Managing Levee Emergencies



Key Messages

This chapter will enable the reader to:

- **Collaborate and plan ahead.** Successful levee emergency response requires proper planning including partner collaboration and adequate resource management.
- **Share information.** Effective and timely communication with stakeholders and community members is essential during an emergency.
- **Respond rapidly.** Early detection and prompt responses can prevent or reduce the impact of a levee emergency.



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Other chapters within the National Levee Safety Guidelines contain more detailed information on certain topics that have an impact on levee emergency management, as shown in Figure 10-1. Elements of those chapters were considered and referenced in the development of this chapter and should be referred to for additional content.

CH 1	СН 2 👫	СН 3	СН 4 🔍
Sources of flood hazard	Potential failure modes	 Flood-related communication Emergency communication 	 Risk assessment Potential failure modes Inundation maps
СН 5 🛛 🕅 🕅	СН 6	СН 7 🏾 🖍	СН 8 🖳
 Levee risk management Risk-informed decision making 		Levee rehabilitation	Construction of long-term repairs
СН 9 📋	СН 10 🛕		СН 12 🌱
 Flood-related inspections and monitoring Emergency preparedness 	Managing Levee Emergencies		 Community flood preparedness Evacuation planning

Figure 10-1: Related Chapter Content

Contents

1	Introd	duction		10-5
2	Prepa	aring for	a Levee Emergency	10-6
	2.1	Collabo	prating with Stakeholders	10-7
	2.2	Unders	tanding Levee Risks	10-9
		2.2.1	Hazards	10-10
		2.2.2	Performance	10-10
		2.2.3	Consequences	10-11
	2.3	Develo	ping an Emergency Action Plan	10-12
		2.3.1	Level of Detail	10-12
		2.3.2	Key Elements	10-14
		2.3.3	Partner Involvement	10-16
		2.3.4	Maintenance and Updates	10-17
		2.3.5	Distribution	10-17
	2.4	Develo	ping Notification Procedures	10-18
	2.5	Unders	tanding Roles	10-19
		2.5.1	Common Levee Owner/Operator Activities	10-19
		2.5.2	Jurisdictional Oversight	10-20
		2.5.3	External Agency Assistance	10-21
	2.6	Classify	ying Incidents	10-21
		2.6.1	Determining Incident Classifications	10-22
	2.7	Plannin	ng Response Actions	10-24
		2.7.1	Notification Procedures	10-24
		2.7.2	Evacuation Procedures	10-25
		2.7.3	Pre-Planned Floodfight Actions	10-26
		2.7.4	Transference of Risk	10-27
	2.8	Using I	nundation Maps	10-28
		2.8.1	Hypothetical Scenarios	10-29
		2.8.2	Inundation Map Key Characteristics	10-30
		2.8.3	Partner Coordination	10-32
		2.8.4	Updating Inundation Maps	10-32
		2.8.5	Digital Inundation Mapping	10-32
	2.9	Managi	ing Critical Resources	10-34
		2.9.1	Stockpiling Floodfighting Materials and Equipment	10-34
		2.9.2	Alternative Sources for Communication and Power	10-35
	2.10	Training	g and Exercises	10-35

		2.10.1	Training	10-37
		2.10.2	Emergency Action Plan Exercises	10-37
		2.10.3	Exercise Development	10-38
		2.10.4	Exercise Evaluation	10-38
		2.10.5	Exercise Participants	10-38
		2.10.6	Exercise Frequency	10-39
3	Mana	aging a l	_evee Emergency	10-39
	3.1	Incider	t Management System	10-40
	3.2	Unified	Command	10-41
	3.3	Emerg	ency Operations Centers	10-43
4	Oper	ating a l	_evee During an Emergency	10-45
	4.1	Incider	t Detection	10-45
		4.1.1	Preliminary Response Activities	10-45
		4.1.2	Flood Source Monitoring	10-46
		4.1.3	Flood-Related and Event-Driven Inspections	10-47
		4.1.4	Instrumentation Monitoring	10-51
	4.2	Data N	lanagement	10-52
		4.2.1	Criteria for Data Collection	10-52
		4.2.2	Tools for Data Collection	10-54
	4.3	Floodfi	ght Actions	10-55
	4.4	Emerg	ency Communication	10-56
	4.5	Evacua	ation	10-56
	4.6	Termin	ation	10-57
		4.6.1	Communication	10-57
		4.6.2	Demobilization	10-57
		4.6.3	Transfer of Command	10-58
		4.6.4	Closeout/Debriefing	10-58
		4.6.5	After-Action Report	10-58
		4.6.6	Transition to Recovery	10-59
5	Reco	overing f	rom a Levee Emergency	10-59
	5.1	Post-F	lood Inspection	10-60
	5.2	Immed	iate Repairs	10-60
	5.3	Long-T	erm Repairs and Rehabilitation	10-62
	5.4	Remov	ring Temporary Floodfighting Measures	10-62
	5.5	Recove	ery Assistance	10-62
6	Sum	mary		10-63

List of Figures

Figure 10-1: Related Chapter Content	10-i
Figure 10-2: Collaboration Before, During, and After a Flood	10-8
Figure 10-3: Potential Failure Modes	10-11
Figure 10-4: Emergency Action Plan Scalability	10-12
Figure 10-5: Leveed Area from the National Levee Database	10-29
Figure 10-6: Hypothetical Sacramento River Inundation Maps	10-31
Figure 10-7: Emergency Responder Floodfight Training Session	10-36
Figure 10-8: Incident Commander During an Exercise	10-41
Figure 10-9: Unified Command—Multiagency/Multijurisdictional Incident	10-42
Figure 10-10: Unified Command—Multiagency/Single Jurisdiction Incident	10-43
Figure 10-11: Unified Command—Multijurisdictional Incident	10-43
Figure 10-12: Sandboil Marker	10-51
Figure 10-13: Workers Repair a Levee	10-61

