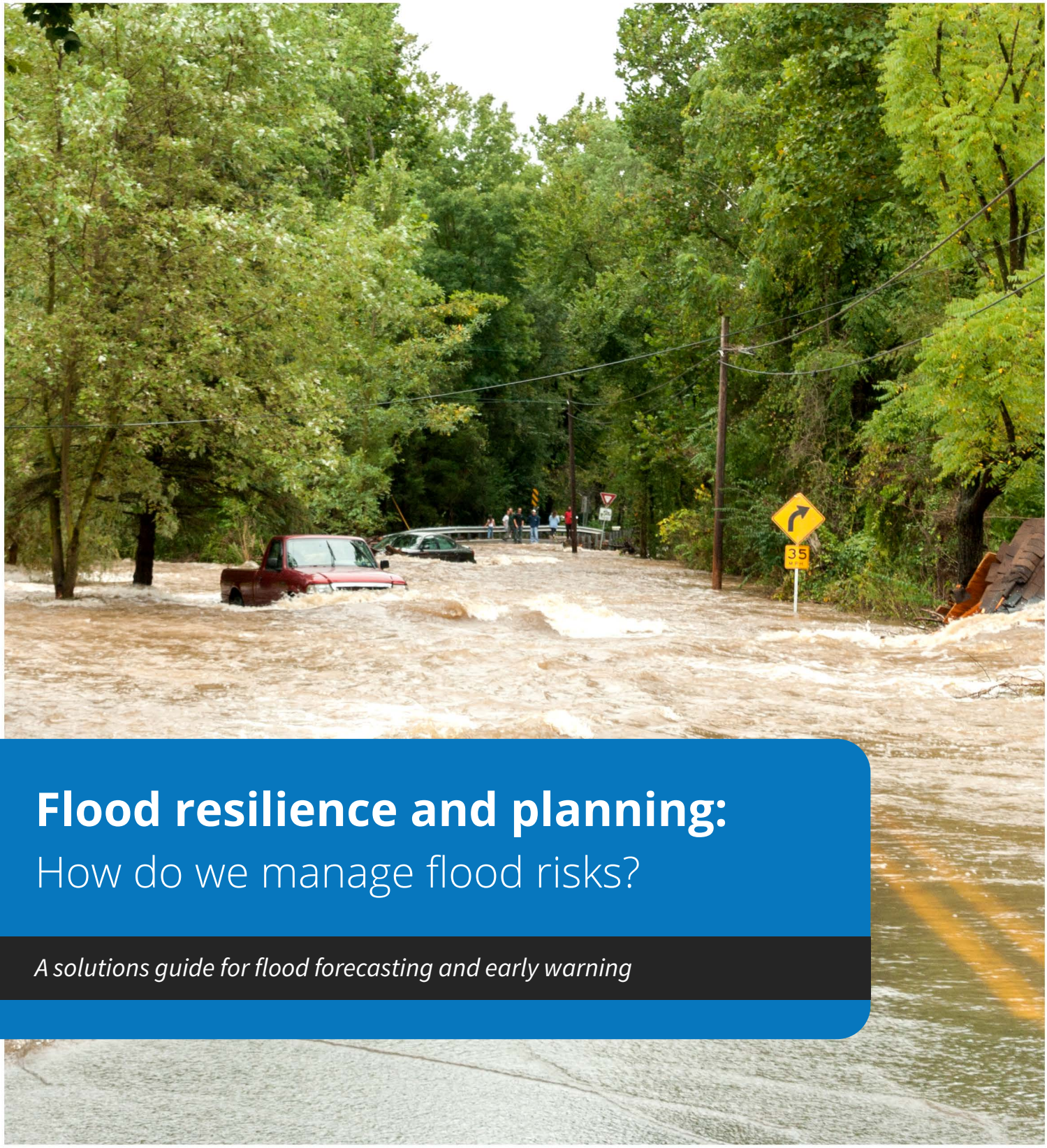

Flood resilience and planning:
How do we manage flood risks?

A solutions guide for flood forecasting and early warning

OneRain
The Rainfall Company

AEM ADVANCED ENVIRONMENTAL MONITORING

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What is a flood and what causes it?

A flood is defined as an overflow of a large amount of water that submerges a normally dry area of land.

Flooding is the most common and widespread of all weather-related natural disasters and is a threat in every part of the world primarily where rainfall occurs. While some floods are seasonal and predictable (large snowmelt, for example), others, like flash floods, can occur very suddenly. Over two billion people worldwide were affected by floods from 1998-2017, and around 20% of the total world population is at risk for at least a moderate flooding event (WHO). The intensity and frequency of flooding is increasing in many places due to human development as well as climate change, resulting in higher exposure to populations already at risk of devastating floods (World Bank). According to the flood professionals, flooding happens somewhere in the world nearly every day, and at any time of year.

There are three main kinds of floods: flash floods, river floods, and coastal floods.

Flash flooding, one of the most destructive and dangerous types of flooding, is caused when an excessive and rapid rainfall event occurs that causes water levels to rise very quickly.

River flooding is caused by either intense or prolonged rainfall or rapid heavy snowmelt that increases water levels in rivers, which then overflow.

Coastal flooding is caused by either an abnormal rise in seawater level above the tidal level in a storm surge, or during a tsunami event when water comes rushing in from the sea.

1.5 Billion

People at risk from flooding globally

Projected to grow to 2 billion by 2050[1]

$40 Billion

In damages globally

Resulting in lack of power and clean water for millions of people[2]

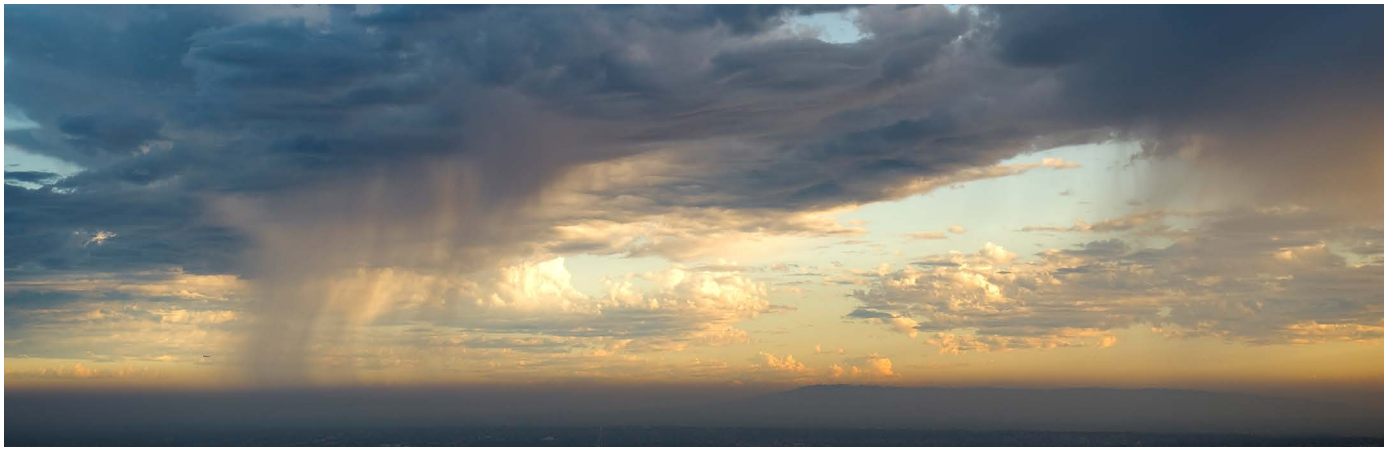
99%

U.S. counties have been impacted by a flood event over the last 25 years[3]

[1] World Bank

[2] Organization for Economic Cooperation & Development

[3] Federal Emergency Management Agency - (FEMA)



The Influence of Climate Change and the Behavior of Rainfall

Climate change has affected the current and expected behavior of rainfall. The actual effects depend on where in the world we are. Which hemisphere we're in, whether we're more polar, temperate or equatorial, coastal or inland, at higher or lower elevations, most places in the world are seeing very significant changes in rainfall. Storms are becoming more or less frequent, are tending globally toward larger annual accumulation, showing higher peak intensities and shorter durations. According to a newly released report by the Intergovernmental Panel on Climate Change, the severity and frequency of both high precipitation events, and dry extremes will continue to increase as the earth warms due to human-induced climate change. This is happening because the water cycle is intensifying.

