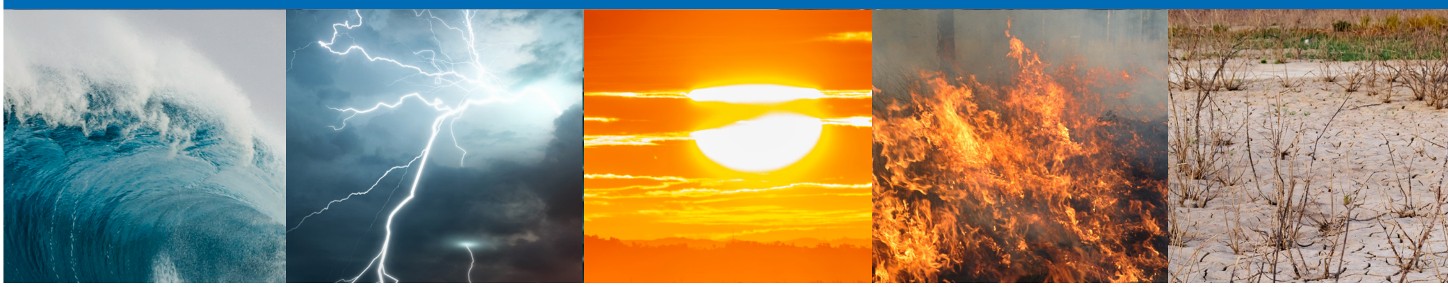
Safeguarding Against Natural Hazards and Extreme Weather Events:

A Resource Guide for Onsite Wastewater Treatment Systems



U.S. Environmental Protection Agency
Office of Wastewater Management
EPA Publication: 830F24004

SAFEGUARDING AGAINST NATURAL HAZARDS AND EXTREME WEATHER EVENTS:

A Resource Guide for Onsite Wastewater Treatment Systems

1 **POTENTIAL IMPACTS TO ONSITE WASTEWATER TREATMENT SYSTEMS (OWTS):**
Explore how sea level rise, increased precipitation, extreme temperatures, wildfires, and drought may impact OWTS. Three broad categories are used to organize and simplify a spectrum of interrelated impacts:

2 **HOW COMMUNITIES CAN PREPARE:**
Learn steps communities can take to prioritize preparedness:

INTRODUCTION

Onsite wastewater treatment systems (OWTS), also referred to as septic systems or decentralized systems, treat wastewater and return the treated effluent to the environment. Due to natural hazards and extreme weather, wastewater treatment systems, including centralized systems and OWTS, may become impaired and require greater oversight or more frequent infrastructure adjustments to ensure proper performance. Wastewater treatment system failure can cause the release of untreated wastewater into the environment, increasing the risk of pathogen exposure and contamination of soils, surface waters, and groundwater. The vulnerability of these systems is dependent on several factors, such as location, use, and infrastructure condition. For example, when exposed to changing environmental conditions, outdated and poorly maintained systems may see greater performance impacts than properly maintained systems. Adapting wastewater systems to be more resilient requires homeowners and communities to identify current and anticipated impacts and devise individual and community-specific mitigation strategies.

PURPOSE AND AUDIENCE

This resource guide is for state, Tribal, and local governments that regulate onsite wastewater treatment systems, as well as onsite wastewater professionals. The guide covers OWTS impacts resulting from sea level rise, increased precipitation, extreme temperatures, wildfires, and drought. Then, the guide outlines potential steps that communities can take to increase the resilience of their OWTS. Specific examples focus on community planning, infrastructure considerations, policy approaches, and education and outreach. The information in this guide is not meant to be exhaustive, and there may be other impacts and mitigation steps worth considering.

BACKGROUND

The U.S. Environmental Protection Agency (EPA) estimates that about 20 percent of U.S. households use OWTS (U.S. EPA, 2002). Some communities rely exclusively on OWTS (U.S. EPA, 2024a). Conventional OWTS digest organic matter and separate floatable materials (e.g., oils and grease) from solids in a septic tank. The liquid (known as effluent) is discharged from the septic tank into a series of perforated pipes buried in gravel, chambers, or other special units designed to slowly release the effluent into the soil. There must be ample soil depth above the local/seasonal water table for wastewater to be adequately treated before it enters the groundwater. Other site-specific conditions can impact where OWTS can be located, including soil composition, vertical separation distance to bedrock, and proximity to drinking water wells. Currently, OWTS are regulated and designed based on standards created at the state, county, and local levels.

Some methods for wastewater site evaluations use outdated assumptions or older protocols. It is critical that decisions about OWTS adaptations or the need to install new equipment be based on community specific information. For more information on potential impacts from sea level rise, increased precipitation, extreme temperatures, wildfires, and drought, please see Appendix 1. Community education is also critical to help OWTS users understand anticipated impacts and equip them with mechanisms for adaptation.

Observed impacts, such as sea level rise, increased precipitation, extreme temperatures, wildfires, and drought may interfere with an OWTS's functionality. Communities may be affected by multiple impacts simultaneously (i.e., cumulative impacts). Some Florida communities, for example, face both sea level rise and extreme precipitation events. OWTS in these communities are likely to experience saturated drainfields, infrastructure damage, and saltwater intrusion, all impacting treatment and operation (Miami Dade County, 2018). In regions affected by extreme heat and wildfires, warmer soils may impact microbial activity, and wildfires may damage OWTS equipment. Understanding OWTS characteristics, vulnerabilities, and location can help communities identify anticipated impacts and potential adaptation strategies.

1. POTENTIAL IMPACTS TO OWTS

1.1 Saturated Drainfields

SEA LEVEL RISE

Sea level rise can cause the water table to rise in coastal areas. This change can reduce the vertical separation distance (VSD) from groundwater to the drainfield area of an OWTS, inhibiting effective treatment and creating a direct pathway for pollution to reach groundwater sources, as shown in Figures 1 and 2. Water tables can increase by 31 to 35 percent of the rate of sea level rise, which effectively reduces the VSD and site suitability (Cox et al., 2020; Mihaly, 2018). Sea level rise can also increase saltwater intrusion into groundwater, which impacts soil structure and can reduce a drainfield's ability to effectively treat wastewater. Communities can help increase resilience to saturation and protect treatment capabilities by increasing the VSD required in regulations that govern OWTS or by requiring treatment technologies that allow for a shallower VSD.

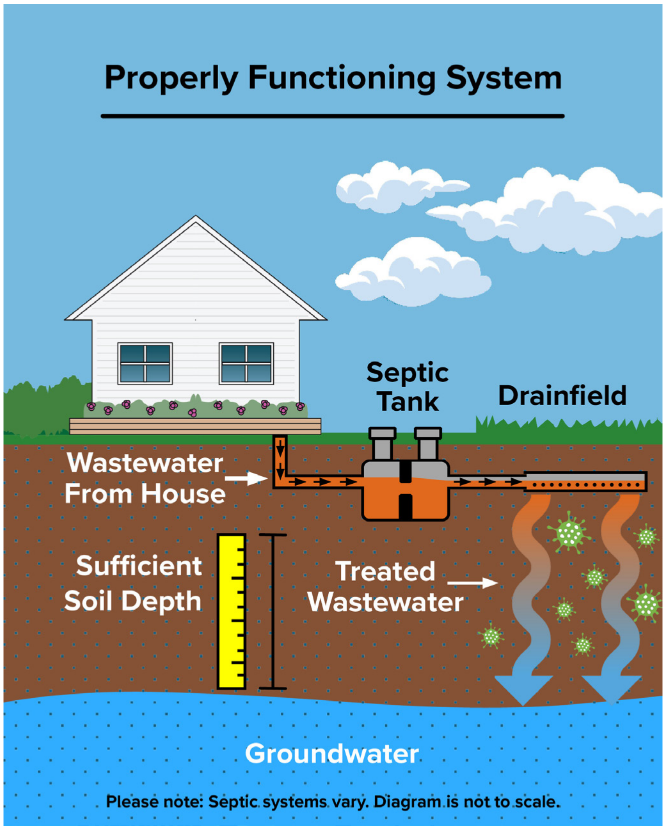


Figure 1: OWTS with a properly functioning drainfield. *Green circular graphics represent beneficial microbes that aid in the treatment of wastewater.*

