(s) must have a minimum duration of three minutes and be repeated at regular intervals through the peak of the event. Interval times of at least every 10–15 minutes are recommended. Exact intervals used may depend on community conditions, battery capacity, vendor specifications, and other factors.
- Activation should continue until conditions improve or are resolved. This could be determined via gauge observations, NWS updates, radar observations, reports from local emergency personnel, or other reliable sources.

## Optional Secondary Alerts

Modern sirens can include voice messaging for additional instructions versus simply a tone. Sirens may also be paired with lights, such as flashing strobes or beacons, when activated.

If operating a siren with voice capability, recommendations include the following:

- Immediately follow the three-minute siren tone with a clear, pre-recorded, or if warranted, live message. Use simple, action-oriented language, such as: “Flash Flood Warning. Move to higher ground now. Avoid low-lying areas. Tune in to local media for updates.”
- Repeat the tone and voice message at regular intervals. Note that voice messaging effectiveness may be reduced in noisy areas or during heavy rain with thunder. Broadcast distance for voice messaging is typically less than tones as well. Messages should be as short as possible for clarity.
- Consider repeating voice messages in multiple languages, where applicable.
- Include evacuation directions or tailored instructions, if warranted and clear.

**Requirement 4.3**

A siren must produce clear, audible alert tone(s) with a minimum activation duration of three minutes per alert repeated at regular intervals.

# NOTIFICATION

Notification includes activating a siren's audible alerts along with multichannel notifications (e.g., social media, SMS, reverse 911, news media, etc.). It may also result in evacuations, placing barricades, first responder activation, communicating with neighboring communities, and other emergency response activities.

## Notification to Emergency Response Officials

Notify emergency managers and public safety officials before siren activation, if possible, or otherwise as soon as possible following activation to inform and initiate emergency response activities. Emergency management and public safety personnel can also confirm that siren activation is valid, not a false alarm, and that activation has occurred.

**Requirement 4.4**

The siren system must be integrated with public messaging systems.

**What About Indoors?**

A siren is an outdoor warning system, but populations are most at risk during flash floods that occur in the evening when people are commonly indoors. While sirens may be audible indoors in some situations, integration with public messaging systems is critical to reaching people inside.

## Mass Notifications to the Public

The siren system must be integrated with public messaging systems, in order to reach as much of the potentially affected population as possible, and the operations plan must identify how the integration will be completed and who is responsible for sending public messages.

Common public notification systems include FEMA's Integrated Public Alert and Warning System/Wireless Emergency Alerts (IPAWS/WEA), alert platforms like CodeRED and Everbridge, Short Message Service (SMS), and public address (PA) systems at parks and campgrounds. See below for additional recommendations for public messaging:

- Include the basic information and actions to take in messaging (i.e., "when you hear the siren, go to high ground, and seek more information").
- Link the siren to IPAWS/WEA for simultaneous wireless emergency alerts to cell phones, radio, and television. See Appendix C for more information.
- Integrate local alert apps and SMS for additional reach.
- If feasible and warranted, link with park and camp PA systems for staff, campers, and visitors to hear audible alerts and detailed instructions.
- Include clear evacuation route instructions and safety measures.

# Integration with Evacuation Planning

Consider the steps below to integrate local evacuation planning with sirens so that alerts, notifications, and actions are well coordinated.

## Align Evacuation Zones with Activation Protocols

- Incorporate siren coverage areas in official flash flood evacuation zones and routes, and share this information with emergency managers and public safety officials.
- Define local criteria for siren activation that aligns with the flash flood risk thresholds and evacuation triggers in emergency plans.

## Pre-Script and Coordinate Evacuation Messages

- Create standardized flash flood siren tones and voice messages signaling mandatory evacuation, clear routes, and safe zones.
- Coordinate all messaging with command procedures used by emergency management, law enforcement, and fire and rescue teams.

## Automate and Synchronize Alerts Across Channels

- Link siren activation to mass notification platforms so that, upon activation, IPAWS/WEA alerts, SMS, emergency radio, and PA systems also broadcast instructions.
- Integrate each alert with map-based evacuation zones, giving recipients location-specific orders. Signage can be added in areas to show how and where to evacuate (see Section 7).

## Joint Agency Training and Exercises

- Schedule routine integrated drills, including monthly audible tests and full-scale evacuation drills, across fire, police, EMS, and public works departments.
- Use after-action reviews to refine siren and evacuation synchronization and messaging.

## Public Education and Outreach

- Launch “Know Your Zone” campaigns to teach residents how sirens relate to evacuation protocols and route maps.
- Provide outreach to special populations (e.g., schools, care facilities, campgrounds, tourists, etc.) so they recognize siren tones and understand evacuation steps.

## Real-Time Command and Traffic Coordination

- Set up command center dashboards that confirm siren and parallel alert activation, monitor evacuation route status, and direct traffic control staff in real time.
- Use mapping developed from evacuation zones, hazards, congestion, and changing flash flood conditions—usually developed in GIS—to direct evacuees.

# False Alarms

A false alarm is defined as siren activation without an actual or imminent flash flood threat, as verified by post-event analysis and review with emergency management officials. To reduce false alarms, it is recommended to use two triggers before siren activation—except in life-threatening or visually confirmed events.

Communities must include a false alarm mitigation policy as part of the siren operations plan. This helps maintain system reliability, minimize public confusion, and promote continuous improvement in emergency response operations. The sample false alarm policy below provides recommended considerations when creating or updating a false alarm mitigation policy.

## Sample False Alarm Mitigation Policy

**False Alarm Response**

- After each false alarm, conduct an incident review to assess
  - the cause (human error, equipment malfunction, detection error, or poorly defined threshold, etc.); and
  - the public impact (confusion, unnecessary evacuations, etc.).
- Promptly notify the public and involved agencies about the false activation, explaining reasons, corrective actions, and steps taken to prevent recurrence.

**Correction**

- For equipment-based false alarms, inspect and repair faulty units before restoring them to service.
- For procedural errors, conduct retraining and/or update policies.

**Escalating Actions for Repeat False Alarms**

- First incident: Public notice and review with system operators.
- Second incident within 12 months: Mandatory retraining for incident personnel and a technical audit of the siren system.
- Three or more incidents within 12 months: Temporary suspension of automatic activation, requiring manual double verification for subsequent activations, and additional public outreach likely needed.

**Continuous Improvement**

- Periodically review procedures and incorporate lessons learned into system protocols, threshold updates, training materials, and public education.