What is the Water Cycle?

The water cycle is the process by which water moves through the environment from the atmosphere to the ground and back via precipitation and evaporation. The water cycle includes precipitation from storms, but also transpiration from plants, runoff, ground water, and condensation from water vapor in the air. One significant impact from climate change on the water cycle is that warmer temperatures raise the limit on the amount of moisture in the air, which can result in more rain.

In addition, as temperatures rise, glacier and snowpack melting will be earlier and faster, resulting in rising sea levels, erosion, and flooding in coastal and low-lying areas.

All this means that being prepared for potential water-related hazards is not only smart, but crucial for communities in order to protect lives and safeguard property and infrastructure.

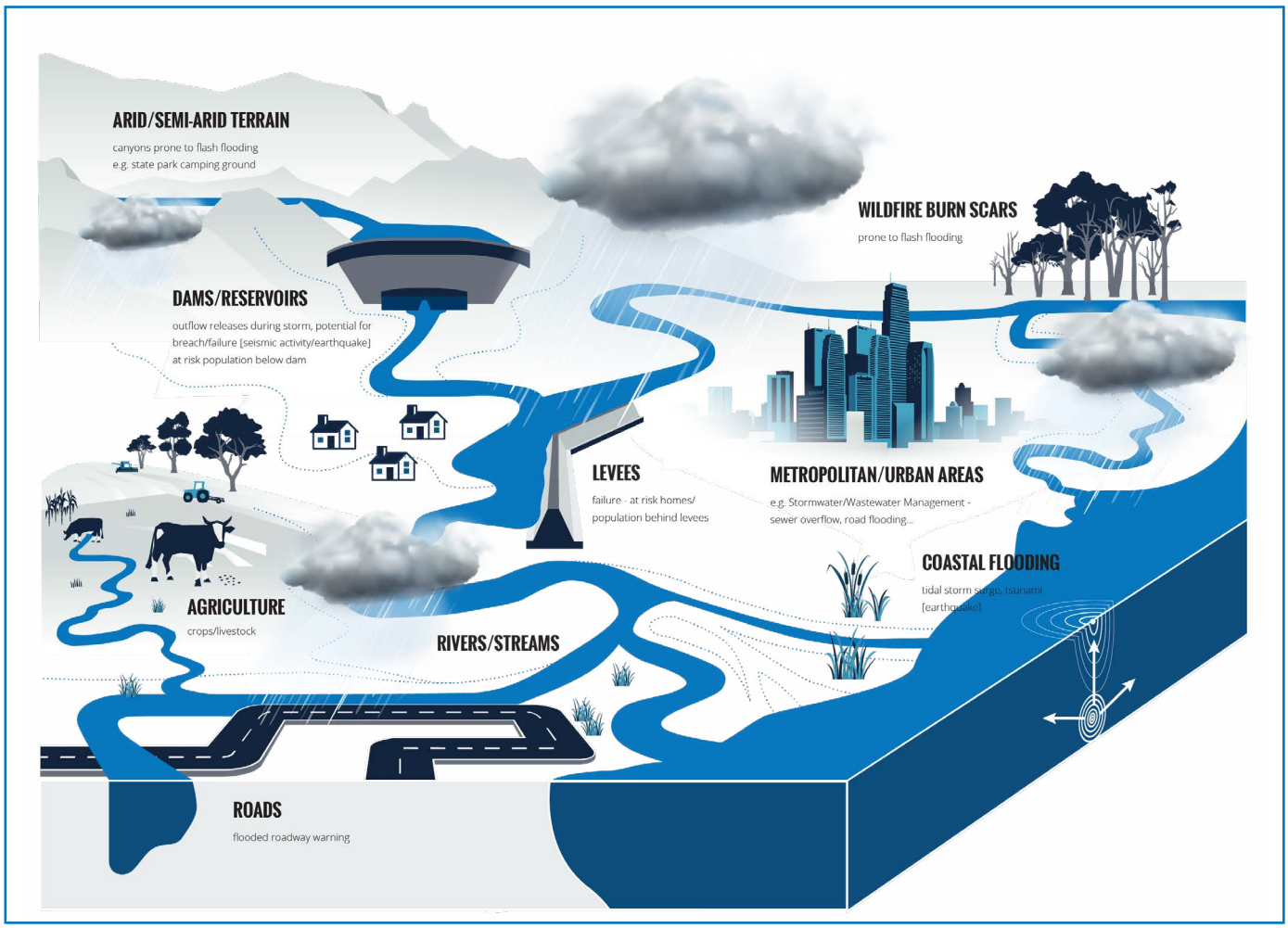
In 2021 the number of flood related fatalities in the U.S. has already more than doubled compared to 2020.

U.S. Flood Fatalities 2010 – 2021

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021 YTD
Flood Deaths	104	113	29	82	41	189	127	180	84	93	59	142

Source: https://www.weather.gov/arx/usflood

Social and economic impacts of flooding



What are the social and economic impacts of flooding?

- Loss of human life
- Social disruption
- Damage to property and infrastructure
- Health and sanitary consequences
- Agricultural losses of crops and livestock
- Business interruption and continuity

What causes flooding?

The impact of flooding is directly related to the rate, duration, and amount of rainfall occurring over an area and the physical landscape conditions on the ground. The speed and duration of flooding can vary significantly. Some flooding can occur slowly as rain continues to fall for several days and saturates the ground. Other flooding, like flash flooding, occurs more rapidly, often developing within hours or days of the causative event (e.g., intense rainfall, snow or ice dam in a river or stream, levee failure, dam/reservoir releases or breach). Some of the highest risks for flooding include both natural and man-made ground conditions that can cause an increase in surface water run-off and rising water levels.

Certain geography and ground characteristics increase the likelihood of flooding:

- Steep terrains
- Impermeable rock (water cannot flow through it)
- Very wet, saturated soils
- Compacted, arid/semi-arid soils
- Increased urbanization and impermeable surfaces
- Deforestation and increased erosion

Flooding can also occur for other reasons:

Wildfire hydrophobic burn scars

Overtopping, releases, or breaches of water containment dams and reservoirs, or failure of protective levees

Urban drainage and sewer overflow

Earthquake-triggered landslides, or storm surges and tsunamis in coastal regions

The destruction due to flooding has been greatly increasing over the years.

Flooding events can greatly impact important infrastructure, especially if this infrastructure is outdated, making it more vulnerable to severe weather. Infrastructure most impacted by floods include roads, dams, pipes, and drainage systems.

Poorly planned drainage systems in urban areas can create flooding problems. Rainfall runoff and flooding creates challenges to stormwater management, especially in low-lying and flat coastal areas. Water may backflow into the drainage and system, causing longer flooding events and damage to stormwater and wastewater systems.

Managing and reducing the risk of floods to communities

Flood risk is often underestimated and the investment in flood resilience disproportionate or inadequate. With more people in the world at risk today from flooding than ever before, being prepared for floods is crucial to decrease negative effects of flooding in our communities.

What's the answer?

- Better urban infrastructure planning and design
- Rehabilitation and strengthening of existing infrastructure
- Improved flood prediction and forecasting
- Advanced severe weather and flood warning systems
- Real-time monitoring and operation controls (dams, sewer systems)
- Flood preparedness: Communication, Emergency Action Plans and Evacuation Procedures

Flood Planning and Risk Analysis

Great advancements have been made in technologies, tools, and services that help reduce the impact of flooding to create safer environments and reduce flood risks. Flood forecasting relies heavily on the tracking of storms and real-time data about rainfall and water levels in streams, rivers, and lakes. But historical storm data combined with real-time data can help predict how extensive the flooding might be with hydrologic modeling and inundation mapping.