List of Tables

Table 10-1: Emergency Action Plan Key Elements	.10-14
Table 10-2: Incident Classifications	.10-22
Table 10-3: Example Guidance for Determining Incident Classification and Pre-Planned Actions for Seepage Issues	.10-23
Table 10-4: Flood-Related Inspection Tasks	.10-49
Table 10-5: Conditions and Attributes to Record During a Flood	.10-53
Table 10-6: Typical Floodfight Actions	.10-55
Table 10-7: Related Content	.10-64

1 Introduction

There are over 7,000 levees that provide flood risk reduction in the United States, with more than 17 million people working and living behind them. Levees are not failsafe and cannot completely eliminate flood risk. Therefore, proper operation, maintenance, and emergency management are necessary to reduce the likelihood of levee breach and the associated potential for loss of life and property.

As climates change, weather patterns fluctuate, levee infrastructure ages, and populations behind levees increase, the potential for floods necessitates a thorough understanding of how to effectively manage a levee emergency.

Levee owner/operators, regulating agencies, and emergency management agencies must be prepared to handle the aspects of potential levee emergencies that fall within their jurisdiction to reduce risks to life and property, while simultaneously taking actions to prevent or stabilize emergency conditions on the levee or reduce the consequences if a levee is breached.

This chapter describes best practices for developing and implementing effective levee emergency management measures to reduce the likelihood and impacts of levee emergencies and improve public safety.

Levee emergency management is divided into four sections as described below.

- **Preparing for a levee emergency**: Section 2 describes emergency planning and preparedness activities to avoid or reduce the risk to human life, property, and critical infrastructure.
- **Managing a levee emergency**: Section 3 describes methods for maintaining situational awareness, coordination, and communication with partners and the public before and during a levee emergency.
- Operating a levee during an emergency: Section 4 provides an overview of incident detection and response actions to be implemented to identify and respond to a levee emergency.
- **Recovering from a levee emergency**: Section 5 includes the initial steps of recovery to be taken concurrently with emergency response efforts or immediately following the emergency.

2 Preparing for a Levee Emergency

Levee emergencies should be considered inevitable, which is why planning and preparing before an emergency is essential. When a levee emergency occurs, a clearly understood and

effective strategy allows for seamless response. Emergency preparedness for levees focuses on actions to take before and during a flood in response to conditions on the levee to prevent emergency conditions from developing, to reduce the likelihood of levee breach should an emergency occur, and to reduce consequences should a levee breach or overtopping occur.

Preparedness activities allow emergency response to occur more rapidly and efficiently. Emergency preparedness is a continual cycle of planning, training, exercising, and improving that includes:

- Collaborating with stakeholders.
- Understanding levee risks.
- Developing an emergency action plan.
- Developing notification procedures.
- Understanding roles.
- Classifying incidents.
- Planning response actions.
- Using inundation maps.
- Additional preparedness activities.
- Managing critical resources.
- Training and exercises.

The following definitions are used throughout this chapter.

- Incident: An incident is an unexpected occurrence that requires some level of a response to ensure or restore levee integrity or functionality. Incidents include both nonemergency and emergency conditions. Many incidents do not require action above and beyond typical operation and maintenance (O&M) activities to protect life or property.
- Emergency: An **emergency** is an incident which endangers the structural integrity of the levee and places life and/or property at risk. Emergencies typically warrant urgent or non-routine response.
- Emergency management: This is the interdisciplinary function of developing the framework and measures necessary to avoid or reduce the impacts from emergencies.



The primary goals of emergency management are to save lives, prevent injuries, and reduce damage to property and the environment.

• Emergency action plan: An emergency action plan is a formal document that identifies potential emergency conditions at a levee. It specifies pre-planned actions to reduce the likelihood of breach and to reduce consequences should breach or levee overtopping occur.

2.1 Collaborating with Stakeholders

Levee **stakeholders** include individuals, groups, organizations, or businesses that have an interest in, can affect, or be impacted by the levee and decisions about the levee. Key stakeholders who share responsibility for managing the levee or managing some aspect of levee risk are partners in levee risk management. Identifying and developing relationships with partners in emergency response is foundational to effective emergency preparation. During an emergency, valuable time can be lost when there is not a clear understanding of who will execute critical tasks, such as recommending and executing evacuation notifications to the public. Partners with a shared understanding of their roles and responsibilities, available resources, and potential consequences of levee breach can respond more effectively.

It is a best practice to develop a levee emergency action plan (section 2.3) in coordination with partners and to include partners in routine training and exercises. Frequent engagement with partners, including annual meetings between levee owner/operators, emergency management agencies, and other key partners can facilitate a better understanding of roles and responsibilities and enhance emergency readiness.

Sharing the emergency action plan and other critical levee information with communities within the leveed area before a flood occurs can build knowledge and awareness early on about levee risk and incident response processes (**Chapter 3**). This kind of engagement builds trust between levee owners, local officials, community members and other stakeholders, increasing the likelihood that emergency warnings and evacuation notices will be heeded. Establishing relationships and trust early can also help community leaders and emergency management professionals identify areas where vulnerabilities may prohibit community members from being able to take action during an emergency. These vulnerabilities should be addressed in the levee and flood emergency planning process. The most prepared and resilient communities are those in which all stakeholders—including local businesses and citizens—understand the importance of the levee, its risks, and all phases of emergency management activities.