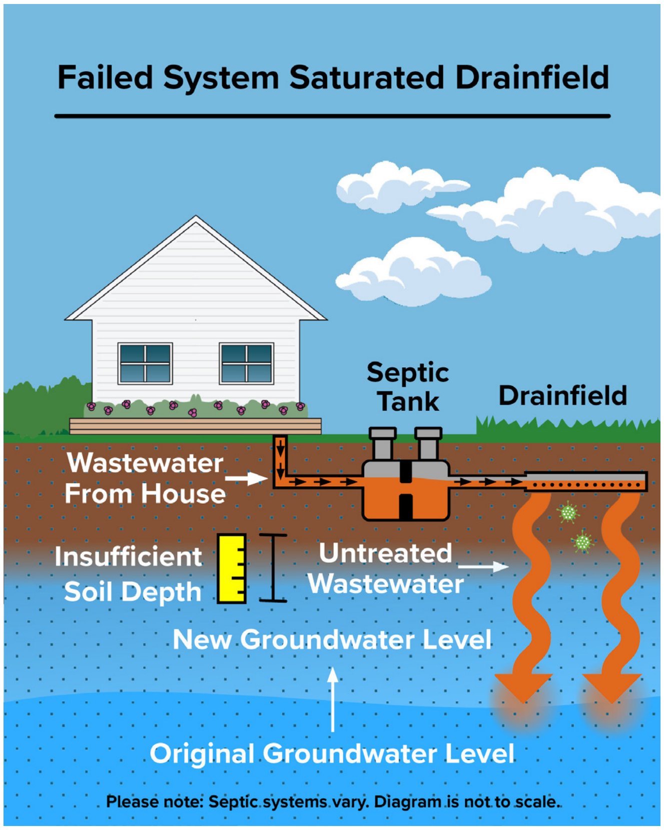


Figure 2: OWTS with a saturated drainfield. *Green circular graphics represent beneficial microbes that aid in the treatment of wastewater.*

There is significant reliance on OWTS along the East Coast (Figure 3). Approximately 50 percent of homes in New England states and the Carolinas rely on OWTS (Mihaly, 2018; University of North Carolina, 2021). New rural developments continue to use OWTS, particularly in areas experiencing sea level rise, including New England, the mid-Atlantic and southeastern states, and island communities such as Hawaiʻi and Puerto Rico (NAHB, 2023; U.S. Census Bureau, 2022).

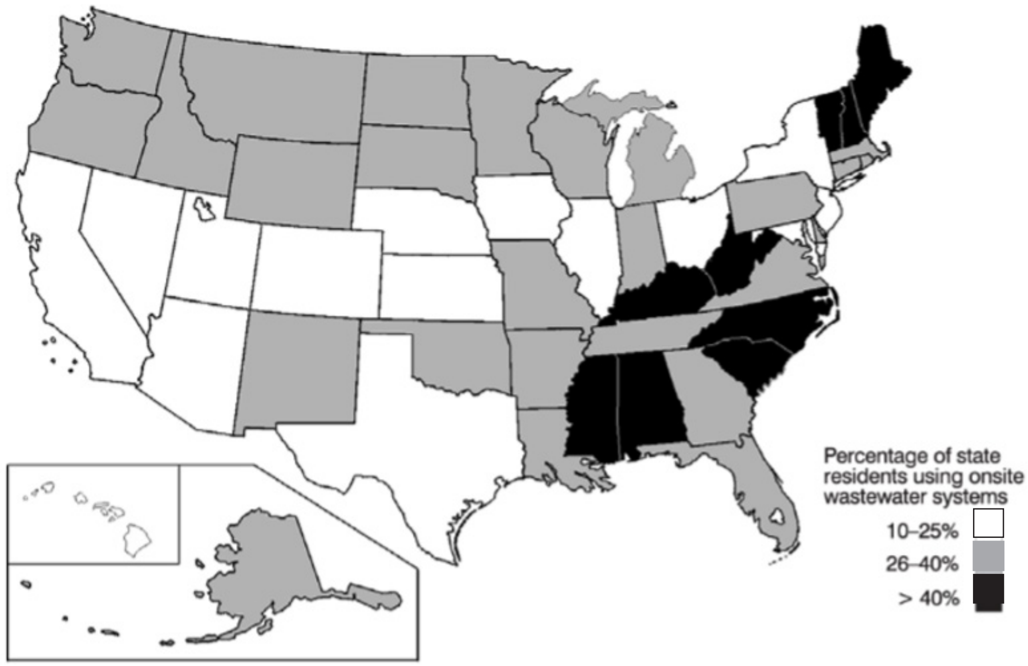


Figure 3: OWTS distribution in the United States.
Source: U.S. EPA, 2002.

INCREASED PRECIPITATION

Drainfield soil saturation from increased precipitation reduces the ability of OWTS to remove nutrients, bacteria, and other pathogens in wastewater. Saturation reduces soil adsorption and impairs interactions with microbes living in the soil.

After floods, the water table can rise and cause OWTS backups, which expose residents to sewage. Soil saturation increases the risk of exposure to insufficiently treated wastewater that percolates to the surface or runs off into adjacent surface water and groundwater. Exposure to wastewater puts people and animals at risk for wastewater-borne diseases. Human health impacts from contaminated water can also quickly become a concern when homeowners or tenants resort to improper disposal of waste through primitive means, such as buckets, during an OWTS backup or failure.

Saturated and failing OWTS drainfields can also contaminate nearby water bodies with excessive nutrients. Higher water tables facilitate the movement of nutrients to adjacent water bodies, which can lead to algal blooms and low oxygen levels, both of which negatively impact nearby aquatic species (University of North Carolina, 2021).

CASE STUDY

Monitoring OWTS Vertical Separation Distance During Extreme Weather

In September 2018, Hurricane Florence hit North Carolina's coast and delivered more than 30 inches of rain (National Weather Service, 2018). Researchers monitored groundwater levels at three OWTS sites to assess how the rainfall affected VSD before, during, and after the hurricane (Humphrey et al., 2021). Site 1 was located near the top of sloped terrain, and therefore had a relatively deep VSD. Sites 2 and 3 were situated on flat interstream divides, which contributed to their relatively shallow VSDs.

Groundwater rose 4.9, 5.6, and 5.9 feet at the three sites, respectively, within the first nine hours of the storm, greatly decreasing the VSD at each site. Groundwater did not inundate the drainfield at Site 1 because, just prior to the storm, the water table had been 13 feet below the drainfield. However, groundwater inundated the drainfields at Sites 2 and 3, which caused groundwater contamination. Groundwater even surfaced at Site 2 for 12 consecutive hours, and the velocity and flow from the storm led to contaminated water dispersion over a large area. The groundwater at each site did not return to pre-storm levels until 27, 40, and 25 days after the storm, respectively (Humphrey et al., 2021).

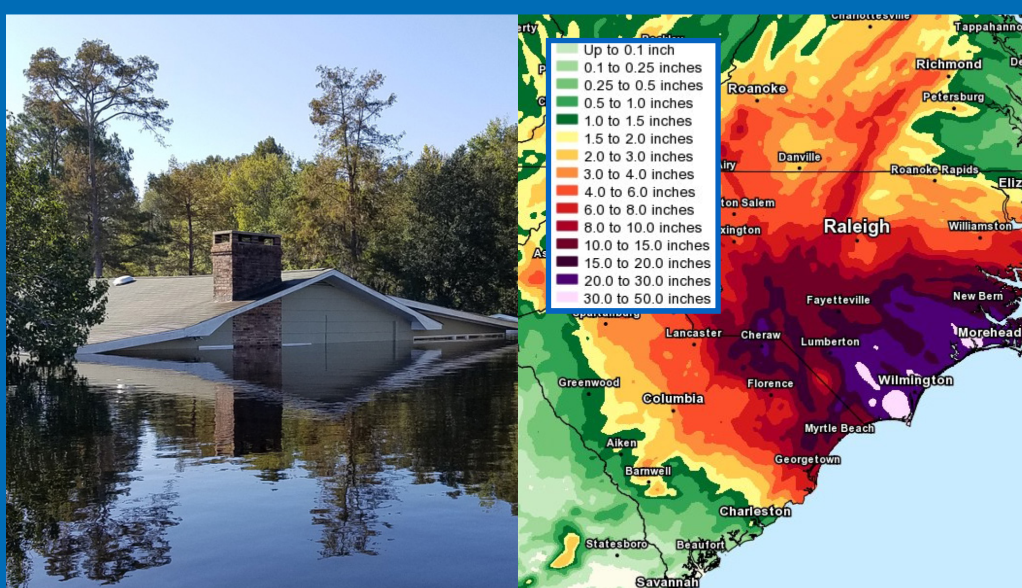


Figure 4: House in Horry County, South Carolina, flooded during Hurricane Florence. Hurricane Florence multi-sensor rainfall estimates, September 18, 2018, 2pm EDT.
Source: Natural Weather Service, 2018. House photograph credited to Jonathan Lamb, NWS; Rainfall map produced by National Weather Service Eastern Region Headquarters.

1. POTENTIAL IMPACTS TO OWTS

1.2 Diminished Treatment Capacity

SEA LEVEL RISE AND INCREASED PRECIPITATION

The availability of oxygen in soils is critical for the function of the different bacteria species that destroy pathogens and transform nutrients in wastewater. When soils are saturated with water due to sea level rise and/or increased precipitation, the soil oxygen levels in OWTS become depleted due to the displacement of air, which reduces aerobic microbial activity and diminishes wastewater treatment capacity. Some research has indicated that OWTS generally take two to seven days to recover and return to normal function after inundation events, depending on the soil type, its drainage characteristics, and proximity to surface water (University of North Carolina, 2021).