Pedernales Falls State Park during flood conditions

# INTEROPERABILITY

Interoperability is the ability of different communications systems and devices to exchange information or services directly with one another in a reliable and effective way. Interoperability in emergency communications is important because it directly affects how quickly and effectively responders can act during incidents, especially when multiple agencies are involved.  This strengthens public trust in emergency services and provides a more defensible record of decisions and communications for after-action review.

It is highly recommended that siren system information be readily accessible by adjacent communities, especially downstream communities, in standardized formats and methods. This exchange of information can be completed through standard operating procedures or Memorandums of Understanding.

The following recommendations should be considered:

- Using internet protocol-based interoperable systems.
- Gauge data should be interoperable with the siren control software to allow seamless monitoring by the siren control software and automated alerting, if desired.
- Consider how easily gauges and sirens can be monitored by an emergency operations center, local responders, emergency managers, etc.
- Coordinate internally and with stakeholders to make interoperability part of the system design and routine operations.

# TRAINING

The following suggestions can guide your community in proper staff training to build awareness and confidence, improve interagency coordination, and foster preparedness for a future flash flood event.

- As part of new staff onboarding, provide introductory training on flash floods, warning sirens, and the community's established procedures for implementing their siren system. Share the operations plan.
- Involve responsible staff in regular tabletop exercises, in coordination with emergency management leads, to practice siren activation scenarios and increase preparedness.
- Conduct refresher trainings and hold discussions about flash flooding with staff, at least annually, to review siren-related roles, notification and communication procedures, and public safety actions.

American Signal Corporation mechanical
Tempest 128 and Tempest 121 sirens

# 5 MAINTENANCE

Proper maintenance keeps sirens performing optimally. Siren vendors will provide system-specific maintenance schedules that communities must follow and document. Communities should develop a maintenance program that includes preventative and corrective maintenance of all system components. This also includes ensuring that gauges used for activating sirens are maintained and functioning.

**Requirement 5.1**

The siren must be inspected annually following vendor guidelines.

Inspection documentation must include, at a minimum,

- inspection findings and any corrective actions required,
- prior year maintenance records, and
- maintenance and inspection documentation for gauges used as activation triggers.

## Preventative Maintenance

Preventative maintenance refers to regularly inspecting siren components and taking actions to keep components from failing, such as lubricating moving parts. Visual inspections and testing should be performed after severe storms (e.g., high winds, hail, floods) that have the potential to damage siren components.

## Corrective Maintenance

Corrective maintenance is performed after a problem has been identified, such as replacement of a non-functioning radio. Corrective maintenance should be performed as quickly as possible, ideally within 72 hours, or sooner if a severe weather event like a flash flood is possible. Promptly address faults identified in any test or inspection—replace batteries, motors, power modules, or communications components as indicated—and re-test. Maintain and utilize spare parts inventory for rapid repairs, and document every corrective action.

# Sample Maintenance Plan

The following is a sample maintenance plan that could be modified to suit the needs of a specific siren system. Review vendor maintenance guidelines, system characteristics, and environmental conditions when developing a maintenance plan.

## Annually

- ☐ Perform comprehensive inspection (includes quarterly elements listed below).
- ☐ Review and update maintenance logs.
- ☐ Replace batteries nearing end of life.
- ☐ Validate siren coverage and acoustic output.
- ☐ Inspect rain and/or river gauges used to activate sirens.

## Quarterly

- ☐ Perform visual inspection of siren poles, mounts, and hardware.
- ☐ Clean siren housings and grills.
- ☐ Test mechanical and electrical components.
- ☐ Verify backup power systems.
- ☐ Confirm communications integrity.

## After a Flood

- ☐ Inspect siren for corrosion, sediment, and debris.
- ☐ Verify waterproof seals on control boxes and enclosures.
- ☐ Check gauge calibration and telemetry connectivity.
- ☐ Test siren activation and voice messaging.
- ☐ Log inspection results and corrective actions.

**Professional Oversight**

Having an annual inspection by an experienced technician can improve siren operations, potentially identifying problems before they become critical. Professional oversight can also help train local caretakers of the system.

Consider having a contract in place for emergency repairs by an experienced technician. The contract should include estimated costs for parts and labor and should specify the amount of time to complete the repair.

# Sample Maintenance Checklist

## Visual Inspection

Visual inspections can be performed quickly and are important to check the integrity of siren components. A visual inspection can be the first sign that there is, or will be, a potential problem that could prevent the siren from working as designed. Visual inspections should be performed during all maintenance and testing activities.

- [ ] Check overall siren and gauge structure, pole/tower integrity, mounting hardware, weatherproof enclosures, conduit, and anti-corrosion coatings. The visual inspection should look for loose hardware, cracks, peeling paint, dents, rust, corrosion, erosion or deposition near the structure, orientation of the structure (e.g. not tilting), etc.
- [ ] At gauges, make sure the sensors are securely installed, especially submersible sensors subject to high velocity, sediment, and debris impact. Inspect electrical cables, connections, conduit seals, and grounding system for weathering or vandalism. Look for frayed, broken, or abraded wiring, loose or corroded connections, dried out or cracked seals, etc.
- [ ] Look for signs of water intrusion in enclosures from rain or flooding. These can be high-water marks of fine debris or residual mineral rings from evaporation.
- [ ] Confirm antennas and communications hardware are securely in place with no visible damage. Inspect antenna cables for cuts, tampering, etc. Make sure directional style antennas are aimed appropriately and have not moved due to wind or vandalism.

## Cleaning

Cleaning debris and vegetation away from sirens can improve operations and prevent problems from occurring. Excessive dirt, vegetation, or debris on or around critical components can inhibit siren and gauge operation.

- [ ] Clean debris, dirt, bird nests, or other obstructions from siren housing, vents, and speaker grills using a soft cloth and non-abrasive cleaner.
- [ ] Remove plant growth or material near the siren base to maintain access and clear sound propagation. Trees within 100 feet of the siren should be removed or cut back to a height well below the siren’s elevation.
- [ ] At gauges, keep vegetation away from gauge housings and sensors, and clean sediment and debris out of sensor conduit and rain gauges.

## Mechanical and Electrical

Mechanical and electrical components need to be well maintained for the siren to function properly. Failure to maintain these critical components may prevent the siren from working when it is needed.