Figure 10-2 depicts multiple ways stakeholders collaborate with levee owner/operators and emergency management agencies to manage levee emergencies.

Figure 10-2: Collaboration Before, During, and After a Flood



It is vital that all entities, jurisdictions, agencies, and authorities that would be involved in an incident at a levee or have responsibilities for warning, evacuation, and post-incident actions be involved in levee emergency preparedness. A wide range of entities are partners in emergency preparation and response. Key entities involved in emergency preparedness include, but are not limited to:

- The owner/operators of the levee for which planning is occurring.
- State and local emergency management agencies.
- Local fire, police, and emergency management services.
- Agencies with flood warning responsibilities (e.g., National Weather Service).
- Land management agencies.
- Other levee owner/operators within the watershed.
- Community leaders and other trusted messengers who can help reach out to members of underserved communities.

- Community members who could be impacted by a levee emergency.
- Transportation and communication entities.
- Federal Emergency Management Agency (FEMA) and other federal agencies.
- Utility companies.

Partner responsibilities during a levee emergency are discussed in more detail in section 2.5 of this chapter.

2.2 Understanding Levee Risks

Understanding the levee risk is an important step in planning for an emergency.

Risk assessments identify and estimate levee risks. These risks can be driven by the hazards to the levee, performance of the levee, or consequences behind a levee. It is a best practice for emergency preparedness planning to address identified levee risk drivers. Best practices for estimating levee risk are detailed in **Chapter 4**.

An understanding of levee risk should inform the scale of emergency planning and preparation efforts. Levees with higher risk should have more extensive and detailed planning and preparation. In particular, levees that have both a potential for life loss due to breach and performance concerns that could cause breach prior to overtopping should have comprehensive emergency preparation and planning that includes all of the best practices identified in this chapter. Emergency planning and preparation for levees

TRAIN BLOCKING CLOSURE STRUCTURE

During Hurricane Ida, a levee intended to reduce flood risks to the Borough of Bound Brook, New Jersey was operationally compromised due to a commuter train blocking a levee closure structure.

The levee includes two vehicle closure structures and two railroad closure structures. The two vehicle structures and one of the railroad structures were closed successfully prior to the storm. However, a New Jersey transit commuter train became immobilized with the tail end of the train across one of the railroad closure structures, preventing its closure. Efforts to move the train were unsuccessful. One gate was closed, while the other was placed against the train with sandbags filling the gaps. However, the arrangement did not hold, and when floodwater from the adjacent creek rose up to the train tracks, water entered the leveed area resulting in significant property damages.

Lessons learned: Pre-coordination and emergency planning between levee owner/operators and the owners of transportation corridors that pass through the levee is essential. Coordination should include plans for typical closures, as well as emergency actions to address unexpected issues. In this case, a plan to move disabled trains and other blockages from the closure opening could have resulted in a more effective response.



Aerial view of a train blocking operation of a closure structure during a flood in Bound Brook, New Jersey.

without a population at risk may be scaled such that the effort and investment is commensurate with levee risk. More discussion on determining the appropriate level of detail for emergency planning is in section 2.3.1.

2.2.1 Hazards

In order to develop hazard-specific emergency action plans, it is important to understand the hazards a levee could encounter. Knowing the specific characteristics of the flood hazard is essential to planning emergency response activities that are appropriately scaled and timed. These characteristics include the:

- Flood source or combination of flood sources that could load the levee.
- Rate at which the flood source typically rises.
- Typical durations of floods.
- Estimated frequency of various flood loadings.

Different sources of flood hazards are discussed in detail in Chapters 1 and 4.

Hazards to a levee can be dynamic and diverse. Earthquakes and weather-related hazards such as extreme winds, drought, extreme heat, and wildfires—can threaten the integrity of the levee. Climate change is increasing the frequency and intensity of extreme weather events. Emergency preparedness requires careful consideration to ensure the frequency and scale of all current and potential future hazards are accounted for.

2.2.2 Performance

Risk assessments identify **potential failure modes**, which are mechanisms that once initiated could progress to breach of a levee. The five most common potential failure modes for a levee are shown in Figure 10-3. These potential failure modes are introduced in **Chapter 2** and are discussed in more detail in **Chapter 4**.

Understanding the potential failure modes which are likely to occur can inform emergency planning and response, including the focus of flood inspections, the development of pre-planned floodfight actions, and the management of materials and resources.



Figure 10-3: Potential Failure Modes

2.2.3 Consequences

Levee emergencies that result in a levee breach can cause loss of life and significant property and/or environmental damage. Risk assessments can provide information regarding the potential consequences of a levee breach, including infrastructure that could be impacted and communities which may have higher exposure to flooding. Community exposure could be influenced by a population's location within the leveed area, ability to access flood risk and emergency information, or ability to get out of harm's way during a flood.

Risk assessments also estimate the depth of flooding in certain breach scenarios and how quickly floodwaters can move through a leveed area. Inundation mapping can be utilized to

portray these impacts visually, as discussed in section 2.8. Consequence assessments are discussed in more detail in **Chapter 4**.

It is a best practice to tailor emergency response actions to the specific characteristics of the leveed area, including community characteristics and the depth and rate of inundation.

The consequences of levee breach may include impacts to other flood risk management infrastructure. For example, a levee breach may impact how water moves through the floodway, increasing the rate or depth of loading on other levees, which could result in cascading flooding or damage. Effective preparedness planning requires identifying and documenting these interdependencies and ensuring proper coordination when a levee is part of a broader flood risk management system.