EXTREME TEMPERATURE

Increased temperatures impact OWTS in both positive and negative ways. Increased air temperatures warm soils, which can increase microbial activity and aid in wastewater treatment. However, increased air temperatures can also increase oxygen demand and compromise aerobic microbial activity, which impacts OWTS biochemical processes (Mihaly, 2018; Cooper et al., 2016). Decreases in the effectiveness of OWTS treatment can lead to wastewater-borne disease outbreaks and pollution of nearby water bodies.

Figure 5: Algal blooms in Lake Erie, Ohio (left), and Shelburne Pond, Vermont (right).
Source: U.S. EPA (left), Lisa B. (right).

Some lab studies show that changes in biochemical oxygen demand (BOD5) and oxygen levels can affect nitrogen and phosphorous removal (Cooper et al., 2016). Dispersion of nutrient-rich waters from OWTS may cause algal blooms in adjacent water bodies and hypoxic conditions for aquatic ecosystems (Figure 5; Mihaly, 2018). Since underground treatment processes can be complex and influenced by many variables, close evaluation of real-world performance may be needed. To develop solutions that work for local conditions in areas vulnerable to extreme temperatures, state and local agencies may want to test and monitor technologies that provide advanced treatment for nutrient removal.

INCREASED WILDFIRES

Wildfires alter the mass, activity, and biodiversity of microbial communities in near-surface soil (Barreiro & Díaz-Raviña, 2021). It may take five to 10 years for the topsoil and subsoil layers to fully recover from a wildfire, especially an extreme one, and in some cases the soil may be permanently altered (Barreiro & Díaz-Raviña, 2021).

Wildfires can also lead to soil compaction and reduced OWTS function. High-intensity fires can cause an increase in soil bulk density because of the collapse of soil aggregation and the destruction of soil organic matter and pore space. This impact leads to an increase in the hydrophobicity of soil particles, resulting in decreased water infiltration (Agbeshie et al., 2022). The toppling of trees during a wildfire can damage OWTS, especially in cases where a tree's roots extend into the drainfield. The loss of vegetation, as well as the large volume of water used during firefighting activities, can make areas affected by wildfires more susceptible to erosion. More research can be beneficial to determine the full extent of the impact of wildfires on the treatment capacity of OWTS.

Figure 6: Wildfire-damaged property with OWTS in Vacaville, California, following the LNU Lightning Complex Fire. Professional inspection is often required to assess OWTS condition post-fire.
Source: Marcia Parker, 2020.

1. POTENTIAL IMPACTS TO OWTS

1.3 Infrastructure Damage

SEA LEVEL RISE AND INCREASED PRECIPITATION

Coastal erosion, a consequence of sea level rise and other factors, can uncover OWTS tanks and piping, rendering them inoperable (University of North Carolina, 2021). When intense precipitation compounds with storm surge events, it can lead to flooded OWTS and destructive erosion. These events can scour, expose, and degrade OWTS infrastructure (Capps et al., 2020). Additionally, if OWTS are not anchored properly into the ground, sea level rise and flooding can raise the water table and push OWTS components upward in the soil, potentially damaging inlet and outlet pipes, along with other infrastructure. In steep areas, extreme single- or multi-day precipitation events can impact soil composition and lead to landslides, damaging OWTS.

INCREASED WILDFIRES

Although they are largely located belowground, OWTS are susceptible to the impacts of wildfires. For example, wildfires can destroy OWTS equipment by melting plastic and fiberglass components, control valves, and purge valves that are located above ground. Fires can even melt components that are several feet underground, such as risers and diversion valves between tanks and drainfields. The weight of equipment used to suppress wildfires, such as fire and brush trucks, may damage OWTS since their locations are often undefined (Steinkraus, 2018).

OWTS equipment that is destroyed by wildfires will likely need to be replaced, causing system shutdowns that may have both short- and long-term implications, including potential human exposure to untreated wastewater.

Wildfires strip areas of vegetation that help to hold soils in place. Therefore, erosion and mudslides are common in areas recently affected by wildfires and heavy rainfall. After a wildfire, OWTS can be buried in multiple feet of mud and pollute nearby waterways with sediment and nutrients (Steinkraus, 2018).

INCREASED DROUGHTS

Droughts can cause groundwater levels to drop, which may lead to land subsidence over time. Subsidence can damage OWTS pipes or compromise the structural integrity of other treatment components (Hughes et al., 2021). When drought occurs in shrink-swell soil types, changes in volume in response to moisture content can cause large cracks to form in the soil, potentially creating pathways for wastewater to travel rapidly with limited treatment.

CASE STUDY

Boulder County Public Health Response to OWTS Damage from Natural Disasters

After several disasters in recent years, including the costliest wildfire in Colorado history, Boulder County has focused on policies that support recovery and rebuilding to limit environmental and health impacts from OWTS damaged by natural disasters. The county overhauled its preparedness documents and created a "Water Quality Playbook." Designed for environmental health specialists and county leadership, it includes important information and procedures related to addressing OWTS after a disaster and serves as a repository for recent lessons learned. The Water Quality Playbook includes policy and primacy considerations, immediate response priorities, and short- and long-term recovery strategies (including internal public health risk assessments). In addition to developing the Playbook, Boulder County amended land use codes to reduce uncertainty around the use of undocumented OWTS after damages from wildfire.

To speed up recovery following disasters and reduce the number of homes using unpermitted OWTS in the county, Boulder County amended its policy to permit accessory dwelling units (ADUs) on properties destroyed by fire that had previously relied on OWTS. ADUs are permitted to remain as permanent structures after the home is rebuilt, which has resulted in an increase in OWTS permit revisions for larger systems that support both ADUs and rebuilt homes. Permitting costs remain in place for homeowners building expanded homes post-recovery, but permitting costs to reconnect homes are waived to ease the burden on homeowners rebuilding homes the same size or smaller. As seen in Figure 7, this has resulted in an increase in the number of issued permits.

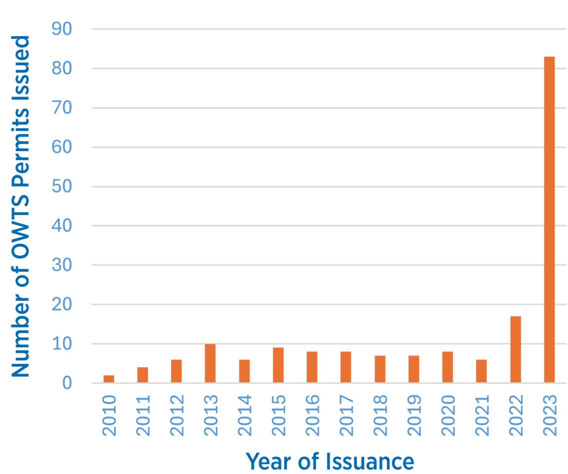


Figure 7: Boulder County OWTS permits issued from 2010 through 2023 in the Marshall Fire Area.

Source: Data analysis conducted by Boulder County Public Health.

Note: The Marshall Fire began on December 29, 2021. A significant increase in OWTS permit issuance can be seen following the fire.

2. HOW COMMUNITIES CAN PREPARE

2.1 Community Planning

Inventories of existing OWTS help communities assess performance, condition, and locations of systems when conducting resilience planning. Integrating this type of data into community planning for infrastructure projects can enable planners to incorporate positive impacts for the community served by OWTS. Geographic information system (GIS) mapping of OWTS allows communities to focus on addressing the actual flooding and saturation observed in their area. For example, potential impacts from natural hazards and extreme weather may be dependent on local hydrologic conditions, so targeted site-specific approaches may be more cost effective than implementing changes universally.

Beyond assessing risk, OWTS inventories can also be used to inform policies and initiate monitoring programs that help make communities more resilient. Routine monitoring is essential to ensure proper OWTS function and identify issues before they affect public and environmental health. Communities can use geospatial datasets to estimate the number of OWTS within jurisdictions, which can prove particularly useful in areas where limited information about septic infrastructure is available (Capps et al., 2020).

An understanding of OWTS ownership and current statutes can help communities identify regulations that need to be updated to account for projected impacts from natural hazards and extreme weather. OWTS are regulated by states, Tribes, and local governments and maintained by property owners or regional management entities. State and local officials, including health officials, are typically involved only when installing a new system or when failures present community risks. However, these officials may need to expand their involvement by developing or enhancing maintenance tracking programs to monitor wastewater treatment effectiveness.

HOW TO ASSESS RISK?