Assessment of Flood Risks

Assessment of flood risks is an integral component for flood planning. To begin your flood planning, a flood risk analysis should be completed, evaluating the risk of flooding and the vulnerability of the specific area. Things that need to be taken into consideration are topography, infrastructure, climate, frequency of storms over an area, and more. Flooding can come from groundwater, surface water, rivers, or the ocean. Being aware of the potential sources that could cause flooding and its potential inundation is necessary for improved infrastructure design as well as the design and implementation of a flood early warning system. Take into consideration what the consequences of the flood would be and the impact on surrounding communities.

"What if" Scenarios and Hydrologic Prediction

Creating hydrologic models can help determine flood risk. Data is collected and stored from radar and rain gauges to provide modeling of the watershed processes that would occur in a flooding event. "What if" scenarios can be tested and analyzed. This can help identify the high-risk areas that need to be modified or reinforced to help protect people and infrastructure from a flood. Past storm analysis with historical data from radar and rain gauges can also be used to better predict flooding events based on rainfall rates. Real-time data collection and interactive visualization provide the information needed to predict possible flooding events based on previous circumstances. This can create more advanced warning time for surrounding communities when dangerous flooding conditions present themselves.

Flood Early Warning Systems

Designing a flood warning solution network involves identifying problem areas where flooding may occur more often than others. The placing of sensing instruments, like rain gauges, water level sensors, and flow rate sensors involves understanding the terrain, planning out density of coverage and accessibility while ensuring that the data from the combination of sensors will reliably communicate potential flooding conditions in a timely manner. Along with accurate and well-maintained sensing instruments, a flood warning solution should include reliable and robust communications systems and a central base station.

Communications and Threat Response

Most importantly of all, flood warnings need to be sent to the communities in threatened areas and a prepared plan of action needs to be in place. Locally owned and operated automated flood warning gauge networks help save lives and reduce property damage by providing critical, real-time information to the National Weather Service and public officials at all levels of state and local government to issue alerts warning people who are vulnerable to flooding. With help from real-time and historical flood data and prediction, flood warnings can be communicated in advance, giving more time for communities to prepare.

Technologies and services that support reducing flooding risks

Today, an array of sophisticated technologies, systems, software, methods, and tools is available to us that provide a better understanding of rainfall and hydrology, flood frequency and magnitude, and the associated flood risks. Through flood risk analysis (identifying risk factors, landscape, infrastructure, climate, frequency of storms over an area), we can better prepare, design, and plan for flooding events, improve resiliency, and employ technologies that help protect lives and property.

Mitigation

Historical radar rainfall, rain gauge and stream data, StormProperties™ Analysis, and realistic Design Storms

Planning

FEWS Network design and maintenance, Modeling, Emergency Action Plan Development

Prediction

Real-Time Flood Forecasts and Modeling with 24/7 Meteorological Services

Detection

Flood Early Warning Systems (FEWS), Remote Erosion Monitoring Systems (REMS), Radar Rainfall Estimates

Response Management

Public Awareness, Public Warning Systems, EAP alarming,

Areas of Flood Vulnerability

1. **At-risk Communities: State and Local Governments**
2. **Dam & Reservoir Operations**
3. **Levees and Water Containment Embankments**
4. **Post Wildfire Burn Scars**
5. **Urban Structural Design and Land-use Planning**
6. **Coastal Areas**
7. **Stormwater & Wastewater Operations**

1. At-risk Communities: State and Local Governments

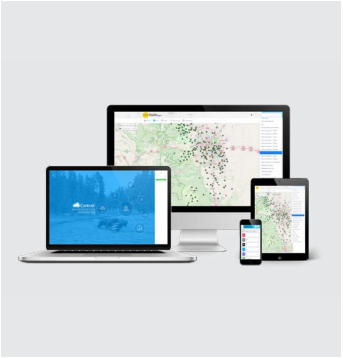
Overview

At-risk communities are considered any development in a flood plain that can be impacted by fast rising flood waters. Impacts include loss of life to destruction of property located within the flood plain. As extreme rainfall events continue to rise in frequency, agencies need to be able to prepare, forecast, and detect flooding events.

Risk Mitigation Solutions

Flood Early Warning System includes hydrological, meteorological, and other environmental sensors, communications, and infrastructure, to receive data as quickly and as reliably as possible, regardless of Internet and power state

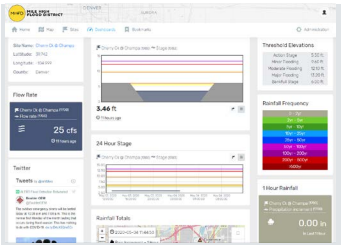
- Complete turnkey solutions or individual components
- **Sensors:** Rain, water level, stage, float switches, stream flow, and full weather station sensors
- **Telemetry solutions:** satellite, radio frequency, cellular, IP, etc.
- Infrastructure, design services, and station hardware



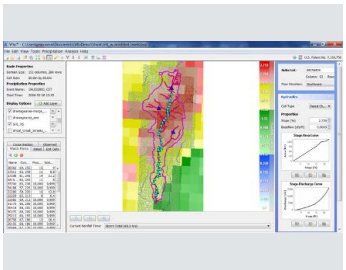
Enterprise Software for 24x7 real-time data collection and processing, decision support, information dissemination and alerting with a public website

Remote Cameras and image collection software to verify flooding conditions and provide additional situational awareness

Driver Warning Systems warn motorists via flashers and/or barrier gates of flooded roadways to eliminate the need for swift water rescues



Hydrologic Modeling and Real-Time Flood Forecasting provide advanced lead time to flooding conditions and indicate which areas might be impacted with flood inundation mapping and modeling



Historical Storm Data and Hydrologic Modeling give engineers and floodplain managers the information to make the correct design decisions and floodplain management

Benefits

- Locally relevant sensors reliably inform real-time flood risk decisions regardless of public infrastructure
- Advanced warning and alerting for agency officials, first responders, and the public
- Situational awareness for proactive response and operational decisions
- Community awareness and education of flood risks reduces rescues and assets

2. Dam & Reservoir Operations

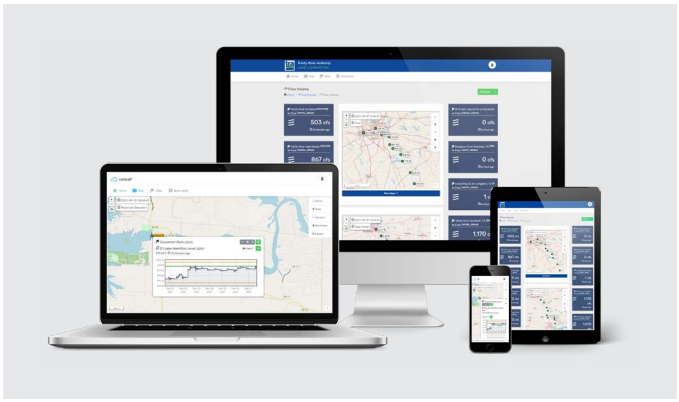
Overview

Dams and reservoirs are human-designed water containment structures that serve many functions including flood control, recreation, water supply, and power generation. Dams create risks—faulty design, poor construction, inadequate maintenance, or advancing age without rehabilitation, can make dams susceptible to failure as they may not function as safely as they should. Flood frequency is an important factor in the risk from overtopping and dam failure. 34% of dam failures in U.S. are attributed to overtopping, according to the Association of State Dam Safety Officials. With more and more development and population growth occurring downstream from dams, there is increasing concerns about dam safety.