2.3 Developing an Emergency Action Plan

Well-developed and practiced emergency action plans facilitate an effective response to and recovery from a levee emergency based on pre-established and coordinated activities, as opposed to purely reacting to an emergency as it occurs. It is a best practice for each levee to have an emergency action plan that is properly scaled, flexible, frequently updated, and exercised often.

2.3.1 Level of Detail

The appropriate amount of detail to include in an emergency action plan will vary based on the physical characteristics of the levee, the complexity of levee operations, and the levee risk. Figure 10-4 provides examples of how some of the key contents of an emergency action plan should be scaled, depending on the characteristics of the levee.

Figure 10-4: Emergency Action Plan Scalability



Levee owner/operators for levees without a population-at-risk may decide to limit their emergency action planning to:

- Developing an organizational chart or roster with contact information.
- Developing a list and map of important levee features to share with partners.
- Sharing a map of potential flood extents from the National Leve Database (NLD).

Levee owner/operators may also choose to include floodfight procedures in their planning to help ensure the levee will provide its intended benefits.

Emergency planning for a levee with any population at risk should include the items listed in the paragraph above, as well as levee and flood source monitoring procedures, detailed emergency notification procedures, and a description of the levee owner/operator's role in evacuation decisions and execution.

Higher risk levees—those with a population at risk and a likelihood of inundation either due to breach or overtopping—should have detailed emergency plans that include all of the best practices discussed in this chapter. The focus of emergency planning should be targeted to address the appropriate risk driver. For example, emergency planning for a levee with identified performance risk drivers likely to cause breach prior to overtopping will include detailed inspection, monitoring, and floodfight actions to address the identified performance concern, as well as detailed emergency notification procedures and a description of the levee owner/operator's role in the evacuation process. Emergency planning for higher risk levees that are not expected to breach prior to overtopping will likely focus on flood source monitoring, detailed emergency notification procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation procedures, and a description of the levee owner/operator's role in the evacuation process, as well as general floodfight methods to address unanticipated performance concerns.

When determining the appropriate level of detail to include in each section of a levee emergency action plan, levee owner/operators should consider the following questions:

- Is there risk to life if the levee is breached? Good emergency action plans for levees where there is a potential for loss of life contain a high level of detail to address and mitigate the risk of life loss. If there is no potential for life loss, the emergency action plan may contain less detail.
- What is located in the leveed area that could be inundated in the event of a levee breach? Determine what is located in the inundation area and how leveed area infrastructure should be addressed in the planning process. Infrastructure that may require special consideration include hospitals, schools, nationally or regionally significant industries, hazardous materials, transportation corridors, evacuation routes, and other critical infrastructure.
- Who is located in the leveed area that could be impacted by a levee breach? Determine what communities are present within the leveed area and the unique needs they may have during an emergency. It is a best practice for all communities within the leveed area to be engaged and considered in the planning process. Targeted efforts focused on long-term relationship building may be required to develop relationships and build trust with traditionally underserved communities.

- Who has decision-making authority for taking emergency action on the levee and within the leveed area? Determine if the decision-making authority for taking emergency action resides at the levee owner/operator level or if local officials need to be involved in the process. Provide clear roles and responsibilities within the plan.
- What floodfight actions and materials will be required to respond to an emergency at the levee? Identify actions and materials that will be necessary to protect the levee during an emergency. An emergency action plan is more effective when it clearly identifies anticipated floodfight actions, the materials needed to support them, and where the materials are located and how to use them.

Regardless of the factors that could affect the level of detail in an emergency action plan, the key elements provided below are found in comprehensive emergency action plans. Additional emergency action plan details, sections, appendices, and references can be incorporated as necessary based on the attributes of that particular levee.

2.3.2 Key Elements

Emergency action plans typically contain a consistent set of key elements. The most common elements are discussed in Table 10-1. Ensuring all key elements are included in a levee emergency action plan provides uniform, comprehensive, and consistent levee emergency planning. Other common elements of an emergency action plan include title page, table of contents, signatures page, statement of purpose, and project description. Supplementary information can also be included as appendices to the plan.

		Additional Information for:		
Key Element	Description of Content	Developing Plan Content	Implementing Plan Content	
Notification flowchart and contact information	A notification flowchart identifies who is to be notified of a levee emergency, by whom, and in what order. Notification flowcharts and emergency contact lists ensure prompt and effective notifications during a potential levee emergency.	Section 2.4 Section 2.7.1	Section 4.4	
Responsibilities	 Clearly defined responsibilities of all partners before, during, and after an emergency improves efficiency and continuity of response efforts. This may include identifying: Notification and communication responsibilities. Evacuation responsibilities, if applicable. Monitoring, security, termination, and follow-up responsibilities. Emergency action plan coordinator responsibilities. 	Section 2.1 Section 2.3.3 Section 2.7.1 Section 2.7.2 Section 2.10	Section 3 Section 4 Section 5	