Use the Federal Emergency Management Agency (FEMA)'s Flood Map Service Center to find your community's flood map and assess local flood risk. The EPA's Creating Resilient Water Utilities (CRWU) initiative provides drinking water, wastewater, and stormwater utilities with the practical tools, training, and technical assistance needed to increase resilience to current and future climate conditions.

- Use CRWU's Climate Resilience Evaluation and Awareness Tool (CREAT) to assess potential climate impacts and related risks. The tool guides users through a climate threat identification process and the design of adaptation plans based on their selected threats. CREAT features a series of five modules, a user-friendly interface, climate data projections, and monetized risk results. CREAT also has import capacity and integrates with other EPA tools such as the Vulnerability Self-Assessment Tool (VSAT) and Resilient Strategies Guide.
- Use CRWU's Climate and Weather Data Maps to review climate model projections and natural hazard data, including projections and data for:
    - Coastal flooding and sea level rise
    - Average precipitation and storm intensity
    - Frequency of storm surge flooding and hurricane strikes
    - Average temperatures and extreme heat
    - Wildfire conditions and risk for water utilities
- Explore real-world case studies of utilities addressing climate change challenges in the Adaptation Case Studies Map for Water Utilities.

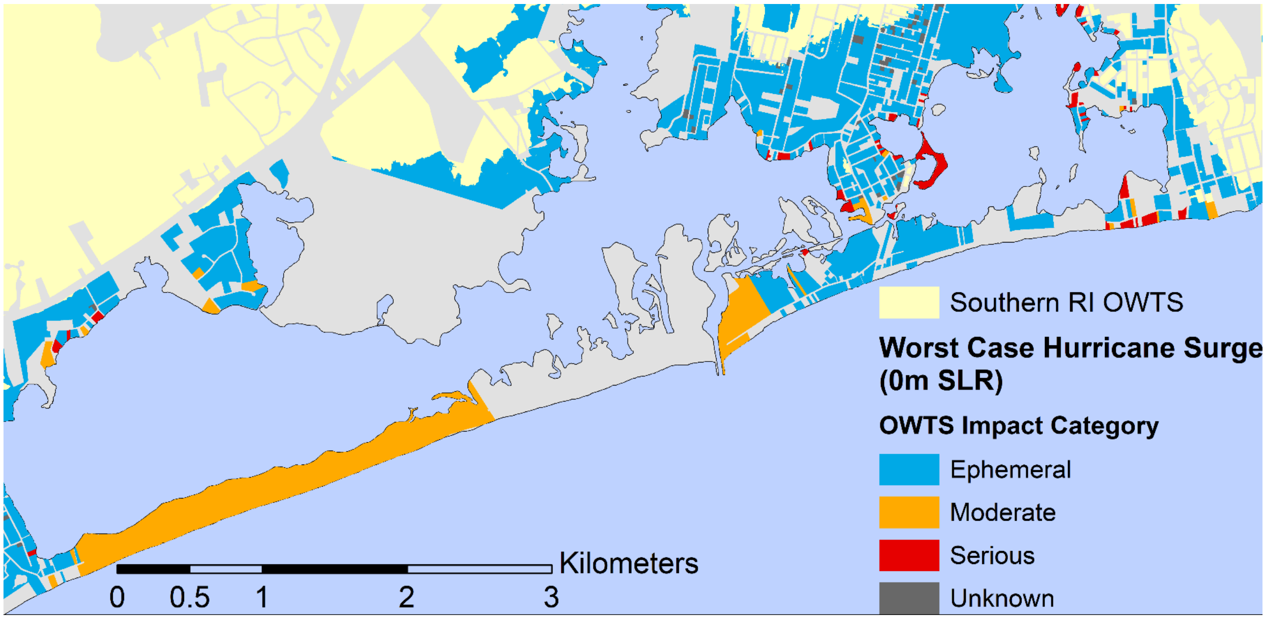


Figure 8: Modeled impacts of hurricane surge on OWTS in southern Rhode Island.
Source: Cox et al., 2020.
Note: Sea level rise is abbreviated as SLR. Rhode Island is abbreviated as RI.

Following natural disasters, communities may choose to survey and document damaged OWTS to analyze them for factors contributing to failures and determine which systems might be most vulnerable in the future. After Hurricane Sandy in 2012, the town of Charlestown, Rhode Island, conducted a damage assessment that included damage to septic systems. Charlestown was also included in the GIS-based modeling study shown in the Figure 8 map, which examined potential impacts of natural disasters on OWTS in southern Rhode Island. For that study, researchers identified properties with OWTS using available tax assessor property parcel maps from the communities (Cox et al., 2020).

Communities can make efforts to identify at-risk OWTS (i.e., OWTS that are failing or prone to failure). Identifying at-risk OWTS in small and disadvantaged communities can help officials proactively address concerns, including failures that contribute to disease outbreaks and water pollution. In some instances, communities with failing OWTS may be connected to centralized wastewater treatment facilities (University of North Carolina, 2021). However, in many rural communities, connection to centralized wastewater treatment facilities may be infeasible or cost prohibitive. These communities may then need to focus their efforts on increasing OWTS resilience.

Regional community planning can encourage the development of cluster systems, which convey wastewater from two or more households or buildings to a treatment and dispersal system located on a suitable site nearby. Cluster systems allow for larger systems with increased flexibility to treat multiple wastewater sources, including commercial sources. A larger, combined system serving multiple lots can be easier to manage and protect from the impacts. Cluster systems also reduce the maintenance burden on individual homeowners.

Wastewater management on a cluster or community level can create job opportunities for service providers and operators and offer potential economic opportunities for resource recovery, such as the reuse of treated water for irrigation.

CASE STUDY

Hawaiʻi Cesspool Prioritization Tool

When data are available, tools can be created to help manage OWTS and the risks caused by failing or inadequate wastewater treatment. In 2021, the University of Hawaiʻi (UH) developed the Hawaiʻi Cesspool Prioritization Tool to help the Hawaiʻi State Department of Health (HDOH) track information on the state's 83,000 cesspools. Unlike septic systems, cesspools lack treatment and therefore pose risks to human and ecosystem health. In 2017, the state passed legislation that requires cesspool owners to upgrade to an OWTS or connect to a sewer before 2050. HDOH requested a statewide tool to help regulators manage future conversion programs and help citizens understand potential risks. The tool can incorporate community needs, such as financial assistance or environmental justice concerns, to help address equity challenges. The Hawaiʻi Cesspool Prioritization Tool is an open-source product designed to be updated as policies or management needs change. A publicly available, web-based map shows the prioritization level for each cesspool location. Census tract areas with cesspools are color coded: red indicates the highest priority areas (those that pose a risk to human and ecosystem health or are adjacent to sensitive natural resources), while orange and yellow indicate lower priority zones (see the Figure 9 map).

UH determined the cesspool prioritization by overlaying the impacts of 15 risk factors with cesspool locations. UH developed these factors using ecological, social, and human health data. For example, UH used sea level rise scenarios to map cesspools that will be inundated by rising seas—both due to horizontal surface flooding and subsurface inundation. More information about the tool is available in this report.

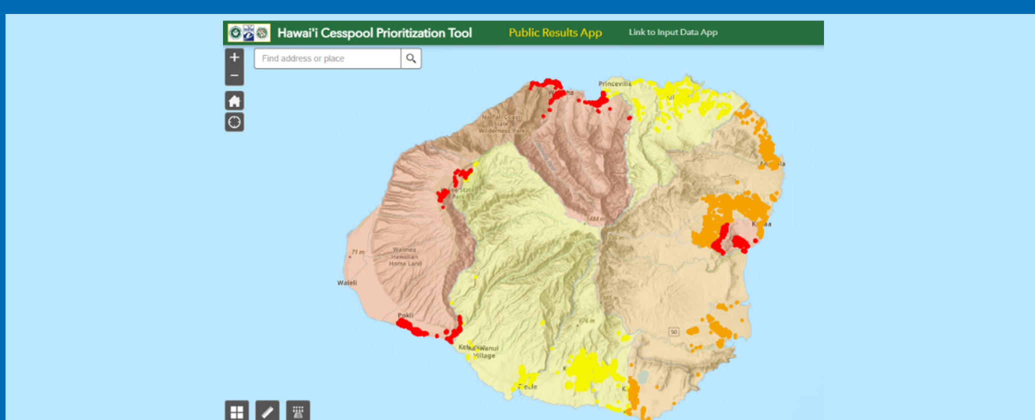


Figure 9: Cesspools on Kauai in the Hawaiian Islands, color-coded to indicate prioritization.
Source: Sea Grant University of Hawaiʻi, 2021.
Note: Priority level 1 cesspools are mapped in red. These cesspools pose the greatest threat to human health and the environment and are adjacent to sensitive natural resources. Priority level 2 cesspools are mapped in orange, and priority level 3 cesspools are mapped in yellow.