- [ ] Inspect and lubricate moving parts, such as bearings, gears, and belts.
- [ ] Test motors, amplifiers, relays, circuit boards, and fuse holders for proper function.
- [ ] Check for loose or corroded electrical connections and ensure all fuses and breakers are intact.
- [ ] At gauges, compare electronic gauge readings to reference gauges or surveyed water levels.

## Communications

Communications components include broadband connections, radios, modems, antennas, and cables. Maintaining reliable communication with sirens is paramount to effective and timely activation. If communications are degraded, the sirens may not activate.

- [ ] Verify communications connectivity through daily and monthly tests.
- [ ] Conduct radio frequency inspections including output, frequency and modulation, receiver sensitivity, and battery voltage during transmissions.

## Functionality

Testing the system is a key step in routine and corrective maintenance to prove that the siren system is operational and ready for activation.

- [ ] Perform testing as described in the Operations section.
- [ ] In addition, perform testing after corrective maintenance and after severe weather events to make sure the system is ready to respond to an emergency.

## Inspection and Repair Logging

To properly document and log routine inspections and repairs for sirens, use structured, standardized logs that include dates, responsible personnel, detailed findings, and actions taken. Good documentation supports regulatory compliance, warranty claims, and provides an audit trail when needed. Communities must follow vendor recommendations and document inspections, tests, repairs, and upgrades so that any changes to the sirens are recorded.

Consider a physical maintenance, inspection, and repair logbook or a digital system dedicated to siren operations. Include standard information illustrated in the example maintenance log below.

- Upon each scheduled inspection or maintenance, complete a log. Keep logs accessible for audits or incident investigations for at least three years (or as required by local and National Fire Protection Association 72 codes).
- Attach or link field checklists, calibration records, photographs, and test results as supporting documentation. Include detailed diagnoses and describe parts ordered or work not yet completed.
- After every repair, repeat critical tests and record results to confirm functionality.
- At least annually, review logs to identify recurring faults or maintenance needs and then update the maintenance plans.

## Sample Maintenance Log

| Field | Description |
|---|---|
| Date/Time | When inspection or repair was performed |
| Siren/Equipment ID | Unique identifier for each siren unit, such as serial number |
| Location | GPS or street address of siren |
| Inspector/Technician | Name or employee ID of person conducting work |
| Inspection Type | Routine, Annual, Special, Post-incident, Repair |
| Checklist/Tasks | Items inspected (visual, mechanical, electrical, communications, power, etc.). Refer to vendor forms. |
| Findings/Condition | Detailed notes, including any issues found |
| Repairs/Actions Taken | Description of repair work, parts replaced, adjustments made |
| Next Step/Follow-up | Further action needed, date for re-inspection |
| Signature/Verification | Confirmation by responsible person |

Guadalupe River at Gruene in New Braunfels, Texas

# 6 PUBLIC EDUCATION AND OUTREACH

**Public education** helps the community understand what sirens mean and what action(s) to take when they are activated.

**Public outreach** engages the community through campaigns, events, and materials to build awareness, participation, and compliance.

**Requirement 6.1**

Communities must conduct public education and outreach to inform populations served by sirens about the system's purpose, testing schedule, alert tones and/or voice messages, and actions to take if activated.

Texas Water Code § 16.501 defines a siren as a "system that produces a sound designed to alert a person who is outdoors of an imminent disaster and encourage them to seek shelter or move to higher ground."

Communities are required to conduct education and outreach around flash flood hazards and local siren system(s) to reduce confusion, strengthen confidence, and increase the likelihood that the public takes effective action when a siren is activated.

Public education and outreach efforts can also position communities for additional benefits, such as eligibility for FEMA's Community Rating System Activity 610 credit, grants, and other cost-saving measures, making public education and outreach a safety priority and a strategic investment. This section discusses best practices for public education and outreach to maximize the effectiveness of sirens.

# EDUCATION

When the public understands what a siren means and expects periodic tests, confusion during real emergencies is reduced. Use the recommendations below to guide planning for your community's siren education efforts.

- Announce audible tests and drills in advance, explain their purpose, and use them as teaching opportunities.
- Provide simple, accessible resources explaining siren meaning, actions to take (i.e., "move to higher ground immediately"), and where to get updates. Include maps of siren coverage, evacuation routes, and emergency contacts.
- Invite NWS to support community public education and outreach efforts to help the public understand NWS products.
- Integrate siren education into school safety protocols and training in alignment with annual safety weeks. Partner with youth programs for interactive activities like flood safety games or "Know Your Zone" mapping.
- Repeat messaging before and during flash flood and camping season, and partner with local media for amplification.
- Host or co-host workshops and/or town halls to demonstrate siren sounds, explain actions, and answer questions. Make sessions interactive with quizzes, mapping stations, or other similar activities. Always include where residents can find official updates (e.g., website, social media, alert apps, local radio, etc.) and how sirens integrate with other warning channels (e.g., text alerts, IPAWS/WEA, etc.).
- Collect feedback after events and drills for continuous improvement. Document lessons learned and update messaging to keep education effective and inclusive.