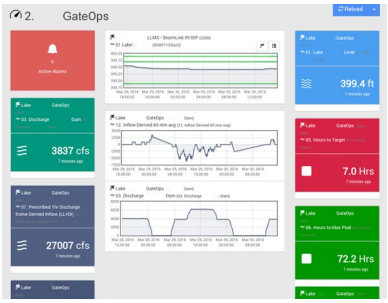
Risk Mitigation Solutions

Dam Early Warning Systems are real-time and redundant monitoring systems with multiple delivery and alerting mechanisms to give advanced warning of potentially hazardous conditions

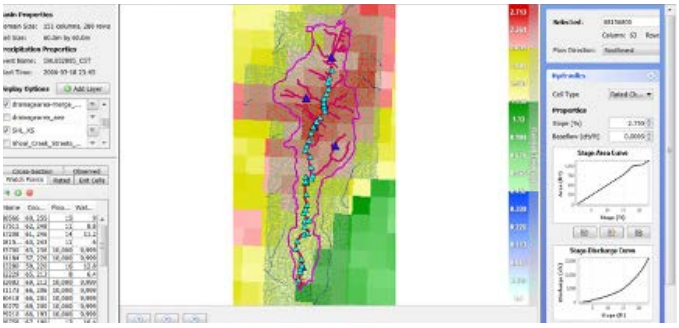
- Complete turnkey solutions or individual components
- **Sensors:** Rain, water level, stage, float switches, stream flow, and full weather station sensors
- **Telemetry solutions:** satellite, radio frequency, cellular, IP, etc.
- Infrastructure, design services, and station hardware
- **Remote cameras** to verify dam status and impacts
- **Sirens** to mass notify downstream communities



Dam Safety Enterprise Software enables operators to see all of the potential impacts, include river flooding, downstream releases, upstream rainfall data, earthquake/seismic data, and wind-loading data. Smart alarming and advance warning notifications with EAP (emergency action plan) information assists in the threat response



Dam Operations Support Tools and Services - Real-time Forecast and Reservoir Operations tools give operators a guide to follow during rainfall events by automatically tracking of actual and forecasted inflow/outflow, reservoir storage volume, water levels, gate positions with gate operation and discharge guidance



Software Models and **Rainfall Data** give engineering firms information to prepare and design for the worst-case scenarios

Benefits

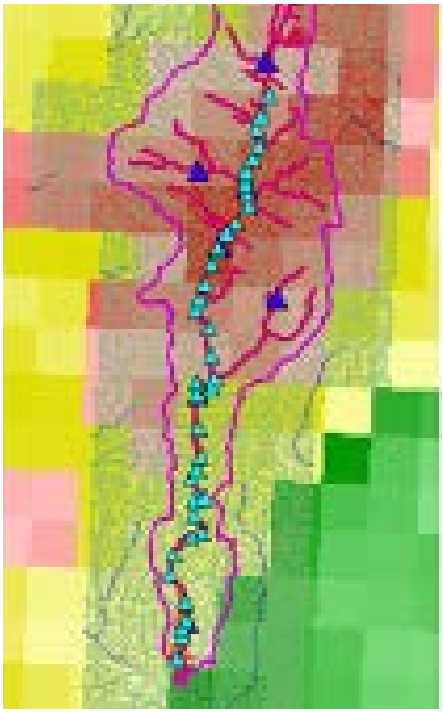
- Situational awareness for proactive response and operational decisions for inflow/outflow and gate operations management
- Early Warning Systems help increase warning times during flooding events
- Forecasted data help anticipate inflow ahead of the rainfall observations
- Real-time notifications of seismic activity can alert personnel to conduct inspections for potential infrastructure stress

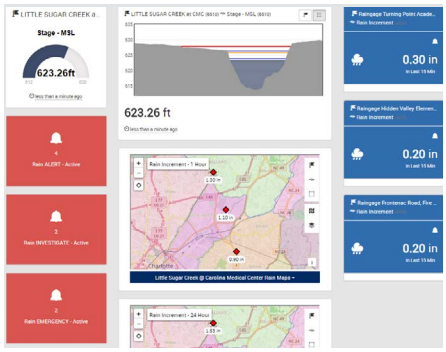
3. Levees and Water Containment Embankments

Overview

Levees, designed to protect communities against flooding, can be particularly vulnerable during intense storm events. Heavy rainfall can put levees at risk of overtopping and the consequences can be catastrophic. Additionally, deterioration and failure due to erosion is of particular concern for communities living near or behind a levee. During high water events, erosion can take place at or below the water surface. Even if a levee is being patrolled during an event, unseen erosion can be threatening the levee's structural integrity.

Risk Mitigation Solutions





Hydromet Monitoring Systems combine real-time rainfall and water level monitoring at vulnerable locations to detect and alert for potential overtopping

Remote Erosion Monitoring Systems automatically warn and alert of erosion at critical levee segments with embedded sensors before the water recedes

Hydrologic Modeling and Real-Time Forecasting provide advanced lead time to flooding conditions and indicate which areas might be impacted with inundation mapping

Benefits

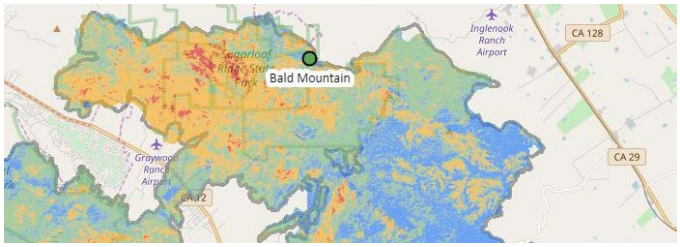
- Early warning can provide time to fight the problem immediately where possible, warn emergency managers and, when appropriate, evacuate citizens that are at risk behind the levee
- Reduce risk to levee personnel having to inspect levee state after flooding event

4. Post Wildfire Burn Scars

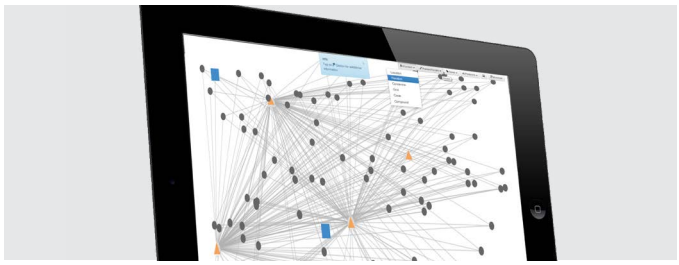
Overview

Wildfires cause serious damage to property and communities. However, the risk continues even after the fire is out. With vegetation gone, rainfall can cause debris flows and flash floods. With fires that burn hot, the soil can become hydrophobic, increasing runoff and the potential for dangerous flooding, debris flows and landslides. With remote difficult terrains and lack of communications infrastructure, monitoring for potential flood threatening conditions can be challenging.

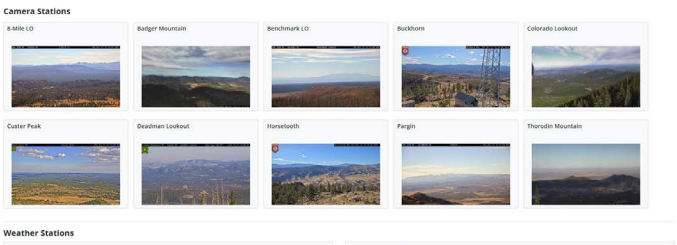
Risk Mitigation Solutions



Flood Risk Analysis Reports documents the rainfall runoff potential of a burn scar



Network Design Services helps agencies quickly get a network off the ground before the rainfall and flooding potential begins



Remote Cameras and image collection software to verify flooding conditions and provide additional situational awareness

Quick-Deploy Early Warning System with multiple environmental sensor measurements and global satellite coverage

Enterprise Software for 24x7 real-time data collection and processing, decision support, information dissemination and alerting with a public website

Benefits

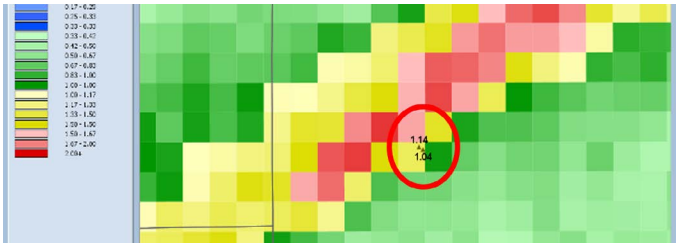
- Remote unattended real-time weather and environmental monitoring
- Advanced warning and alerting
- Situational awareness for proactive response and operational decisions

5. Urban Structural Design and Land-use Planning

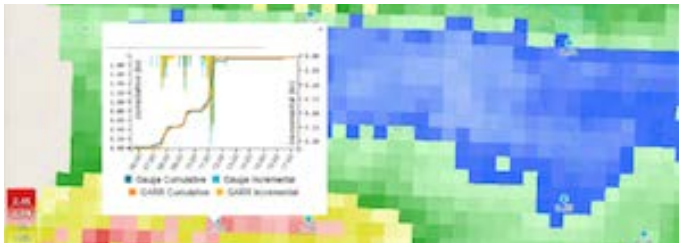
Overview

Urban flooding occurs when rainfall runoff is channeled from roads, parking lots, buildings, and other impervious surfaces to storm drains and sewers that cannot handle the volume. An important aspect of any land or structural development design is managing the flow of water across the surface, as well as under, a site. For civil engineers responsible for planning and design, accurate estimation of the spatial distribution of rainfall is critical to successfully model hydrologic and hydraulic processes. Having the means to assess all the possible rainfall-related hydrologic storm events and conditions helps build appropriate designs for water stormwater runoff, flow, and drainage, and wastewater capacity to lessen the impacts of flooding.