2. HOW COMMUNITIES CAN PREPARE

2.2 Infrastructure Considerations

Consistent infrastructure monitoring and evaluation are critical to track information such as OWTS location, age, condition, permits, maintenance history, depth to water table, and land surface elevation. The average household septic system should be inspected at least every three years by a septic service professional (U.S. EPA, 2024i). Advanced OWTS with electrical float switches, pumps, or mechanical components should be inspected more often, generally once a year.

Table 1 provides a non-exhaustive list of infrastructure considerations for OWTS. The first section presents risk-based best management practices to better protect current systems. The second section focuses on redesign and reconfiguration options. The third section focuses on advanced systems that may be considered, particularly when there are chronic system failures.

ONSITE AND DECENTRALIZED WASTEWATER TECHNOLOGY CLEARINGHOUSE

The Searchable Clearinghouse of Wastewater Technology (SCOWT) provides onsite and decentralized technology resources to assist communities' decision-making processes.

CONVENTIONAL AND ALTERNATIVE OWTS

Information on the 10 most common types of OWTS, including illustrations and technological details, is available on the EPA's septic system website.

Figure 10: Flood-damaged advanced nitrogen reducing OWTS in coastal Rhode Island. Storm surge flooding displaced buoyant components of the OWTS. This type of damage can be mitigated with proper anchoring. Source: Matthew Dowling, 2012.

Table 1: Infrastructure considerations to address the impacts on OWTS.

Risk-Based Best Management Practices (BMPs): Installing new OWTS and related technologies can be cost prohibitive to homeowners. Solutions to protect existing systems from the current and anticipated effects of climate change may be preferable in these cases to maximize results with minimum cost.	**Risks Addressed**
Protect OWTS from land disturbance and soil compaction (Amador et al., 2015): • Install enclosures or barriers to hold soil in place. • Add items such as watertight lids and fencing. • Elevate control panel boxes and electrical components.	
Protect OWTS from rising waters: • Anchor all buoyant components (e.g., fiberglass air-filled textile filters, pump basins, etc.) to prevent floating during flood events. • Properly grade and slope areas around septic system components to reduce flood scouring. • Brace septic system components properly to withstand saturated soil conditions. • Plant resilient native plants with shallow root systems to hold soils and prevent erosion. • Elevate all electrical components above base flood elevation. • Add artificial buffers or swales to divert excess water from OWTS. • Install backflow valves to prevent return flow and protect your property from sewage backups.	
Protect OWTS from power risks: • Install backup power to ensure that systems remain operational during power outages. • Install power shutoffs for emergency situations.	
Reduce the risk of OWTS failure: • Use water efficiently to reduce the amount of wastewater entering the OWTS. Learn more about how to conserve water at the WaterSense website. Watersense, an EPA-sponsored program, is both a label for water-efficient products and a resource for helping you save water.	

Key: Sea Level | Precipitation | Temperature | Wildfires | Drought

Table 1: Infrastructure considerations to address the impacts on OWTS.

OWTS Redesign/Reconfiguration: When BMPs do not address some of the issues related to climate change, more costly projects may be required.	**Risks Addressed**
Increase OWTS treatment capacity: • Install additional drain lines, larger septic tanks, and holding tanks. • Elevate drainfields to create more VSD. A mound system is one possible configuration for an elevated drainfield system.	
Consolidate systems: • Install cluster systems to consolidate treatment and dispersal off-lot. Cluster systems help alleviate the challenges of small individual lots, difficult soils, and sensitive locations. Maintenance responsibilities are transferred from individual homeowners to a maintenance professional. • Design shared systems to pool financial resources so that climate change resilient features can be incorporated. • Consider whether advanced treatment options like membrane technologies can be integrated into cluster systems to generate treated wastewater for reuse (University of North Carolina, 2021).	

Key: Sea Level | Precipitation | Temperature | Wildfires | Drought

Figure 11: Example of septic system installation.
Source: SimplyCreativePhotography

Table 1: Infrastructure considerations to address the impacts on OWTS.

Advanced Solutions: Advanced systems may be required for properties that experience chronic system failures, especially those that have low soil permeability or that are situated near high water tables, in coastal regions, or in elevated areas near streams or creeks. These are locations where OWTS failures are likely to pollute well water and affect adjacent water body quality (U.S. EPA, 2024j).	**Risks Addressed**
Increase treatment and/or capacity: • Add advanced treatment systems with natural or synthetic media that utilize oxygen to improve total treatment. • For properties near water bodies that are prone to nutrient contamination, upgrade OWTS to advanced nutrient removal treatment systems, such as passive nitrogen-reducing biofilters or recirculating sand filters (U.S. EPA, 2024j; Southeast New England Program, 2021; Stony Brook University, n.d.). The [Massachusetts Alternative Septic System Technology Center] provides information on onsite treatment technologies for nutrient removal and beyond. • Use nature-based solutions to help treat effluent from OWTS, particularly on a community scale. Examples of nature-based solutions include treatment wetlands and facultative ponds (The Nature Conservancy et al., 2021).	Sea Level, Precipitation, Temperature, Wildfires, Drought
Limit flooding impacts/prevent drainfield oversaturation: • Use curtain drains, fill caps, and silt applications to help divert stormwater and groundwater from the drainfield during heavy precipitation events (University of North Carolina, 2021). • Install alternative dispersion for drainfields, such as shallow pressurized drainfields or drip dispersal, which are installed closer to the surface than conventional OWTS and may be less impacted by rising groundwater levels.	Sea Level, Precipitation
Explore water reuse and conservation applications to address site/geographical constraints: • Investigate regulatory and technical feasibility for water reuse systems that treat wastewater for specific end uses, such as toilet flushing or irrigation. Source separation may be necessary to focus on the reuse of gray water (i.e., household wastewater from sinks, washing machines, and showers). • Employ water conservation measures to reduce wastewater volumes, which may allow for reduced drainfield size. WaterSense makes it easy to find and select water–efficient products. [WaterSense labeled products] are backed by independent, third-party certification and meet the EPA's specifications for water efficiency and performance. • Where appropriate and approved, use innovative decentralized methods, such as incineration, biodigestion, and waste recovery systems, to reduce nutrient loading from OWTS.	Sea Level, Precipitation, Temperature, Wildfires, Drought

Key: Sea Level | Precipitation | Temperature | Wildfires | Drought

2. HOW COMMUNITIES CAN PREPARE

2.3 Policy Approaches

OWTS are regulated by states, Tribes, and local governments. The EPA does not regulate OWTS. Depending on the state, cities and towns may have the authority to establish OWTS standards that address local conditions and needs. States can periodically review their onsite wastewater system design regulations to ensure protection of human and environmental health. States can also assess the ability of their wastewater infrastructure financing and funding programs to fund OWTS construction, upgrades, and repairs. Onsite wastewater professionals and health regulators can adopt new OWTS technologies if regulatory requirements are in place, they have the support of state and local agencies, and sufficient funding is present.

FUNDING FOR OWTS

Potential federal, state, Tribal, and local funding sources for OWTS construction, upgrades, and repairs can be found on the EPA's septic system website.

Most OWTS are selected, approved, and installed based on current site conditions (e.g., VSD, soil morphology, lot size, wastewater quantity). Long-term climate change projections are typically not considered during this process. Wastewater managers can proactively take steps now to adapt to future climate change events. For example, managers could require extra VSD buffers for areas anticipating higher water tables due to sea level rise.

To allow for adequate treatment, state regulations require OWTS to have a specific VSD, measured from the bottom of the drainfield to the water table or to a restrictive layer such as bedrock. VSD requirements for several states are included in Table 2. VSD requirements are determined from measurements related to soil profile depth or soil characteristics (e.g., texture and structure). OWTS might not meet VSD requirements if proper soil characteristic determinations are not used. States may consider revisiting regulatory VSD requirements on a regular basis and requiring soil science training for design professionals.

Table 2: Examples of state vertical separation distance regulations for conventional systems.

State	State Regulation	VSD (inches)
Arizona	AAC R18-9-A312	60—120
Florida	AR 62E-6.006	24—42
Massachusetts	AR 301.12.212	48—60
Minnesota	AR 7080.2150	36
Nebraska	AR 124.4.002	48
North Carolina	15A NCAC 18A	12—18
Oregon	OAR 340-071-0220	24—48

Sources: Henneman, 2020; Mihaly, 2018; University of North Carolina, 2021.
Note: This table provides select examples and is not for regulatory use. State policies are subject to change. Please refer to state regulations for specific requirements and terminology.

State and local permitting authorities may want to explore and establish additional requirements to further protect public and environmental health. For example, the city of Gloucester, Massachusetts, adopted OWTS regulations that are stricter than those found in the State Environmental Code due to unique site conditions, such as shallow VSD, rapid soil percolation, high groundwater tables, and the presence of wetlands and fractured bedrock (Gloucester Health Department, 2008). Additionally, the town of Rye, New Hampshire, requires that OWTS be pumped out once every three years in the Parsons Creek Watershed (Mihaly, 2018; Town of Rye, 2016). Implementing these kinds of locally based standards may be a challenge in under-resourced areas, but state funding assistance programs may provide some support. Importantly, adequate staffing, funding, and expertise are necessary for effective development and implementation of OWTS policies.