Table 10-1: Emergency Action Plan Key Elements

		Additional Info	ormation for:
Key Element	Description of Content	Developing Plan Content	Implementing Plan Content
Incident detection, evaluation, and classification	An incident classification system allows for quick and clear communication regarding the severity of an incident. It is helpful for each pre-established classification to be associated with typical levee conditions that are likely to be experienced and the associated response actions.	Section 2.6	Section 4.1
Response actions	 Monitoring procedures. Notification and evacuation procedures. Pre-planned floodfight actions and materials. Procedures for responding during periods of darkness, weekends, holidays, and adverse weather. 	Section 2.7	Section 4
Additional preparedness activities	 Additional information found in a comprehensive emergency action plan: Implementation time: The total time from detection, required to determine the severity of incident, notify appropriate partners, and take necessary actions. Site access: Primary routes for reaching the levee during an emergency and alternate access options if the main access route is impacted by flooding of the leveed area. This may include the various levee access methods (e.g., foot, boat, helicopter). Stockpiling floodfight materials and equipment: Location and quantity of resources for response actions. Contact information for local contractors, suppliers or organizations who may support response activities. Alternative systems of communication: Available communication systems such as emergency sirens, cellular phones, direct connect, email, intranet, radios, social media, satellite phones and couriers, along with operating procedures for each system. Alternative sources of power: Location, mode of operation, means of transportation for alternative power sources for operations. Training and exercises: Types and frequencies of training to ensure those involved in the implementation of the 	Section 2.1 Section 2.7.3 Section 2.9 Section 2.10	Section 4.4

		Additional Information for:		
Key Element	Description of Content	Developing Plan Content	Implementing Plan Content	
	 emergency action plan are thoroughly familiar with the plan and their responsibilities. Public awareness and communication: Description of necessary activities to raise awareness before an emergency and ensure effective communication during an emergency. 			
Inundation maps	Inundation maps delineate the specific geographical area(s) that would be flooded due to a hypothetical levee breach, overtopping, or malfunction/misoperation of a levee feature. These maps are developed in coordination with the appropriate emergency management agencies. These maps can improve the effectiveness of response actions and evacuation plans by identifying when access routes may be inundated and the depths of flooding.	Section 2.8		
Post-event actions	Documentation and recovery procedures.	Section 4.6	Section 5	

2.3.3 Partner Involvement

The first step of emergency planning is identifying all levee emergency management partners. Effective levee emergency planning includes close coordination with all entities, jurisdictions, emergency management agencies, and regulating agencies that typically would be involved with an incident at a levee or that have statutory responsibilities for warning, evacuation, and postemergency actions.

The process of emergency planning is often as important as the actual plan due to the connections made among the various partners. A list of partners that are typically involved in levee emergency management is provided in section 2.1.

Emergency planning will not be helpful if those responsible for executing the plan are not trained on how to execute it together. Training and exercising a levee's emergency action plan with partners provides opportunities to evaluate the effectiveness of the plan and determine whether the goals, objectives, decisions, actions, and timing outlined in

EMERGENCY ACTION PLAN COORDINATION

It is a best practice for levee emergency action plans to be written and updated in close coordination with partners to ensure consistency and common understanding. Good coordination efforts address the following questions:

- What incidents necessitate heightened awareness?
- At what point during an incident should the levee owner/operator notify emergency management agencies?
- Who in each organization will be responsible for sending and receiving notifications?
- Who will be responsible for decisions about and coordination of protective actions such as evacuation and re-entry?

The goal of coordination is to develop a joint understanding of evolving dependencies and interdependencies. the plan are appropriate and comprehensive. Gaps or deficiencies in the plan identified during training, exercises, or real-world events should inform updates to improve the plan. Additional discussion of training and exercises is provided in section 2.10.

2.3.4 Maintenance and Updates

Annual reviews of the emergency action plan ensures the plan remains relevant and useable. It is important to immediately update the plan to incorporate changes in personnel and contact information, as well as significant changes to levee or emergency procedures.

It is also beneficial to review the plan after floods and events triggering its activation to determine if there are opportunities for improvement. These reviews may prompt plan updates following emergencies. Feedback provided by stakeholders may also trigger an update. Coordination with partners and redistribution of the plan during significant revisions will help ensure continued understanding of roles and processes by all.

2.3.5 Distribution

All partners should have access to the emergency action plan; however, managing distribution of a levee emergency action plan can be an important part of levee security. It can be helpful to develop a distribution list that is included as an appendix to the plan. The distribution list should include all stakeholders that would be involved in implementing the plan. The list should be reviewed and refined during emergency action plan updates.

In some cases, there may be a need to maintain document control and protect critical information. A good way to do this is by assigning a copy number to each copy of the plan that is distributed and requesting that other copies of the emergency action plan not be made.

When outdated emergency action plans have been replaced in their entirety with new versions, it is good policy for the outdated controlled copies to be returned to the developer or destroyed to prevent misuse. Document control can be maintained for emergency action plans that are made available electronically, through the use of a secure web portal accessible only to the entities on the established distribution list. In addition to electronic copies of the plans, it is best practice to have a limited number of hard copies available in the event of a power outage, cyberattack, or lack of access to the electronic versions of the plan.

To protect critical information, it may be important to limit distribution of technical data and personal contact information contained in the plan. This type of information control can be accomplished by placing technical information—such as engineering details, potential failure modes, and facility details—into an appendix to the emergency action plan and limiting dissemination of the appendix to those who have a specific need for the information. It is also important to ensure that plans containing critical information are labeled appropriately.

Additionally, uploading completed or revised emergency action plans to the NLD linked to the respective levee is encouraged for ease of access by local emergency management agencies and other state and federal partners (USACE, 2016).

2.4 Developing Notification Procedures

It is a best practice for levee owner/operators to develop and maintain accurate notification flowcharts and emergency contact lists for their levees to ensure prompt and effective

notifications during a levee emergency.