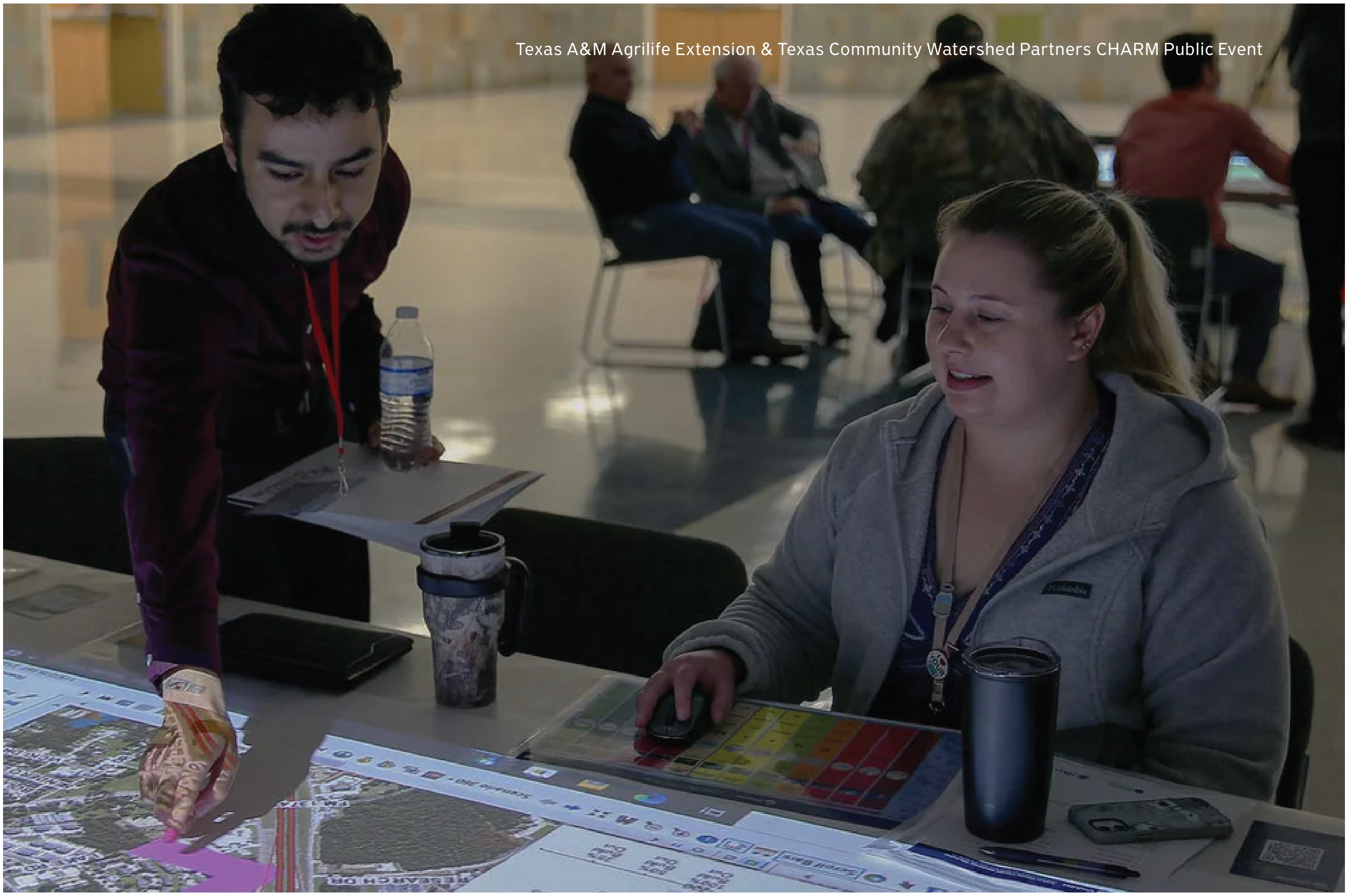
"Prior to the full-scale tonal exercise that we do in the spring and fall, we hand out fliers to businesses letting them know about the upcoming testing [and] reinforcing the protective actions they should take."

Alert Warning Program Manager for Howard County, Maryland

# OUTREACH

Community engagement creates opportunities for dialogue, trust-building, and hands-on learning. The following strategies outline practical ways to engage the community and integrate siren education into everyday activities.

- Partner with organizations that have trusted community relationships (e.g., neighborhood associations, faith-based groups, schools, youth programs, senior centers, disability advocates, civic clubs, universities, and local businesses) to share messages and materials.
- Use multiple channels, such as radio, TV, social media, official websites, newsletters, and seasonal mailers (e.g., utility bill inserts) to explain siren purpose and tones.
- Add booths, demonstrations, and Q&A sessions at existing community events, such as fairs, festivals, sporting events, and emergency management expos.
- Use signage and announcements at large gatherings and tourist locations. This might include parks, campgrounds, hotels, concert venues, festivals, and sporting events. Include reminders for safe travel after events.
- Provide accessible fliers, maps, and quick-reference cards in plain language, multiple languages, and ADA-compliant formats. Include captioned videos and visual aids for residents who are deaf or hearing impaired.
- Work with disability advocacy groups and organizations serving transient residents or those with limited access to technology to increase access and understanding.
- Post materials online for easy access and keep copies at publicly owned buildings (e.g., town halls, libraries, etc.). Provide handouts to realtors and title companies to distribute to new homeowners. Partner with universities to engage students.


Texas A&M Agrilife Extension & Texas Community Watershed Partners CHARM Public Event

# GATHERING FEEDBACK AND MEASURING SUCCESS

Public education is not complete without evaluating whether the message is understood and acted upon. Communities should establish simple, practical methods for gathering feedback after outreach activities, siren tests, and drills.

- Post-event surveys distributed online, through social media, or at community meetings can measure whether residents know what the siren means and what actions to take.
- Focus groups or informal discussions during town halls and seasonal preparedness fairs provide additional insight into public perceptions and areas for improvement.
- Consider tracking engagement metrics, such as attendance at workshops, participation in drills, and reach of social media campaigns to check effectiveness of their efforts.
- After-action reviews following real flood events or full-scale exercises should include an assessment of public response and identify gaps in communication.

# CASE STUDIES

# CITY OF SAN MARCOS, TEXAS

San Marcos has operated 14 sirens since 2011.

The City of San Marcos, Texas (the City), first installed an outdoor warning system with 14 sirens in 2011 through a FEMA grant. Due to a lack of maintenance, the sirens became inoperable and the City contracted with a vendor to repair and restore functionality to the system. The City spent around $110,000 on system-wide repairs and upgrades, and the system became fully operational again in August 2024.

## KEY LESSONS

- **Schedule regular maintenance to prevent issues and costly repairs**
- **Develop a detailed, explicit contract with the siren vendor**

The sirens are designed to notify the community of threats to public safety, including flooding, severe weather, and fire. The sirens are primarily located along the river and are automatically activated for flash floods when the National Weather Service issues a warning for the City. Automatic activation was important for the City as they believed a quicker response time without human intervention would lead to more saved lives. Their siren systems can also be manually activated as needed.

The siren system has three different tones, but the City's main message to residents is simple: if you hear any tone from a siren outside of the monthly testing window, "Get off the rivers, seek shelter, and use other means to find out what's going on." Additionally, residents and visitors receive mass notifications and early warnings, primarily using Everbridge and FEMA's Integrated Public Alert Warning System (IPAWS). The City conducted outreach to provide education on the IPAWS system and encourages the public to sign up for Everbridge. This information, coupled with the City's website, social media, and other disaster assistance organization outreach, allows people to respond to impending disasters.