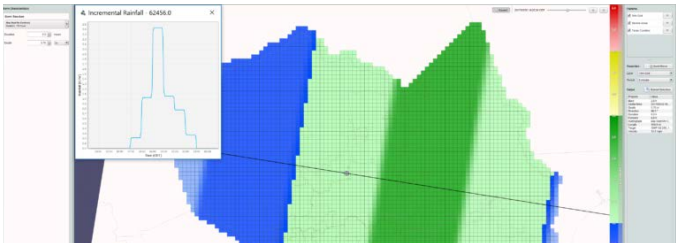
Risk Mitigation Solutions



Location-specific (georegistered) **Gauge-Adjusted Radar Rainfall (GARR)** data provide ground-truthed spatially distributed rainfall information over areas of interest



Real-time, future, historical Gauge-Adjusted Radar Rainfall data are used in rainfall runoff and hydraulic and hydrologic modeling



Design Storm Tools can create custom "design storms" to calibrate hydrologic models for "what if" scenarios and can be applied to subsurface model simulations of ground water flows and in the planning and design of stormwater and wastewater facilities

Forecast Services and Software Applications and tools deliver hydrologic predictions and Quantitative Precipitation Forecasts (QPF)

Benefits

- More accurately model for the design of drainage, stormwater, and combined sewer systems
- GARR provides high quality inputs for hydrologic models and improves model and design results
- Design storms can represent the behavior of rainfall specific to a study area
- Ability to precisely characterize storm events or flow problems as a basis for design-oriented modeling
- Hydrologic models of past events can be extrapolated to potential future events

What is GARR?

Gauge-Adjusted Radar Rainfall (GARR) consists of gauge and radar input processed for bias correction, quality control, and filtered to user-specific grids, catchments, or basins in model-ready format. This product supports efficient use of GARR in hydraulic and hydrologic modeling by delivering a hydrologic input product of known/documented accuracy.

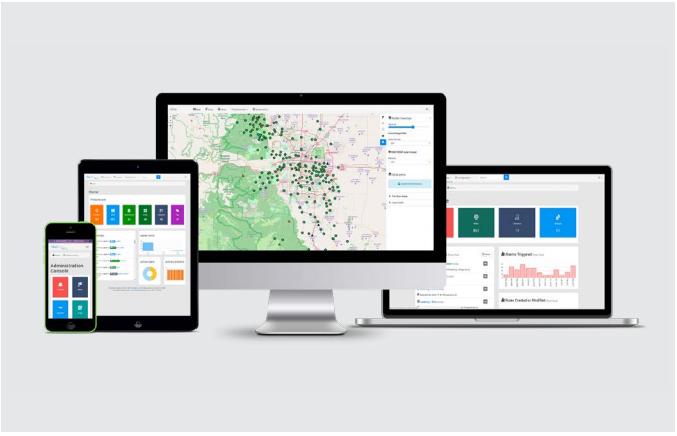
6. Coastal Areas

Challenges

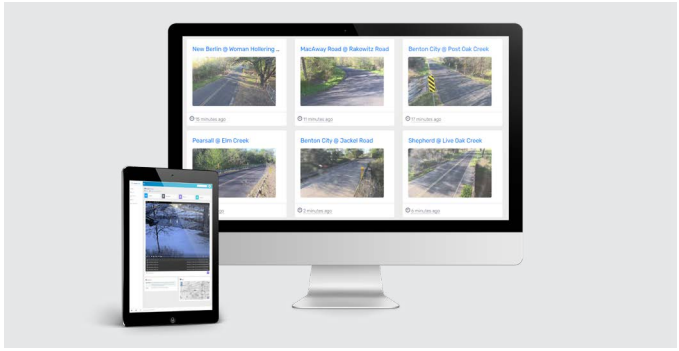
Many low-lying coastal communities around the world already live with the threat of coastal flooding. Coastal flooding is traditionally a nuisance threat with impacts being predictable and relatively less life threatening. Driven by high tides and either high winds and/or heavy rain, these flooding events are more inundation driven. However, residents can still be trapped in their cars or property can be habitually flooded leading to increase insurance costs and resident complaints.

Risk Mitigation Solutions

Hydromet Monitoring Systems combine real-time rainfall and water level monitoring at vulnerable locations can detect and alert for potential overtopping



Enterprise Software for 24x7 real-time data collection and processing, decision support, information dissemination and alerting with a public website



Remote Cameras and image collection software to verify flooding conditions and provide additional situational awareness

Driver Warning Systems warn motorists via flashers and/or gates of flooded roadways

Benefits

- Local sensors can warn critical personnel of nuisance flooding and the impacts
- Save time by quickly seeing the extend and impacts of coastal flooding
- Easily triage areas to focus on with situational awareness software and data forecasting

7. Stormwater & Wastewater Operations

Challenges

Combined stormwater and wastewater systems can be easily impacted by intense rain and flooding conditions. Shared systems combine both stormwater from rainfall and wastewater from residents. During heavy rainfall events, impacts can include backups into homes as well as strain on processing infrastructure. While the impacts aren't as devastating as traditional flooding events, these events can result in fines and public outcry from residents.