A notification flowchart is a communication guide that identifies who is to be notified of levee conditions during a flood, including a levee emergency, by whom, and in what order. It can be beneficial for levee owner/operators to develop internal and external notification flowcharts. Internal flowcharts are used to keep levee owner/operator staff aware of ongoing flood operations. Internal charts are usually implemented when a flood is forecasted and then used throughout the flood for internal coordination. External notification flowcharts are used to keep external partners aware of conditions on the levee once it is loaded and to initiate emergency warnings and inform evacuation decisions should an emergency occur.

It is best to limit notification responsibilities for a single individual to no more than three or four parties and to take into account the magnitude of other responsibilities the person has been assigned.

Notification flowcharts should be

SAMPLE NOTIFICATION FLOWCHART



developed in collaboration with appropriate partners to identify who to include and how complex the notification process needs to be. One flowchart or a set of flowcharts may be needed depending on the number of entities involved. At a minimum, useful notification flowcharts will identify communication processes for the levee owner/operator, the local emergency management agency, and the entity responsible for making evacuation decisions. The National Weather Service should also be included in notification flowcharts since they issue flood warnings, particularly in the event of a levee breach or overtopping, which need to be informed by levee conditions. In some cases, particularly when working with underserved communities, trust can be an issue. It is a best practice to identify trusted community leaders that can be included in the notification process to increase the likelihood messages will be received and heeded.

Instructions on how to use the notification flowcharts can be developed to support efficient implementation of the notification process. Thoroughly and regularly exercising notification flowcharts with all involved personnel and partners helps ensure the accuracy of the flowcharts and that all responsible individuals understand their role in the process.

Notification flowcharts that clearly present the information listed below and are included in the emergency action plan are easier to use during an incident.

- Description of the notification flowchart purpose, especially if there is more than one flowchart.
- Prioritization of notifications.
- Specific agencies and individuals who will be notified with names, positions, and telephone numbers.

Supplemental contact information, such as radio call numbers, fax numbers, e-mail addresses, direct connect numbers, and alternate contacts, may be included in a list or table of emergency contacts.

2.5 Understanding Roles

Understanding the roles of all partners responsible for responding to an incident during a flood is important for emergency preparedness. When organizations work to understand their role for incident response within the broader community, as well as work to assign and clarify roles within their organization, both organizations and individuals gain a better understanding of their responsibilities during an emergency.

2.5.1 Common Levee Owner/Operator Activities

The primary objective during a levee emergency is to protect life and property by maintaining integrity of the levee and to facilitate actions to get people out of harm's way if levee overtopping or breach is unavoidable.

These objectives can be accomplished by assigning specific individuals the responsibility to perform, oversee, and make critical decisions concerning the following activities:

- Maintain situational awareness (flood source monitoring).
 - Monitor meteorological forecasts that may predict the probability of high rainfall or a storm.
 - Monitor flood stages.
- Constantly verify and assess conditions at the levee.
 - Inspect the levee and features.
 - Implement necessary preliminary response actions.

- Actively monitor events as they unfold and prepare to implement full response activities.
- Notify participating emergency management agencies of levee conditions.
- After the peak of the emergency, initiate post-response and recovery activities to allow a return to normal conditions.
- Communicate termination of the emergency at the levee when emergency conditions have subsided.

2.5.2 Jurisdictional Oversight

Responsibilities for managing flood risks and responding to levee emergencies is commonly shared across several federal, state/territory, regional, tribal, and local agencies. Most activities to reduce the risk communities face from floods are handled at the local level.

Every levee emergency begins at the local level. If the levee owner/operator is unable to handle the emergency, there are many ways the government can assist. For example, the county or state may provide additional assets (e.g., trucks, tractors, radios, helicopters) for flood-related inspections and financial assistance for response and recovery activities.

If a levee owner/operator runs out of supplies, they can request assistance from local and state governments, and if necessary, local and state governments can coordinate additional assistance from the federal government. Depending on the lead time available before an incident occurs, decisions and requests for resources may be made several days in advance so that resources can be mobilized and in position before the arrival of the hazard. Incidents that occur without warning present significant complications and resource challenges. During emergencies, actions to stabilize the levee, evacuate, or shelter-inplace may occur simultaneously with limited resources.

It is important to remember that in order for the government to provide assistance, an emergency declaration must be made. Each level of government has criteria in place that determines whether a situation can be declared an emergency. In instances where an



incident at a levee does not meet these criteria, assistance from that level of government will not be provided. Plans should be in place to supplement resources by other means in these situations.

EMERGENCY RESPONSE

2.5.3 External Agency Assistance

It is vital that levee owner/operators are aware of the type of support that external agencies within their community can provide, and whom to contact to receive the necessary support. A list of common groups that often assist in responding to levee emergencies include:

- Emergency management departments
- Law enforcement agencies
- Fire departments
- Public works departments
- Communication specialists
- Utility/power companies
- Transportation agencies
- Mass care/shelter facilities
- Agriculture/natural resources
- Public health and medical facilities
- Search and rescue agencies
- Hazardous material cleanup companies

Identifying all potential resources and coordinating with the identified resources before an emergency will allow for more efficient communication during an actual emergency. Building relationships with local power and communication suppliers prior to an emergency can allow for early warning of power outages when possible and the potential for priority repairs, when appropriate.

2.6 Classifying Incidents

Using clear, concise language to describe a flood event is important when communicating

TRUCK STRANDED ON LEVEE DURING FLOOD

In 2019, several roads around the Missouri River levee in Chariton County, Missouri, were closed as a result of construction and flooding. Due to all of the main roads being closed, a truck driver used his global positioning system (GPS) to find an alternate route.