Examples of actions that health departments and OWTS regulatory authorities can take to prepare for potential impacts of natural hazards and extreme weather include the following:

☑ **Improve new construction setback requirements to ensure that septic systems are placed in areas that are not likely to flood or pond, consistent with climate change projections.**

- For areas prone to flooding or other natural disasters, implement appropriate design and construction standards or develop buyback programs to prevent building in these areas.
- Establish VSD requirements using projected high-water marks and increase VSD requirements for tidally impacted groundwater tables using the FEMA flood zones as a guide.

☑ **Require advanced technological solutions designed to be resilient or to address local conditions —especially in vulnerable, high-risk areas prone to failure (see Table 1).**

- Monitor advanced systems for compliance with contaminant reduction benchmarks/ regulations and require corrective adjustments for systems not meeting standards.
- Work with other jurisdictions to develop best available technology lists to address shared/common contaminant problems (e.g., nitrogen, phosphorus, pathogens).

☑ **Establish municipality data-sharing platforms and operation and maintenance plans to ensure OWTS are functional and compliant.**

- Require regular OWTS inspections, particularly for areas vulnerable to natural disasters.
- Offer incentives for inspection and pump-outs to establish routine maintenance and encourage documentation of treatment and performance.
- Establish responsible management entities that operate individual OWTS as utilities to reduce the burden on property owners and streamline system maintenance and data collection.

☑ **Involve local governments, where appropriate, to leverage their regulatory authority and ensure that OWTS are installed and managed properly.**

- Require damage assessment inventories of systems impacted by hazards to help model future impacts and identify design and installation practices that mitigate hazards. These inventories can inform policy revisions.
- Use GIS mapping of OWTS and other contamination sources to track flood risk and highlight potential areas of concern.
- Consider backup power requirements or incentives for individual and community systems that experience climate impacts and rely on pump stations.
- Implement licensing requirements for OWTS professionals such as permitting staff, designers, installers, and other service providers.
- Implement a title transfer program requiring septic system inspection during property sales to ensure the OWTS is functioning properly. During inspections, consider assessing systems or past impacts and future climate vulnerabilities as well.

CASE STUDY

Policy Change Efforts for Adaptation in Nags Head, North Carolina

The town of Nags Head, North Carolina, is experiencing an increase in heavy precipitation, sea level rise, flooding, storm surges, erosion, and rising groundwater tables due to climate change. More than 85 percent of Nags Head's wastewater is treated by OWTS, many of which are failing due to these compounding challenges (Town of Nags Head, North Carolina, 2022). In 1999, Nags Head launched a Septic Health Initiative, a non-regulatory, proactive management plan that provides homeowners with the following for their OWTS: free inspections, water utility bill credits for septic pump-outs, low-interest loans for repairs/replacements, and water quality testing.

Nags Head is working to implement its Decentralized Wastewater Management Plan, which proposes new provisions in response to climate change impacts. Through implementation of the plan, the town has improved management of OWTS by helping locate, maintain, and monitor the systems. In turn, there has been an increased acceptance of alternative wastewater treatment and management technologies. The town also recognizes the importance of VSD for effective OWTS treatment, and, through the plan, outlines inspection frequencies, management oversight, onsite options, and soil suitability for each VSD depth.

2. HOW COMMUNITIES CAN PREPARE

2.4 Education and Outreach

Education and communication about OWTS operation and resilience are critical for helping property owners maintain their OWTS. Engaging a broad audience is important to facilitate collaboration, establish networks, and disseminate consistent messages and strategies. For example, communications about adaptation strategies may require coordination between municipalities, health regulators, state legislators, and OWTS professionals. Increased communications between OWTS regulatory authorities, professionals, and property owners can help build adaptive capacity, which is especially important when sharing information about system maintenance, challenges, and malfunctions (University of North Carolina, 2021). Although conventional household OWTS should be professionally inspected and pumped on a regular schedule, OWTS owners rarely receive information about the proper care of their systems over time. Wastewater professionals, real estate agents, and regulators can establish consistent touchpoints and communication practices to encourage proactive behaviors and incentivize regular maintenance.

LEARNING HOW TO MAINTAIN OWTS

Visit the EPA's How to Care for Your Septic System for OWTS tips related to pump inspections, water efficiency, waste disposal, and maintenance, as well as answers to frequently asked questions.

See homeowner training materials on the National Onsite Wastewater Recycling Association's (NOWRA's) website, including the OWTS User Guide and Online Homeowner Training.

University outreach and extension services can provide educational opportunities, including decentralized workforce training and apprentice programs. For example, universities could incorporate training into environmental science and engineering curricula to equip new professionals with an awareness of the potential impacts of climate change on OWTS.

OWTS DISASTER RESOURCES

The National Environmental Health Association (NEHA) created a toolkit complete with guides that OWTS users can use before, during, and after disasters to protect their health and system. Each guidance document is accompanied by a checklist with reminders that homeowners can use to prepare. The documents cover the following disasters:

- Hurricanes and flooding
- Wildfires
- Earthquakes
- Winter weather
- Power outages

The EPA has also provided post-flood event septic system guidance on their ground water and drinking water website.

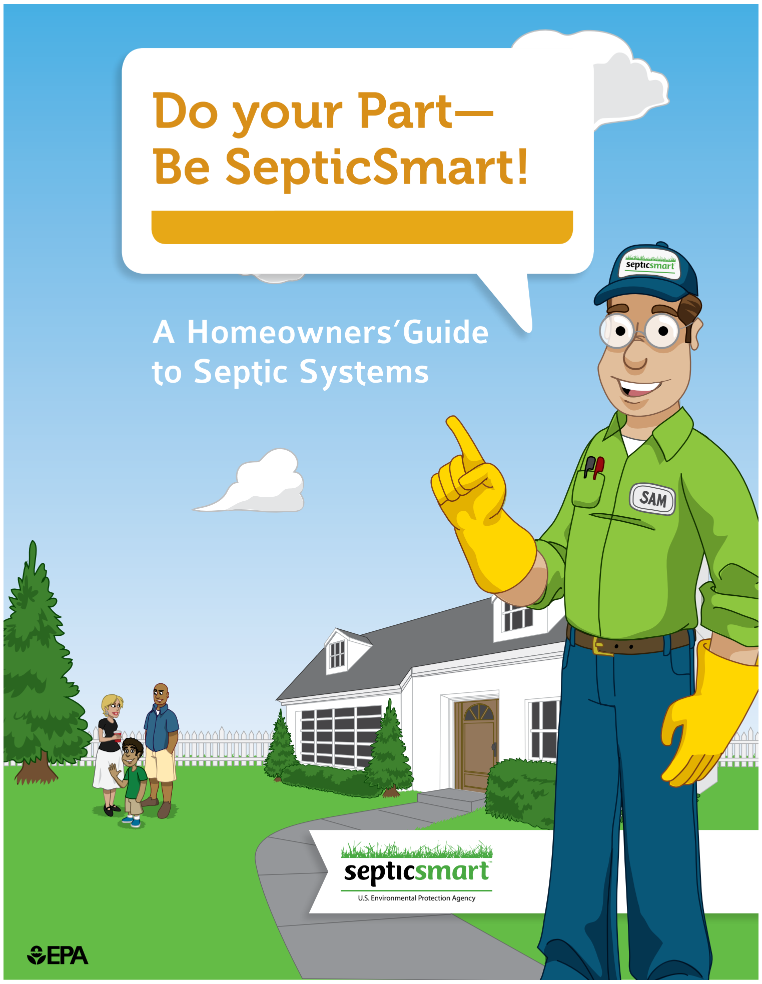


Figure 12: The EPA's SepticSmart Homeowners' Guide to Septic Systems.
Source: U.S. EPA, 2024k.
Note: The EPA's SepticSmart program provides a wealth of online resources for homeowners, local organizations, and government leaders.
For details see: https://www.epa.gov/septic/septicsmart-education-materials.

Tailored trainings for an audience of OWTS service providers, inspectors, designers, installers, and regulators can help keep them informed about climate impacts on system operation and maintenance and address knowledge gaps that may stall adaptation (Kirchhoff & Watson, 2019). Continuing education requirements for OWTS professionals can help encourage completion of OWTS adaptation and resilience training.

Community leaders and educators can focus on using plain language to communicate OWTS information. NOWRA's OWTS User Guide provides an example of this approach, summarizing the technical components of OWTS in plain language to help community stakeholders reach sound decisions related to OWTS management. The EPA's Homeowners' Guide to Septic Systems, shown in Figure 12, provides information about septic system maintenance and operation.