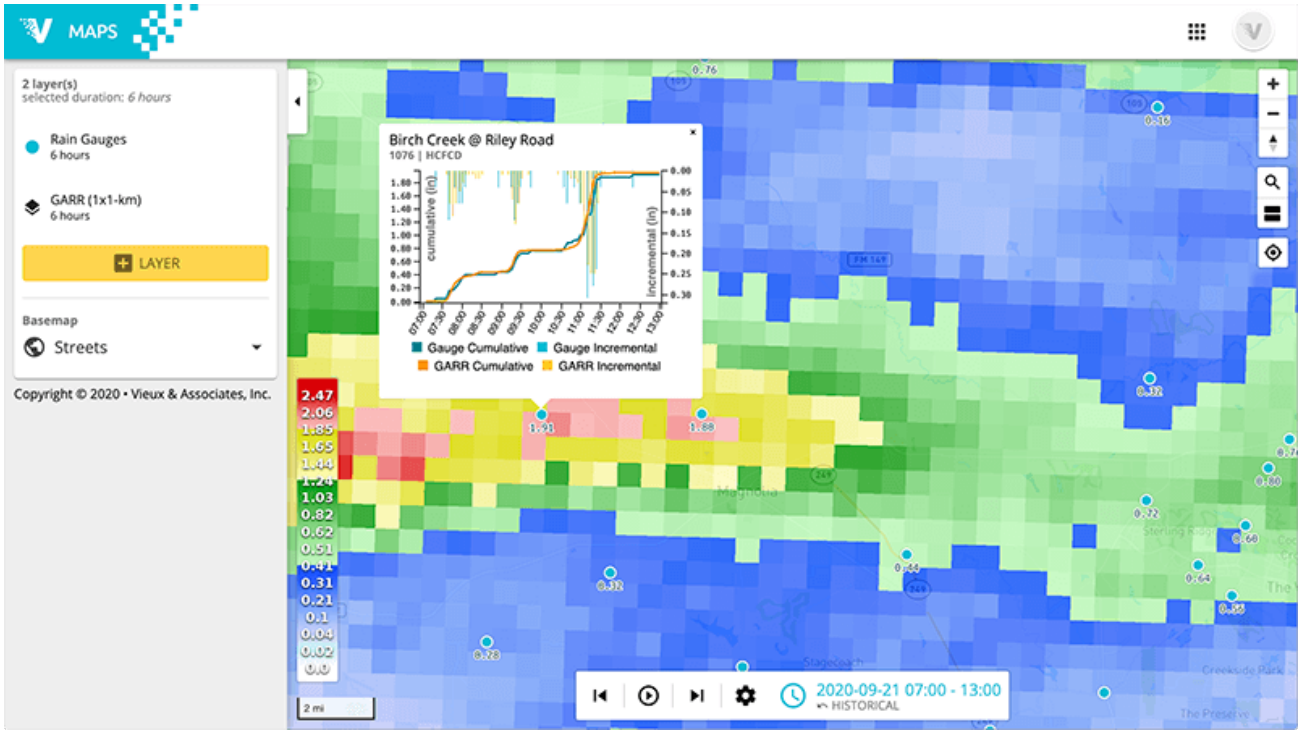
Risk Mitigation Solutions

Realtime Software and Data Services - Real-time hydrologic applications, flood threat, stormwater forecasting, quantitative precipitation forecasting, inundation mapping, ...

Real-time, future, and historical **Gauge-Adjusted Radar Rainfall (GARR)** data services are used for high-resolution rainfall runoff modeling, sewer capacity studies, and Inflow and Infiltration (I&I) assessment

Subsurface model simulations of ground water flows that intersect sewer pipes

Real-time Control (RTC) – near real-time GARR and radar nowcasts provide input into RTC algorithms. Predictive rainfall forecasts one to two hours into the future for 60-minutes beyond currently detected precipitation



Benefits

- **Collection system optimization** – near real-time GARR monitoring provides feedback on system responses
- High resolution rainfall assists with programs for sampling, monitoring, MS4 compliance, Green Infrastructure & Low Impact Development, and modeling of stormwater runoff for mitigating the impact of flooding
- Hydrologic networks help measure the rainfall and resulting flows to properly manage stormwater
- Optimized Combined Sewer Overflow operations help prevent flooding

Planning and designing a Flood Early Warning System network

A highly effective Flood Warning System is designed to maximize the lead time necessary for advanced warning and to allow sufficient time to make decisions and take action during potential flood threats. The goal is to prevent or reduce the loss of life and minimize property damage by providing response teams, stakeholders, and the public with timely, accessible, and accurate information.

Automated real-time Flood Early Warning Systems demand highly accurate hydrometeorological remote sensor technologies, high quality data, and timely robust and reliable data communications. Ensuring that no single point of failure exists across the network and data collection platform is critical.

Determining Flood Hazard Threats	**Identifying and knowing the areas of concern:** characteristics of the watershed, drainage basin, topography, climate and environmental factors, regional past storms and rainfall records, probabilistic storms. Evaluation of hydrologic and hydraulic studies, local drainage (natural and constructed), historical flooding, post-flood reports and damage assessments.
Identification of Monitoring Locations	**Site-specific considerations:** remoteness, property ownership, any permitting requirements, accessibility and safety for installation and maintenance, availability of existing communications infrastructure, environmental risks including potential measurement issues (e.g., exposure to sun for solar panels, impacts of future tree growth for rain gauges, washout for stream gauges).
Data Communications and Network	Evaluation and verification of critical data communication paths at monitoring locations, redundancy, and resiliency considerations (multiple in and out paths for delivery and receipt of critical data is highly important for mission-critical flood early warning systems), determining telemetry options such as ALERT2, IP, cellular, satellite, etc., and reliability during storm events, when and how often data is transmitted, network design and provisioning.
Instrumentation Planning	Based on the flood hazard threats, selecting the gauge sensors and placement for optimum flood threat detection lead time (e.g., upstream from flood hazard risk as well as downstream), and determining the coverage and distribution of sensors is key to the flood warning system performance. The local geography and the types of storms the area experiences factor in to the planning and number of gauge sites.
System Software and Mission-Critical Deployment	Specialized enterprise-level software is required for the automated real-time data collection, processing validation, analysis, mapping, visualization, and alerting of current conditions from the hydrometeorological network. For mission-critical flood early warning systems, the software must be able to maintain its availability and provide real-time information to the right people when and where it is needed. The software should be capable of redundant server operation with a core network architecture that maintains continuous automated real-time database replication for system failover. Hosting data centers should have geographic separation so that a disaster at one data center would not impact the operations at the second data center. To ensure the availability of critical data, the system should provide built-in database backup tools. Additionally, all services used for data collection, alarming, and analysis should provide heartbeat updates and allow system administrators to view status information on processes and to receive alerts on failing, inactive, or system latency services. The software user interface should provide complete administration, data management, and graphical visualization with secure Web-based access. It comprises multiple integrated technologies, aggregated datasets, mapping tools, interactive displays, data services and reporting to analyze, identify, communicate, and automatically alert on potential flood-threatening conditions. The software should provide the ability to send alarm and status notifications via SMS (short message service), text, phone, email, pager, Web applications and other devices hosted by software and/or performed through fully compatible third-party software. The software should have the ability to create alert notification escalation processes.

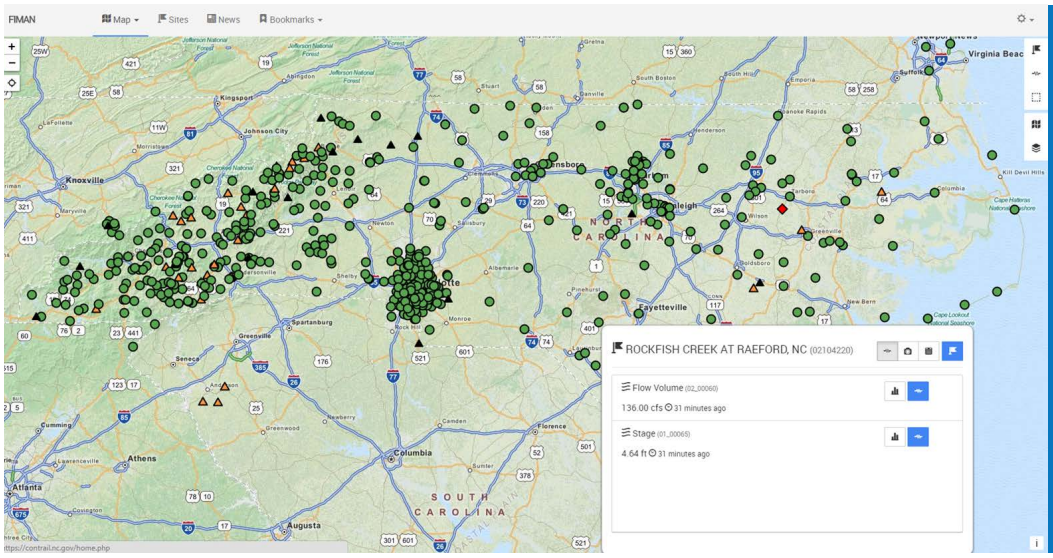
	**Field Services – Site Installation**	Professional installation of monitoring equipment by trained engineers and technicians experienced with hydrometeorological networks can provide services from pre-construction to site completion. Pre-construction services may consist of site surveys to determine if the proposed site is suitable for the equipment being installed and what preparation will be required to successfully install the equipment. For radio systems, engineers may conduct a physical on-site radio path study using software to determine the viability of a proposed communications path and fully test the transmission path. Field services is responsible for installation, deployment, equipment calibration and testing, and help establish communication with interfacing systems.
	**Training**	A training plan for operational personnel and those responsible for maintaining the flood warning system should be prepared. The training should include programs for software system administrators and users, as well as training of field staff on equipment.
	**System Performance and Ongoing Operation**	**Equipment Maintenance:** Routine, preventive, and proactive maintenance is key to ensuring that a flood warning network provides accurate, reliable information during a hydrological event. An established maintenance program ensures field instrumentation at the monitoring locations operate at optimum and that the Flood Warning System continues to work as intended. Integrated software tools can provide a complete system performance data analysis and provide insight into battery problems, charging system failures, over-reporting sensors, plugged tipping bucket funnels and other issues. For optimum performance in the field, monitoring equipment requires maintenance on an annual basis, whether annual calibration, cleaning, firmware, or product updates. Inventory and maintenance software can help track assets and maintenance management. **Software Maintenance:** The Flood Warning System software should be updated on a scheduled basis to ensure maintainability, security, and supportability. Maintenance and support should include security patches, improvements, and changes needed to keep up with current versions of operating systems, database and software library versions. These system updates should remediate known security vulnerabilities, protect against vulnerable functionality, maintain stability, and provide access the latest features in the software.
	**Preparing a Plan of Action**	**Establish a communications and information dissemination strategy:** who needs to know and should be first in line to be notified of threatening conditions, escalation processes, and emergency action plan, information dissemination methods, community outreach.