The GPS led the truck driver to the top of a levee that overtopped both in front and behind his truck. The truck driver contacted 911 who alerted the local Chariton County Sheriff's office. The Sheriff's office contacted USACE who was able to use their helicopter to rescue the truck driver. The truck remained on the levee for months.

Ensuring proper road closures are in place to protect the safety of the public and avoid this type of situation is an integral part of managing a levee emergency.



View of the Fruit Stripe Gum semi-truck blocking a levee crown road during a flood.

with the public and other supporting organizations. An incident classification system provides common terms and consistent definitions that can help quickly and clearly communicate the severity of an incident, general levee conditions, and associated incident management activities. Development and use of an incident classification system helps expedite activities such as evacuation of the leveed area.

To promote nationwide consistency, four levee-related incident classifications, described in Table 10-2, are suggested to aid communication during an emergency. Regardless of the incident classification system chosen for a community or levee, it is important for all entities involved in flood emergency response to understand the incident classification system and the expected responses.

Classification	Description
High flow	Indicates water is flowing through or over the levee as intended by design. This classification may be used to convey to the impacted public that leveed areas may be affected by the flows, but there is no apparent threat to the integrity of the levee. Examples of high-water flow releases that could come through or over a levee include pipe, outlet, or a designed overtopping section.
Non-breach	Indicates a levee-related event that will not, by itself, lead to a breach, but requires investigation, increased monitoring/floodfight action, and notification of internal and/or external personnel. A certain water elevation or storm surge may be defined that requires increased monitoring and surveillance above normal O&M procedures as non-breach. Additionally, this emergency classification may be applied to limited overtopping for a levee with no risk of breaching due to a designed overtopping section or other features designed to withstand wave energy during hurricanes.
Potential breach	Indicates that levee conditions are developing that could lead to breach. Potential breach conveys that time is available for analyses and decisions, and actions should be taken to prevent escalation of the incident to a full breach.
Imminent breach	Indicates the levee has breached, is actively breaching, or is about to breach. Imminent breach typically involves a continuing and progressive loss of material from the levee.

Table 10-2: Incident Classifications

2.6.1 Determining Incident Classifications

It is a best practice for pre-flood preparations to include the development of an incident classification system and guidelines that describe how incident classifications will be applied to the levee. For consistency in decision making, it is best to assign a single individual the responsibility of assessing performance concerns and assigning an incident classification. Table 10-3 provides sample guidance for determining incident classifications for different types of incidents. This table should be modified to guide incident classifications at a specific levee. Levee specific information that can be considered when developing guidance for incident classification includes:

- The level of risk associated with the levee.
- Flood source levels or predictions that indicate response actions are required.
- Instrumentation readings that indicate possible performance concerns.
- Past levee performance.
- Confidence in the success of future floodfight actions.

		ISSUE: SEEPAGE
Incident Classificatior	Action	Actions to Be Taken
	Notify	Notify the floodfight team of the seepage issue. Consider issuing non-breach notice to partners and the public describing seepage, floodfight actions, and the status of the levee.
Non-breach: Seepage without soil movement, or sand boils	Monitor and inspect	Inspect at least daily. A rising flood source may warrant more frequent inspection. Monitor flood source forecasts. As flood water rises, seepage issues are likely to worsen.
that are easily managed with routine floodfight measures.	Floodfight	Raise the water level over each sand boil by placing a ring of sandbags, pipe, or barrel around the boil, blocking culverts in ditches, or using any other means of detaining water that is most practical for the site. The sandbag ring or barrel must have a water discharge elevation that allows water to flow while slowing the water flow enough to prevent soil movement.
Potential breach:	Notify	Notify floodfight team and partners of the seepage issue. Issue potential breach notification to the public in accordance with the emergency action plan. Consider starting voluntary evacuations of areas that would be impacted quickly by a breach and populations requiring more time to evacuate.
Localized seepage or boil(s) observed along the levee with muddy discharge and	Monitor and inspect	Inspect at least once every six hours and monitor flood source forecasts if conditions are stable. Inspect levee continuously if the flow rate or the material movement from the boils is increasing or if the flood source is rising.
increasing flow. Emergency floodfight measures are required, but are expected to be successful.	Floodfight	Raise the water level over the sand boil as described for the non- breach classification. Continue to raise the height of the water as necessary to prevent soil movement. If the size or number of boils makes sandbag rings ineffective, place an emergency seepage berm over the entire seepage area using material that is less permeable than the underlying soils, or build an impermeable soil ring around the entire seepage area to impound water over the seepage area and create a water berm.
Imminent breach: Sand boils becoming	Notify	Follow the notification and evacuation processes in the emergency action plan. Notify floodfight team of the seepage issue.
increasingly active, moving large amounts of material and floodfighting	Monitor and inspect	Continuously inspect the levee performance from a safe location. Drones or other remote observation tools may be considered.
actions have not been successful. Cracks, sinkholes, or subsidence of nearby levee has beer observed. Floodfight actions are not possible or not effective.	¹ Floodfight	Floodfight actions are likely not safe. If safe and possible, continue to reinforce the area impacted by the sand boil(s) by placing additional gravel or sand over the area or raising the water level over the sand boil(s). Should the ground surface become very soft, 'quick,' or start to move, evacuate the area immediately.

Table 10-3: Example Guidance for Determining Incident Classification and Pre Planned Actions for Seepage Issues

2.7 Planning Response Actions

Developing pre-planned actions allows for seamless response to incidents and emergencies. Correlating pre-planned actions to incident classifications allows for quick, clear communication of levee conditions to initiate those actions. It is a best practice to develop specific pre-planned actions correlated with the pre-established incident level classification for all plausible levee issues. Pre-planned actions should include incident/emergency notifications and floodfight actions. Table 10-3 provides example response actions that can be used as a starting point to develop levee specific actions that reflect unique levee conditions, available resources, and level of risk.