Local health departments or municipal wastewater management districts can use risk communication strategies in discussions with OWTS managers and community members to ensure they take proactive actions and know how to proceed before, during, and after a disaster (University of North of Carolina, 2021).

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APPENDIX 1: BACKGROUND INFORMATION ON IMPACTS

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A.1 Sea Level Rise

As the Earth traps more heat due to an increase in greenhouse gases in the atmosphere, water bodies get warmer too. This increased temperature expands the water in Earth's oceans, causing it to "swell" and increasing the oceans' volume of water. In addition, when land ice (such as ice sheets and glaciers) melts, the meltwater eventually flows into the ocean, increasing the amount of water (U.S. EPA, 2024b). Both of these climate-related outcomes contribute to sea level rise. Sea levels have been tracked since 1880, using a combination of long-term tide gauge data and recent satellite measurements. The available data indicate that the global average absolute sea level is increasing by an average of 0.07 inches per year.

The Figure A.1 map shows cumulative changes in relative sea level from 1960 to 2023 at tide gauge stations along U.S. coasts. Relative sea level reflects changes in global sea level as well as changes in land elevation (i.e., relative sea level rise accounts for land subsidence). Some east coast states, like Virginia and North Carolina, experience over 0.2 inches of rise per year. Sea levels have risen between 3 and 8 inches off the coast of Hawai'i since 1960 (U.S. EPA, 2024b).

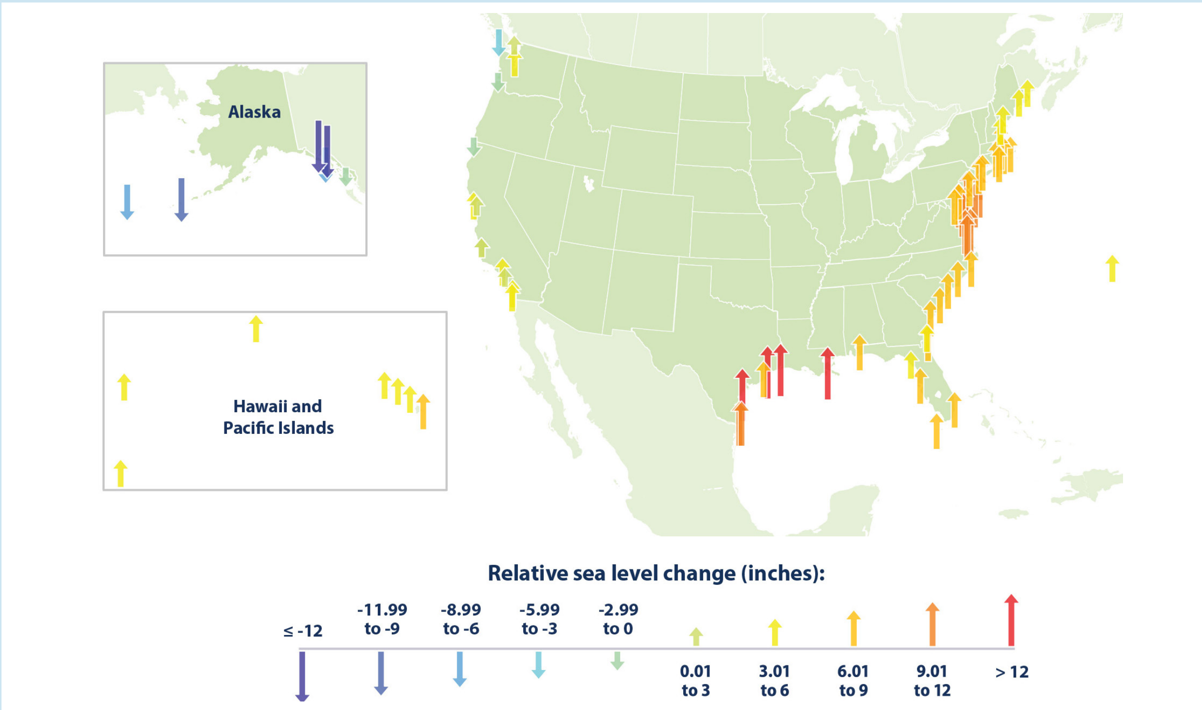

Figure A.1: Relative sea level change along U.S. coasts from 1960 to 2023 (inches).
Sources: U.S. EPA, 2024b; NOAA, 2024a; NOAA, 2024b.
For details see: https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level

APPENDIX 1: BACKGROUND INFORMATION ON IMPACTS

A.2 Precipitation

Climate change also affects the intensity and frequency of precipitation. Higher atmospheric temperatures increase atmospheric moisture, in turn increasing overall precipitation. Heavy precipitation across the contiguous United States has trended upward since the 1950s (Marvel et al., 2023). In recent years, a larger percentage of precipitation has come in the form of intense single-day events that result in floods, erosion, and injuries (U.S. EPA, 2024c). Nine of the top 10 years for extreme one-day precipitation events have occurred since 1995 (U.S. EPA, 2024d). Data on heavy precipitation can be found on the EPA's Climate Change Indicators website.

Additionally, available data suggest that wet areas of the United States are getting wetter, and dry areas are getting drier. The Figure A.2 map shows the percent change in total annual precipitation since 1901 for the contiguous United States and since 1925 for Alaska.

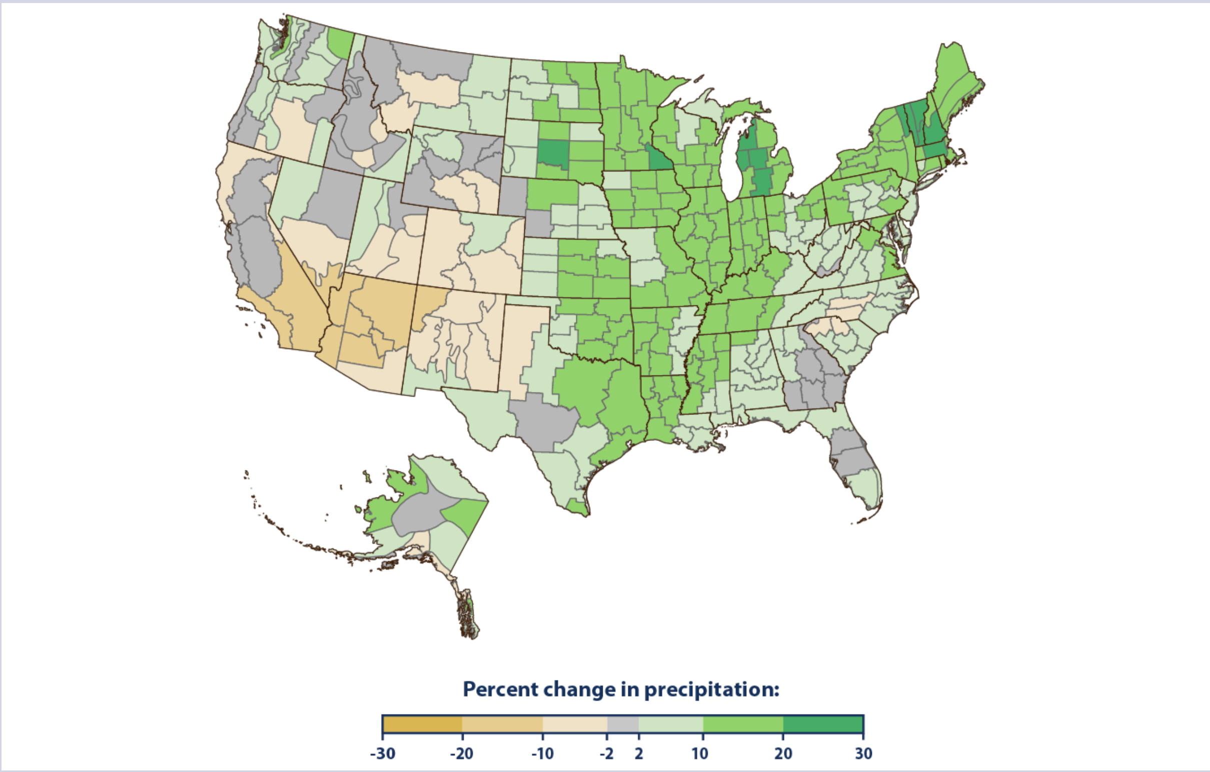

Figure A.2: Percent change in precipitation in the contiguous United States from 1901 to 2023 and in Alaska from 1925 to 2023.

Sources: U.S. EPA, 2024c; U.S. EPA, 2024d; NOAA, 2024a.

Note: In some cases, the EPA's climate change indicators do not cover all states and territories of the United States. Inclusion of a geographical area is contingent on the availability of nationally consistent, reliable, and comparable data for a given indicator.