Solutions in Action

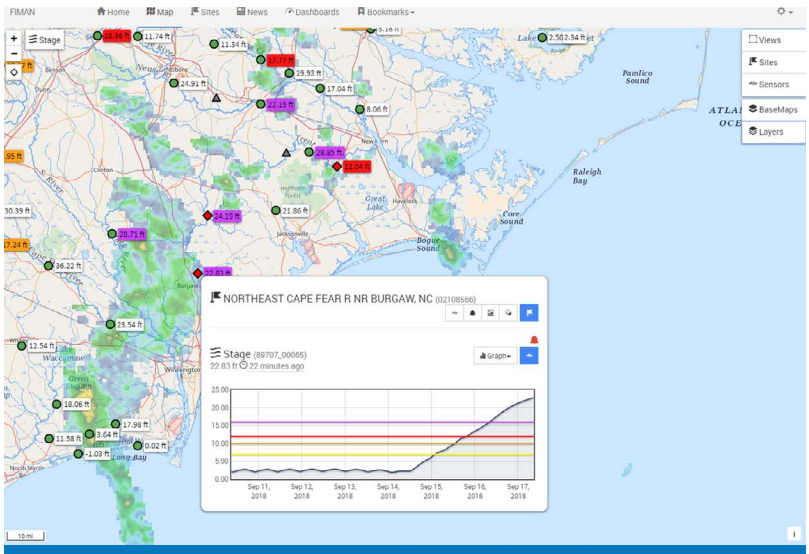
North Carolina Division of Emergency Management

Statewide Rain and Stream Gauge Monitoring Network

The North Carolina Flood Inundation Mapping and Alert Network (FIMAN) uses real-time data from a statewide ALERT network, USGS stream gauges and flood inundation models to support their on-line flood inundation mapping engine. The inundation maps are based on the best available elevation and engineering data, and methods developed through the NC Floodplain Mapping Program.



The FIMAN system supports a gauge network of over 530 sensors for rain and stream monitoring around the state. The network covers the entire 500-mile length of the state.



North Carolina Emergency Management showing Contrail stage displays during Hurricane Florence, September 2018

North Carolina mobile screen capture of Contrail during Hurricane Florence, September 2018

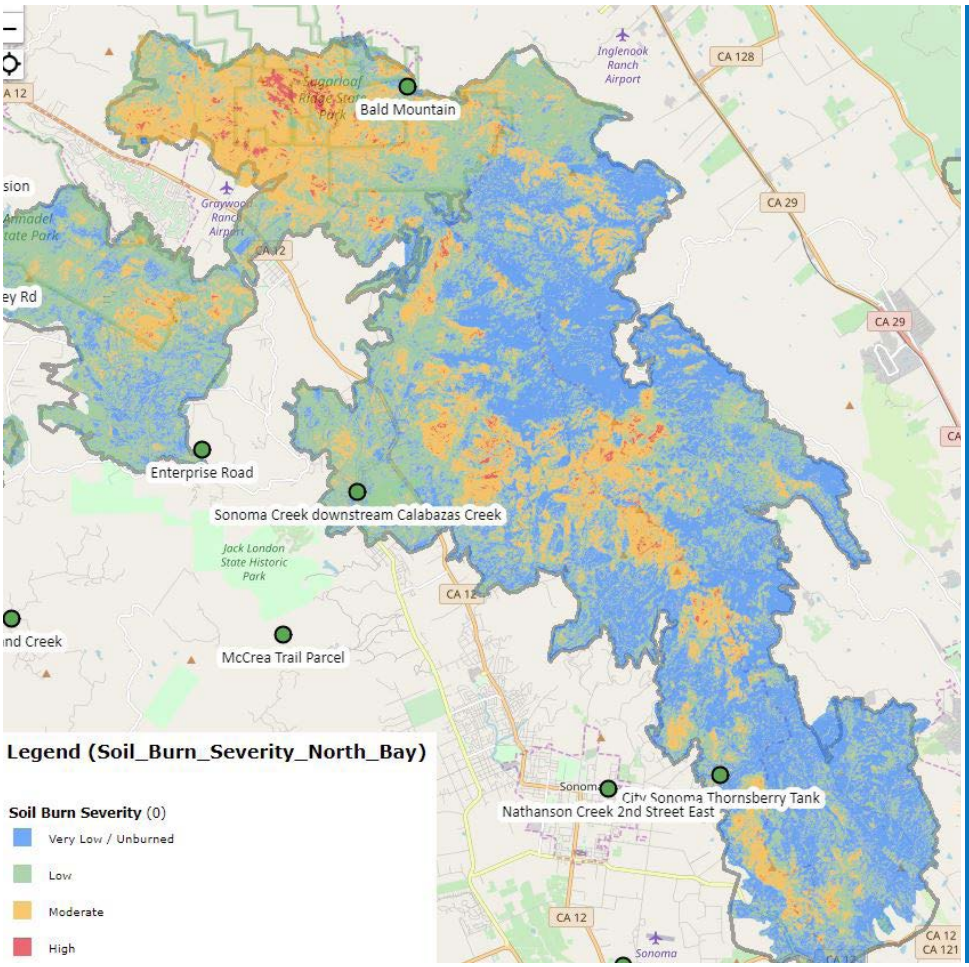
Solutions in Action

County of Sonoma, California

Rapid Deployment of Flood Warning System following Devastating Wildfires

In October 2017, the Sonoma County region experienced damaging firestorms. The resulting fire burn scars and ground conditions throughout the Tubbs and Nuns area left the region highly vulnerable to life-threatening flash flooding and debris flows during heavy rainstorms. As they headed into the rainy season, Sonoma County and City of Santa Rosa officials knew that a flood warning network was needed as quickly as possible to assist the County and National Weather Service in detecting potential flooding conditions.

Led by Sonoma County Water Agency (SCWA) and working collaboratively with a team from OneRain Incorporated and other local agencies, a plan was put in place to implement a new real-time environmental monitoring and flood warning network to measure rain and water levels at critical locations in and around the burn scars. OneRain designed and completed the new end-to-end Flood Warning network within four months—from conception to final implementation. when water comes rushing in from the sea.



Contrail® data collection and monitoring software provides data feeds to the National Weather Service and a front-facing public website (**https://sonoma.onerain.com/**) keeps the community informed

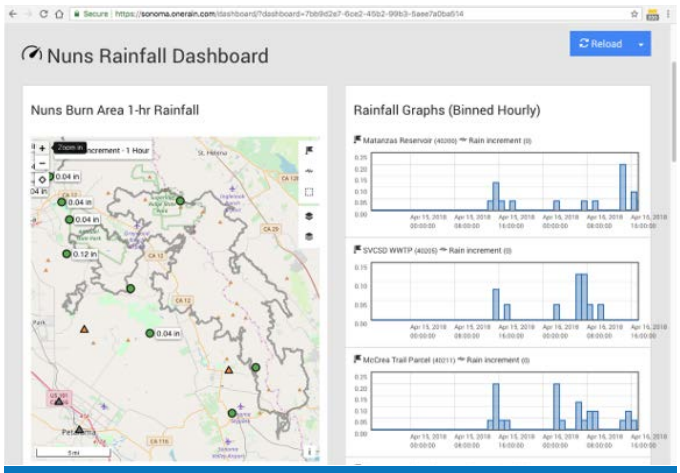
Project Scope

The timing and speed of installation of the new ALERT2-based radio telemetry network was critical. Strategic monitoring site locations within and downstream of the burn scar areas were chosen. OneRain conducted a radio path analysis and designed an optimized network plan that would leverage other existing ALERT2 networks in the area.