The City stressed the importance of a reasonable, clear, and detailed contract between communities and siren vendors. The siren vendor should be willing to teach the client how to fix minor issues and provide other training on the system as needed. To keep the system fully functional, the City's contract with their vendor includes detailed language on vendor maintenance obligations. The City uses a siren maintenance process that rotates between light and heavy years of vendor staff inspecting the siren system equipment. If quick repairs are needed, the average repair time is less than 24 hours if the replacement part is available.

# COMAL COUNTY, TEXAS

## Comal County recently retrofitted and upgraded their siren system.

## KEY LESSONS

- **Be prepared to invest significant amounts of time and money to install and maintain any siren system**
- **Test different power sources to determine which works best in your situation**

Comal County, Texas (the County), is situated in the infamous “flash flood alley.” The County’s current flood warning system has been in place for over 10 years. Recently, the County invested approximately $2 million in updating the system, which was funded through the County’s budget. The funds covered updates for two systems: a low water warning system (consisting of sensors at low water crossings that can trigger flashing lights during flash flood conditions) and a high water warning system (consisting of sirens that are activated based on the water surface elevation and rate of rise data from sensors). Presently, the lights and sirens must be manually triggered by emergency management staff; however, County officials are working with the software vendor to add an automatic triggering capability.

Where feasible, the County integrated hardware from the old warning system as part of the upgrade. But the scope of the upgrades has resulted in a system that County officials are far more confident in. In a similar vein, County officials emphasized that there are less expensive alternatives for a high water warning system, but their experience was that utilizing a more expensive system is well worth the investment. The County has budgeted an additional $500,000 to expand the system in 2026. Annual maintenance costs for the system total $200,000, and the County has three employees dedicated to the operation and maintenance of these systems.

An issue the County sought to solve was connectivity with the high water warning system. The existing system’s cellular modems struggled to maintain a reliable connection. Due to repeatedly searching for and reconnecting to a cell signal, the power draw of the unit surpassed the recharge rate of the equipped solar panels, leading to the batteries being drained rather than recharged. This issue was addressed by switching the units to AC power and fiber as the primary power and communications sources, respectively. Solar power and cellular are now used as backups for their respective sources.

County officials emphasized that installing a siren system is not a quick process. Budgeting for the system (identifying costs, attending budget hearings, passing the budget, etc.) takes about one year. Once passed, receiving the required hardware could take an additional six to nine months depending on the number of sirens being constructed. On the software side, bigger issues can be resolved quickly, but smaller bugs can persist depending on the software vendor’s response time. In total, County officials estimate a reasonable timeframe for the implementation of a new siren system to be 18 to 24 months.

# GUADALUPE COUNTY, TEXAS

## Guadalupe County operates 27 sirens along the river for floods and tornadoes.

## KEY LESSONS

- **Use multiple channels to disseminate emergency information to the public**
- **Consider higher-quality siren parts for potential better long-term value**

Guadalupe County, Texas (the County), finished installing its initial 23 multi-hazard siren warning system during the late 2000s. In December 2025, the City of Seguin added four additional sirens, bringing the total to 27. Most sirens are strategically placed along the river, but some are located in densely populated areas as well. The sirens will automatically activate based on tornado and flood warnings from the National Weather Service. The sirens can also be manually activated by emergency management officials if needed.

The County's siren system currently uses one tone for all hazards and does not have voice messaging capabilities (although the County would like to upgrade the system to include voice messaging in the future). Once the sirens are activated, additional information is disseminated through various channels: reverse 911, FEMA's Integrated Public Alert & Warning System (IPAWS), Everbridge, radio, and social media. Even prior to a potential disaster, communications are sent out with important information and the line: "Go to your preferred media outlet to see information."

The County cooperates heavily with all its jurisdictions. The County operates an Emergency Operation Center (EOC) with the City of Seguin and can ask other municipalities to join if needed. Because most flooding occurs along the river, the County can activate its sirens first and then the affected city's sirens. The County's recent software upgrade also allows the City of Seguin to activate the County's sirens. County officials stressed the importance of constant communication with the municipalities and stated they intend to start implementing joint exercises in the near future.

County officials said the secret to the longevity of its current siren system is regular maintenance. The County makes sure to keep records of all data related to the system, including service records. The County budgets $60,000 each year for maintenance. Assuming no major issues are found, only around $20,000 of those funds are used (the excess rolls back into the general funds budget). They also spend $2,800 for the control software annual license.

A lesson learned from the County is to invest in better batteries. Previously, County officials bought less expensive batteries—the type that can be bought easily in an auto shop—but these would need to be replaced after two years. After investing in more durable batteries from a commercial vendor, batteries are now replaced every four to five years, which means the initial higher price of the batteries is offset by the lower replacement and maintenance costs. For major maintenance issues, the County's siren vendor can arrive at the site within 24 hours.

Similarly, the vendor responds quickly if any issues are noted during automated silent testing of the siren system, which occurs twice daily. Audible tests are run each Saturday at noon. The County has not received pushback from the public regarding the audible siren test. The opposite is actually true: the public often voices concerns when the sirens do not go off as planned. If there is a storm event during the planned testing window, the audible test is skipped for that week.

# BOULDER COUNTY, COLORADO

Boulder County sees public education and outreach as critical parts of a siren system.

## KEY LESSONS

- **Conduct regular team training on alert systems**
- **View flood response as a multi-jurisdictional concern**
- **Build expertise in flood-related data interpretation**
- **Perform ongoing public outreach and education before disasters**

Boulder County, Colorado (the County), implemented its original siren system more than 30 years ago, with coverage based on flood hazards identified at that time. Following the 2021 Marshall Fire, the County received a $1 million Department of Justice grant to replace aging sirens. The upgraded system features tone alerts and voice messaging, with improved technology that delivers much clearer voice instructions.

The siren system is manually activated through reports from first responders to 911 centers and is integrated across the County, covering all municipalities except one. Activation authority is documented in the County's Emergency Operations Plan, dispatch agreements, and 911 center standard operating procedures. There are also regular trainings on activation procedures.

Decisions to activate sirens are based on life safety considerations, not jurisdictional boundaries (though affected jurisdictions are notified). Before activating sirens for flood warnings, emergency management officials review multiple data sources, including gauge readings, hydrographs, radar, and other incoming information. County staff receive specialized training to interpret these data and are informally referred to as "para-meteorologists." This approach equips frontline personnel with the skills needed for informed, rapid decision-making, significantly reducing disaster alerting times.