For details see: https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-precipitation

APPENDIX 1: BACKGROUND INFORMATION ON IMPACTS

A.3 Temperature

The average surface temperature of the contiguous United States has increased at a rate of 0.32°F to 0.51°F per decade since the late 1970s (U.S. EPA, 2024e). The rate of temperature change is highest in Alaska and the western, northern, and northeastern states (Figure A.3). Nationwide, unusually hot summer days (defined as days that exceed the 95th percentile of daily maximum temperatures) have become more common over the last few decades, especially in the western states (U.S. EPA, 2024e). Data on changes in high and low temperatures can be found on the EPA's Climate Change Indicators website.

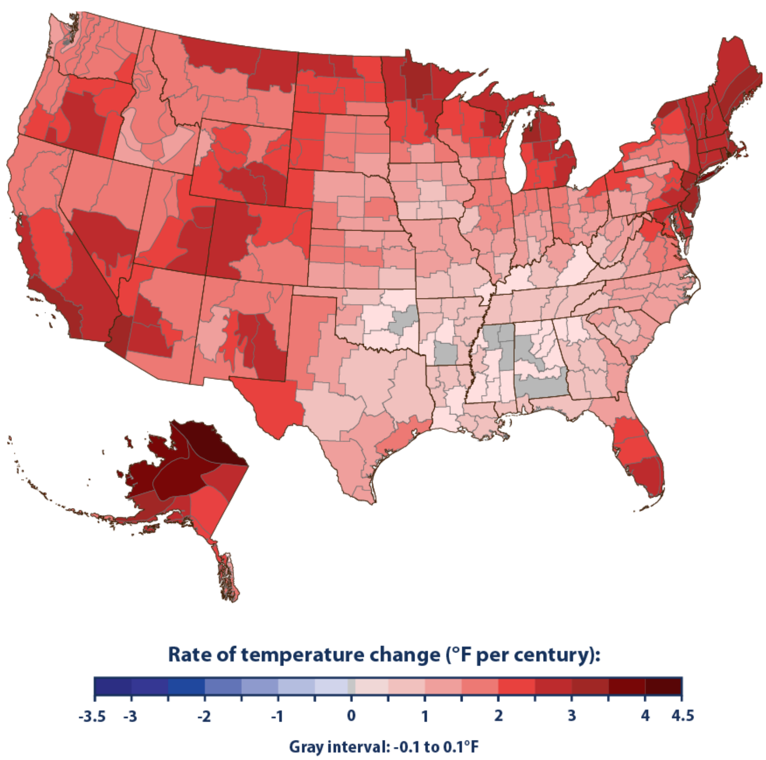

Figure A.3: Rate of temperature change in the contiguous United States and Alaska from 1901 to 2023 (°F).
Sources: U.S. EPA, 2024d; U.S. EPA, 2024e; NOAA, 2024a.
Note: In some cases, the EPA's climate change indicators do not cover all states and territories of the United States. Inclusion of a geographical area is contingent on the availability of nationally consistent, reliable, and comparable data for a given indicator.
For details see: https://www.epa.gov/climate-indicators/climate-change-indicators-us-and-global-temperature

APPENDIX 1: BACKGROUND INFORMATION ON IMPACTS

A.4 Wildfires

On average, 70,000 wildfires occur annually in the United States. Trends in wildfire data show that wildfires are increasing in duration, frequency, and size (U.S. EPA, 2024f). Western states have seen the largest increases in burned acres—even when accounting for a state's size (Figure A.4). In the Figure A.4 map, a wildfire is defined as "a wildland fire originating from an unplanned ignition, such as lightning, volcanos, unauthorized and accidental human caused fires, and prescribed fires that are declared wildfires" (U.S. EPA, 2024f).

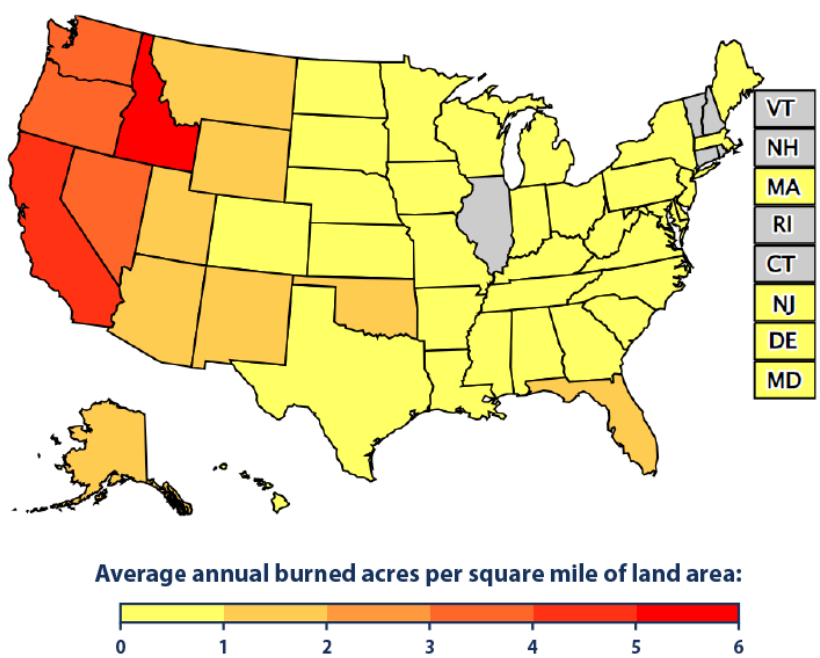

Figure A.4: Average annual burned acreage per square mile of land area by state for the contiguous United States and Alaska from 1984 to 2021.

Gray coloring indicates states that did not have fires large enough to be included.

Sources: U.S. EPA, 2024f; MTBS, 2024.

Note: In some cases, the EPA's climate change indicators do not cover all states and territories of the United States. Inclusion of a geographical area is contingent on the availability of nationally consistent, reliable, and comparable data for a given indicator.

For details see: https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires

APPENDIX 1: BACKGROUND INFORMATION ON IMPACTS

A.5 Drought

Although conditions over the last 50 years have been wetter than the historical average since 1900, some areas of the country have seen an increase in droughts over the past century, as shown in Figure A.5 (U.S. EPA, 2024g). The Figure A.5 map shows changes in the Standardized Precipitation Evapotranspiration Index (SPEI), which measures the combination of precipitation and atmospheric water demand (evapotranspiration). This index gives a broad overview of drought conditions in the United States. It is not intended to replace local information that might describe conditions more precisely for a particular region. Drought can impact agriculture and ecosystems in areas with negative SPEI, particularly in the western United States where water demand is greater than water supply.

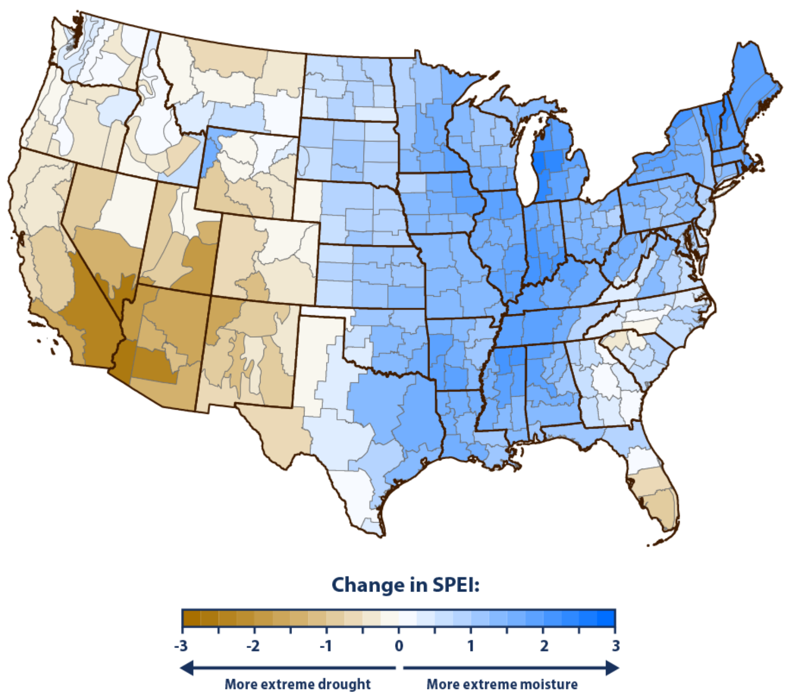

Figure A.5: Total change in the five-year Standardized Precipitation Evapotranspiration Index (SPEI) in the contiguous United States, 1900 to 2023.

Sources: U.S. EPA, 2024g; Western Regional Climate Center, 2024.

Note: In some cases, the EPA's climate change indicators do not cover all states and territories of the United States. Inclusion of a geographical area is contingent on the availability of nationally consistent, reliable, and comparable data for a given indicator.

For details see: https://www.epa.gov/climate-indicators/climate-change-indicators-drought