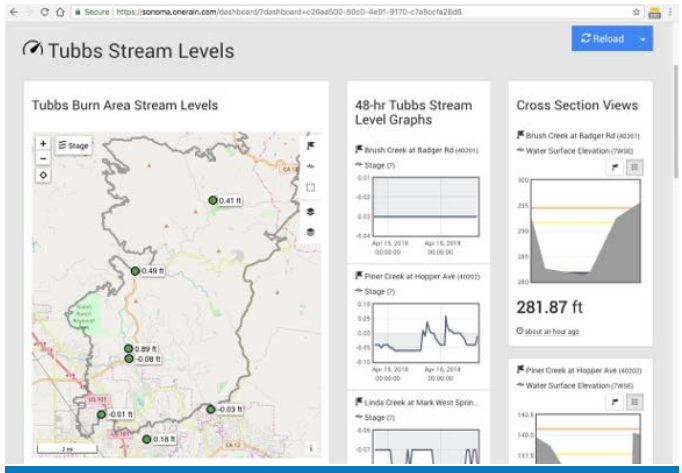
More than 26 critical site locations, within and downstream of the areas burned, were installed with High Sierra Electronics' ALERT2 automated streamflow and rainfall gauges. Additional soil moisture sensors were installed to track saturation in areas vulnerable to destabilization and debris flows. Sensors can report new information every minute with less than 1% data loss. OneRain's Contrail® software platform provides SCWA with secure 24/7 real-time data collection, archiving, monitoring, and visualization used in decision support. SCWA and other officials and responders receive advanced notifications of potential flood-threatening conditions via email and SMS. The data feeds sent from Contrail to the National Weather Service are used in developing their official active hazardous weather warnings and advisories. The general public can also view up-to-the-minute rainfall, streamflow, and other data at **https://sonoma.onerain.com/**.

OneRain engineers install new High Sierra Electronics' ALERT2 rain gauge on burn-scarred hillside

A new rain gauge upstream on Bald Mountain burn-scarred hillside



Contrail software Rainfall Dashboard
SCWA Flood Warning System



Contrail software Stream Levels Dashboard
SCWA Flood Warning System

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The need on the heels of the October fires was imminent, and the pace at which we had to act was daunting. OneRain definitely stepped up to the plate to help us navigate this rapid deployment of our gauge network. Their expertise and professionalism were invaluable throughout the process.

— **Jay Jasperse,** Chief Engineer, Sonoma County Water Agency

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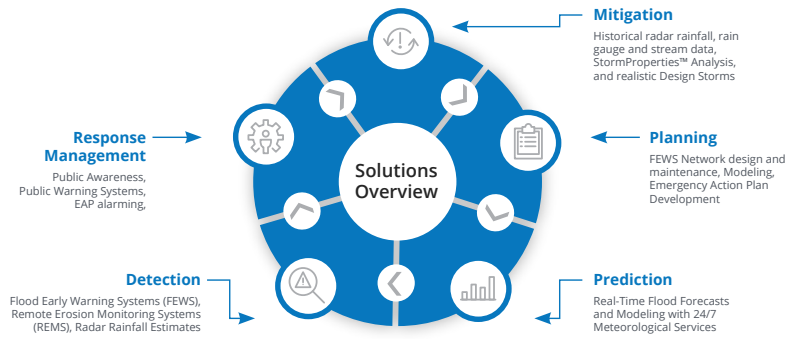
Solutions Overview Summary

Reducing the risk of flooding to communities takes a holistic approach to the complete flooding life cycle and smartly applying systems, tools, and services. Every situation is unique in its challenges and every solution should have flexibility in its capabilities and be uniquely designed to meet the specific needs.



Flood Early Warning Systems (FEWS)

Detect flooding conditions regardless of environmental state. With multiple telemetry options, a FEWS measures hydrological, meteorological, and other environmental variables. Flexible sensor technologies meet any challenges with a stream or watershed.

What to look for:

- Turnkey solution with open protocols
- Multiple telemetry options to meet any environmental or mission critical need
- Multiple water level and rain gauge sensor types to meet stream and water shed needs (i.e., non-contact water level sensors for debris-heavy streams)
- Enterprise software to combine sensor data, metadata, EAPs, camera images, and data management needs

Driver Warning Systems

Alert drivers of flooded or swift water conditions with barrier gates and flashers. Working completely autonomously, these systems are designed to reduce the numbers of flooding related deaths.

What to look for:

- Work autonomously with multiple redundant sensors
- Flexible deployment options for the warning sites
- Multiple water level sensor technologies

Remote Erosion Monitoring Systems (REMS)

Detect and alert of erosion along critical levee segments, reducing the need for risky and costly manual inspections of levees following an event.

What to look for:

- Embeddable erosion sensors that can be added post-construction
- Quickly receive alerts of erosion to critical segments
- Provide data to all appropriate stakeholders

Hydrologic Modeling and Real-time Flood Forecasting Services

Receive advanced lead time of flooding conditions, including timing, areas impacted, and time to resolution.

What to look for:

- Hydrologic models that can designed to meet challenges of each watershed
- Ran in real-time in a secure and reliable environment
- Display all critical information

Historical, Future, and Real-Time Gauge-Adjusted Radar Rainfall Services

Gridded rainfall data that is calibrated to quality-controlled rain gauges on the ground. Can drive models, operational decisions, and dam operations.

What to look for:

- Most accurate (spatial and magnitude) estimation of rainfall available
- Integration into models and enterprise visualization
- Extrapolate into the future for best estimation of rainfall totals
- Archive-quality historical documentation of past events

Design Storm Tools

Understand all of the ways your design storm could interact with your system. While keeping the same rainfall distribution, the design storm tool can easily change the storm's characteristics (orientation, speed, areal coverage, etc.)

What to look for:

- Export in model ready formats
- Change storm characteristics without changing the rainfall distribution

Meteorological Services

24/7 meteorological services include meteorologists on-call and specially designed weather reports and services that deliver actionable but human-verified insights.

What to look for:

- Proven and reliable history
- 24/7 on-call support from meteorologists
- Global coverage

Dam and Reservoir Operations Tools and Services

Detect impacts from dams and reservoirs in your area of interest and safely operate your dams with early warning systems, reservoir operations support, and enterprise software.

What to look for:

- Integrate with Flood Early Warning Systems
- Verify conditions with redundant stations and cameras
- Automate EAP alerting and visualization with enterprise software

About OneRain Incorporated

OneRain is a company of rainfall, water, and weather monitoring experts. Since 1992, we have been helping our clients understand and manage their water-related missions, from flood warning and forecasting, to dam safety, stormwater, wastewater, and water resource management. Our results help improve hydrologic decision making and design standards across the United States and around the world.

We are the leading provider for agencies with critical missions that depend on understanding real-time rainfall and hydrology. Our vertical involvement in water measurement—from gauges through remote sensing and storm analysis—enables us to collect and distribute the best real-time and historical hydrometeorological data available.

Our complete systems approach to hydrological management and flood early warning includes nationwide 24/7-supported enterprise level software and local data collection software for Web visualization, EAP-related alarm management and triggered event notifications, Gauge-Adjusted Radar Rainfall estimation, rain and other hydromet gauges, real-time satellite telemetry services and integration, storm properties analyses, and professional consulting services.

Serving as a committed partner to our private and public sector clients, OneRain helps optimize water management, heighten regulatory compliance, achieve successful civil works, and save lives.

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AEM ADVANCED ENVIRONMENTAL MONITORING

OneRain is a member of the Advanced Environmental Monitoring (AEM) family of innovators.