When sirens are activated, Everbridge, a critical event management and mass notification platform, distributes warning messages. The County distinguishes between two types of imminent disaster messaging:

- Warning – Advises residents to consider options and prepare to move to safety.
- Order – Issued in cases of severe danger, with urgent instructions like "Move now."

While sirens play a key role in motivating flood response, the County emphasizes that they are only one tool in the toolbox. Public outreach is equally critical. Residents must understand how to respond to sirens and prepare for disasters. The County conducts extensive outreach, including

- a preparedness section on its website,
- community workshops,
- partnerships with underserved communities,
- collaboration with floodplain managers, and
- translation of materials into multiple languages.

# HOWARD COUNTY, MARYLAND

Sirens were chosen to maximize coverage in flood-prone areas.

## KEY LESSONS

- **Develop formal agreements on how others can activate sirens if sirens are placed in areas outside public land**
- **Communicate through targeted channels to maximize impact**
- **Use a local siren system vendor for quicker service**

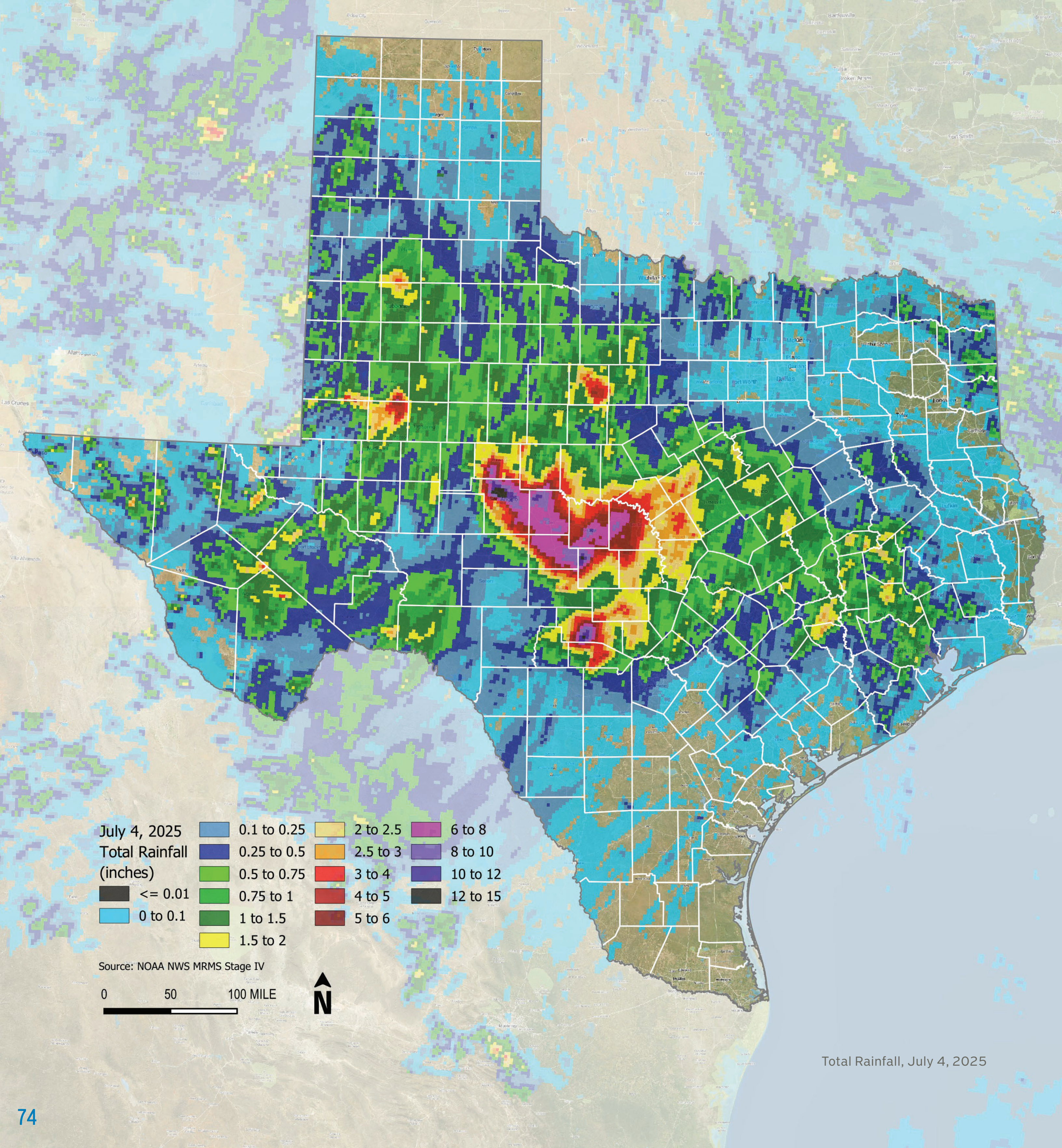
Howard County, Maryland, (the County) experienced catastrophic flash flooding in 2011, 2016, and 2018 that was concentrated in Historic Ellicott City (the City). Because Historic Ellicott City is a low-lying area located at the confluence of multiple bodies of water, the City is particularly susceptible to flash flooding with little to no warning time. The County implemented the Ellicott City Safe and Sound Plan (the Plan), an initiative designed to minimize flood risks in one of its most vulnerable areas. As part of the Plan, four sirens were placed in Downtown Historic Ellicott City. Each tower has a pole extending approximately 40-60 feet above the base with a speaker array on top. The units produce a very loud tone (rated at 120 decibels within a 100-foot radius) audibly warning individuals in outdoor spaces and strobe light attachments provide a visual warning. There are also two mobile trailer units plus one unit that can be assembled when needed. The County has spent over $500,000 on its siren system for a per unit cost of about $70,000 per siren.

The sirens were chosen to maximize coverage in flood-prone areas. All sirens were placed on public land owned by the County except one, which was placed in a housing development owned by the Howard County Housing Commission (a quasi-governmental agency). The County developed a Memorandum of Understanding with the Housing Commission that specified how the sirens can be operated.

The sirens are only used in response to flash flooding conditions. The units are automatically triggered by the National Weather Service (NWS) issuing a warning for the City, an area with its own unique NWS designation. The units can also be manually triggered by officials in the County. Before activating the sirens, Emergency Management officials look at gauge data, live camera footage of areas of concern, and other inputs. When the siren system is activated, residents and visitors are encouraged to seek higher ground immediately. Public outreach and education efforts focus on providing information to tourists in flood-prone commercial areas through local businesses, as well as connecting with the full-time residents of the City.

The County recently switched to a new local siren system vendor to add additional cloud-based redundancies and to reduce maintenance wait times. The siren vendor performs an annual check of the system, and the County checks the system daily through automated alerts. An alert is also sent to Emergency Management officials in the following situations: a tower is offline for more than 30 seconds, a console disconnects for more than 10 minutes, or a door in the system opens. An audible test is conducted on the second Thursday of each month, and Emergency Management officials also conduct semi-annual full-scale exercises with the system. The batteries for the system are replaced every two years on a staggered schedule.

# APPENDICES




Total Rainfall, July 4, 2025

# APPENDIX A

# REQUIREMENTS

Communities impacted by SB 3 are not eligible for financial assistance from the TWDB, other than funding for sirens, until they comply with the requirements in this guide (Texas Water Code § 16.502(j)) as summarized below.

| Planning | | Page |
|---|---|---|
| 2.1 | Communities must identify a primary and backup administrator responsible for their siren system with full oversight and awareness of the system and associated activities. | 13 |
| 2.2 | Joint siren operations between municipalities, counties, and/or other government agencies must include a signed and/or adopted Memorandum of Understanding or similar written agreement with documented roles and responsibilities. | 13 |

## Installation

| | | Page |
|---|---|---|
| **3.1** | Communities must follow and document a process for siren site selection. | 22 |
| **3.2** | Sirens must produce an audible alert of no more than 130 dB(C) at a distance of 100 feet from the siren. The siren's coverage area is defined as the area in which the audible alert is at least 70 dB. | 32 |
| **3.3** | Sirens must have the following:<br>• Both local and remote manual overrides for triggering the siren.<br>• A primary power source capable of operating the siren continuously and reliably.<br>• A backup power source different than the primary power source that is sufficient to operate the siren as designed in the absence of the primary power source (as detailed further below).<br>• Automatic transition between primary and backup power in the event of failure.<br>The backup power source must provide sufficient power for:<br>• 24 hours of standby.<br>  ◦ "Standby" refers to the operational state where the system is waiting for a trigger signal and is capable of alert when a trigger signal is received.<br>• 30 minutes of alerting.<br>  ◦ This requirement has been modified from the FEMA standard of 15 minutes to provide for a series of 10, three-minute audible alerts.<br>Batteries used for power supply must:<br>• Be automatically and fully recharged to at least 80 percent of maximum rated capacity from the fully discharged state in 24 hours or less.<br>• Be a low-maintenance design with a vendor-specified lifespan of at least five years. Note that this value has been modified from the FEMA standard of three ears based on industry experience and advancements in battery technology. | 35 |
| **3.4** | Sirens must have a backup communications method that is sufficient to operate the siren as designed in the absence of the primary communication method.<br>The siren must provide automatic transition between primary and backup communication methods in the event of failure. | 39 |
| **3.5** | When used as a siren activation trigger, gauges must use at least one form of telemetry capable of transmitting data to a central location at a minimum of every 15 minutes. | 40 |
| **3.6** | Sirens must be tested immediately after installation and the results must be documented. | 42 |
| **3.7** | Sirens must include at least one stream gauge as an activation trigger. One gauge may serve as a trigger for multiple sirens. | 42 |
| **3.8** | All siren electronic components must be elevated to or above the 500-year, 24-hour maximum water surface elevation. | 43 |

## Operations

**Page**

**4.1** An operations plan must be assessed annually and include, at minimum, — 45

- roles and responsibilities, including who is responsible for authorizing activation;
- detection protocols (i.e., trigger(s), threshold(s), etc.);
- activation protocols (i.e., how and when a siren is activated);
- notification protocols for officials, emergency managers, and the general public;
- testing protocols; and
- a false alarm policy.

**4.2** Sirens must be tested daily using silent tests and monthly using audible activation to verify sirens are receiving communications and are operational. Primary and backup systems must be tested. The monthly audible activation can be cancelled if severe weather is present or forecasted. All tests must be conducted on a fixed, documented schedule, and test results must be documented. — 47

If a test fails, corrective action(s) must be initiated within 72 hours and retesting performed after corrective action(s) are completed. Corrective action(s) and retesting must be documented.

**4.3** A siren must produce clear, audible alert tone(s) with a minimum activation duration of three minutes per alert repeated at regular intervals. — 51

**4.4** The siren system must be integrated with public messaging systems. — 52

## Maintenance Requirements

**5.1** The siren must be inspected annually following vendor guidelines. Inspection documentation must include, at a minimum, — 58

- inspection findings and any corrective actions required,
- prior year maintenance records, and
- maintenance and inspection documentation for gauges used as activation triggers.

## Public Education and Outreach Requirements

**6.1** Communities must conduct public education and outreach to inform populations served by sirens about the system’s purpose, testing schedule, alert tones and/or voice messages, and actions to take if activated. — 64

# APPENDIX B

# SAMPLE SIREN MEMORANDUM OF UNDERSTANDING

The following is a sample outline of the components that belong in a Memorandum of Understanding formalizing interagency cooperation in implementing and operating a siren system. Roles, responsibilities, coordinated protocols, schedules, and official signatures are important elements of an MOU.

## Title:

Memorandum of Understanding for Flash Flood Warning Siren System Operation

## Purpose:

To establish collaborative protocols for operation, maintenance, and emergency activation of the outdoor warning siren system in the region.

## Parties:

This agreement is entered into between [Agency/Authority 1], [Agency/Authority 2], and [Other Cooperating Agencies] (hereafter "the Parties").

## Objectives:

- Coordinate activation and operation of flood sirens during emergencies.
- Share real-time flood data, alerts, and sensor information.
- Facilitate joint maintenance schedules and cost sharing.
- Define communications protocols before, during, and after siren activation.

## Roles and Responsibilities

- Clearly list each agency's duty (activation, monitoring, maintenance, and public information).
- Specify the responsible agency and designated backup for siren activation.

*(sample siren Memorandum of Understanding continued)*

## Activation Protocols

- Establish criteria and approval chains for activating sirens, and leveraging joint hazard assessment and real-time weather and sensor data.
- Document when and how parties are notified prior to, during, and/or after siren activation.

## Data/Information Sharing

- Agree to share sensor, weather, and public alert data in real time or near real time across agencies.
- Set up secure data exchange channels as needed.

## Maintenance and Testing

- Establish joint schedules for system testing, siren maintenance, and drills.
- Allocate responsibility and budget for ongoing maintenance.

## Funding and Cost Sharing

- Agree upon a cost-sharing formula for installation, operation, repairs, and upgrades.

## Public Education and Outreach

- Coordinate the messaging for alerts and public education, ensuring clear, unified instructions.

## Review and Amendment

- Schedule regular review meetings and specify how amendments to the MOU will be handled.

## Duration and Termination

- Define the effective period of the agreement and process for renewal or termination.

## Signatures

- Authorized representatives of each participating agency sign and date the agreement.

# APPENDIX C
# Integration with IPAWS

The Integrated Public Alert and Warning System (IPAWS) is a national alerting system managed by FEMA. Its purpose is to ensure that official emergency messages—such as warnings about severe weather, natural disasters, or public safety threats—reach the public quickly and reliably. It works as follows:

- Wireless Emergency Alerts (WEA): Short, authenticated alerts to mobile phones.
- Emergency Alert System (EAS): Broadcasted alerts over radio and television.
- NOAA Weather Radio: Alerts through the National Weather Service's radio network.

IPAWS is the central system that connects agencies to multiple communications channels to warn people during emergencies. Additional information can be found on FEMA's IPAWS website. The following is the general process for integrating siren operations with IPAWS.

## Establish Alerting Authority and Permissions

- Confirm your agency is eligible and recognized as an "Alerting Authority."
- Contact your state IPAWS Point of Contact (POC) to review local alerting policies and requirements.

## Complete IPAWS Training and Compliance

- Ensure key staff complete FEMA's Emergency Management Institute (EMI) Independent Study course, IS-247 IPAWS for Alert Originators.
- Once staff have completed the course, submit training certificates to the IPAWS Program Management Office at ipaws@fema.dhs.gov.

## Select IPAWS-Compatible Mass Notification Software

- Confirm with your potential or current software provider that they can meet your public alerting needs.
  - More information is found on this website: www.fema.gov/emergency-managers/practitioners/integrated-public-alert-warning-system/technology-developers/alert-origination-software-providers
  - Ensure your siren controller and mass notification platform can send and receive Common Alerting Protocol formatted messages.

## Apply for Memorandum of Agreement with FEMA

- Request the Memoradum of Agreement (MOA) application from the IPAWS office. Complete the application and return via email.
- You will receive an email from the IPAWS office containing your MOA for signature, public alerting application, identification number, name, and additional instructions. Sign and return the MOA to the IPAWS office.
- Your MOA will be reviewed and signed by FEMA authorizing officials and returned to you. You will receive your digital certificate and a separate email with the password. Contact your Alert Origination Software Provider to load your digital certificate and credentials into your alert origination software.

*(integration with IPAWS continued)*

After completing the steps on the prior page, your organization should be able to exchange messages with other agencies but is not yet able to alert the public via IPAWS. The following steps will allow public alerting to be implemented. These steps can be completed concurrently with the application.

## Apply for Public Alerting Permission

- Complete and submit the public alerting application to your designated state official (the IPAWS office will provide contact information).
- Once your state contact returns the signed public alerting application, send it to the IPAWS office. (Some state officials will send the application directly to IPAWS. Check with your state Point of Contact for guidance.)
- Complete the EMI independent study course IS-251, IPAWS for Alerting Administrators.
- Submit your certificate of completion to the IPAWS office.

## Integrate Siren Activation and Alert Workflow

- Configure your system so an authorized flash flood alert triggers both siren activation and sends a CAP-IPAWS alert to FEMA.
- Enable geotargeting, allowing alerts to be sent via WEA and EAS only in affected zones.
- Link common endpoints (e.g., sirens, IPAWS, radio/TV stations, local PA systems) to the same alert procedure.

## Test and Validate Integration

- Conduct end-to-end tests of siren and IPAWS synchronized activation using the IPAWS "Demo" environment.
- Document successful message transmission to IPAWS-OPEN for EAS, WEA, and NWS weather radios.
- Coordinate with FEMA, state, and local partners for system validation and address any issues before live deployment.

## Operational Procedures and Continuous Improvement

- Define and train staff on workflows for simultaneous siren and IPAWS alerts during real flash flood emergencies.
- Schedule routine coordinated IPAWS tests in parallel with siren tests and update protocols as needed.
- Maintain compliance documentation and software certificates.

# APPENDIX D

# Sample Incident Command Checklist for Siren Operations and Emergency Operations Center Coordination

The following is a sample incident command checklist for coordinating between siren operations and an Emergency Operations Center (EOC) during a flash flood emergency. Consider additional checklist items based on your siren system and community characteristics.

## Siren Activation Planning

- Review EOC evacuation zones, trigger points, and incident action plan for siren activation criteria.
- Pre-script siren signals and voice messages coordinated with EOC messaging to parallel channels (IPAWS/WEA, PA, and text alerts).

## Communications and Notification

- Establish and test direct communications link (radio, phone, and digital dashboard) between siren operations and the EOC.
- Ensure mutual access to real-time incident status updates and system health information that can be provided through internet protocol-based interoperable systems, web-based crisis management platforms, briefings, etc.

*(sample checklist for EOC integration)*

## Activation and Initial Coordination

- Receive incident notification or flash flood risk assessment from the EOC or field command.
- Confirm personnel serving as the incident commander, EOC director, and siren lead, including contact information, for the flash flood event.
- Participate in the initial EOC/incident command system briefing; clarify objectives, zones, and expected siren operations.

## Authorization and Logging

- Receive formal EOC authorization/approval for siren activation, including documented time, method, and area.
- Log all communications, activation steps, warnings issued, and EOC instructions for post-incident review.

## System Testing and Monitoring

- Confirm technical readiness (audible/silent tests) before activation; troubleshoot as needed.
- Monitor and report back to the EOC on siren status during and after activation, including malfunctions or coverage issues.

## Incident Operations

- Activate sirens as directed, matching the EOC evacuation strategy and public safety messages.
- Work with field units (police, fire, and public works) via the EOC to verify evacuation coordination and community awareness.
- Remain available for follow-up activations, adjustments, or additional alerts if required.

## Demobilization and Debrief

- Deactivate sirens per EOC instructions and incident closure guidelines.
- Attend after-action review/debrief with the EOC and partner agencies.
- Submit all siren logs and reports to the EOC for incident recording and archiving, as well as to support continuous improvement efforts.

# APPENDIX E

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South Fork of the Guadalupe River after the July 4, 2025, flash floods

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