Understanding how the levee is likely to perform as water levels rise is critical to developing proactive pre-planned actions. Triggers based on current or projected flood source conditions can be developed to inform flood operations. The most useful triggers take into account the rate of rise of the flood source, past performance of the levee, available resources, and the complexity of the levee and the leveed area.

Due to trends in climate change, triggers and pre-planned actions may need to account for increasingly heavy precipitation with rapid flooding potential, higher flow releases from reservoirs, rain-on-snow compound events, increased wave heights, and increasing wind strength. For example, more frequent events may require adjustments in how resources are managed. More extreme events may require the identification of additional labor resources, adjustments to flood operation plans, or updates to emergency notification procedures. An increase in how quickly the flood source rises may require that operation and response thresholds be adjusted.

2.7.1 Notification Procedures

During an emergency there is limited time for determining who should communicate and what should be communicated. When there is a likelihood of life loss associated with levee breach or overtopping, effective notification procedures are essential. Pre-planned and coordinated processes can help ensure notifications are timely and informative.

It is a best practice to develop checklists and/or pre-scripted messages for each incident classification level to help adequately describe the situation to emergency management agencies and other stakeholders.

Examples of a notification checklist and pre-scripted messages are included in Appendix 6-I of Chapter 6 of the Federal Energy Regulatory Commission Engineering Guidelines (FERC, 2015).

An emergency message toolkit that contains information on the appropriate properties of an emergency message, example messages and templates, and other helpful information relating to communicating during a levee emergency can be found in The Guide to Public Alerts and Warnings for Dam and Levee Emergencies (Milleti and Sorensen, 2015).

During a flood event, it is a best practice for those responsible for operating the levee to relay periodic and emergency status reports to the emergency management agencies and other partners, in accordance with notification flowcharts described in section 2.4. Pre-scripted

messages can help ensure the timeliness and clarity of all flood- and emergency-related information.

Local emergency management agencies and others responsible for emergency communication will issue warnings and notices to the public. Levee owners can work with their local emergency management agency to provide information about levee conditions to the National Weather Service during floods. The National Weather Service will consider levee information when developing emergency messages and can help to quickly disseminate warnings concerning flash flooding, levee breach, or levee overtopping to the public through the National Emergency Alert System and wireless emergency alerts.

It is beneficial to identify an individual who will have the primary responsibility for disseminating information to the public and handling media inquiries. These individuals are often trained public information officers, but at a minimum, this should be someone knowledgeable of the levee

SAMPLE PRE-SCRIPTED MESSAGE TEMPLATE FOR IMMINENT BREACH

[Insert title and organization of a local, familiar, authoritative message source.]

The levee in [describe the levee's location in terms that everyone can understand here] started to breach at [insert time here]. Flooding has begun and will quickly worsen. There is rapidly moving water that will reach depths of [insert depth here] feet, which can [describe impacts on people, houses, and cars].

The flooded areas will include: [describe the boundaries of the area that will flood in a way that everyone can understand].

[Evacuation information – typically provided by local sheriff's office or office of emergency services.]

This message will be updated in [insert number of minutes here] minutes or sooner if new information is available.

(Milleti and Sorensen, 2015)

and incident response activities. It is also useful to identify a designated location to handle these communications, such as a joint information center.

Communications are more successful when the individual with primary communication responsibility works with media outlets and community leaders to craft pre-planned messages. It is important to give thought to the appropriate language, format, message, and messenger, particularly when seeking effective ways to provide emergency information to traditionally underserved communities and vulnerable communities. **Chapter 3** provides additional information on engaging with underserved populations.

It can be helpful for pre-flood notification planning to include identification of conditions under which deviation from the approved notification process may be warranted. In some situations, time may be allowed for on-site personnel to consult with others within their organization prior to initiating notifications to emergency management agencies. However, under an imminent breach incident, steps in the notification process may need to be skipped in order to provide timely notification that facilitates the necessary actions.

2.7.2 Evacuation Procedures

Local and county government agencies are typically responsible for issuing evacuation orders and for evacuation planning. Close coordination with the appropriate governmental agencies and community leaders to clarify the roles of all partners in the evacuation process and facilitate the timely sharing of levee information that informs evacuation decisions is a best practice.

Pre-emergency collaboration with key partners includes:

- Establishing preferred lines of communication.
- Defining roles and responsibilities during an evacuation.
- Ensuring an understanding of the levee's specific incident classification systems (section 2.6).
- Utilizing the levee's risk assessment to establish the most effective evacuation routes and identify potential issues with existing evacuation routes.
- Communicating intended evacuation actions with the community.
- Collaborating with communities to develop solutions for those that may require additional assistance due to lack of mobility/transportation, lack of access to technology/information, or limited English proficiency.

Evacuation planning should recognize there may be communities or locations within the leveed area that require non-typical means of notification. Populations that do not speak English, lack mobility or means of transportation, have limited access to technology, live in extreme poverty, or other characteristics that increase their vulnerability may have difficulty receiving and responding to evacuation notifications. Residences, recreation areas, and campgrounds that are immediately adjacent to the levee pose unique notification challenges, as typical means of notification may not provide adequate time for individuals in these areas to act.

EVACUATION PLANNING RESOURCES

Evacuation Planning and Re-entry Course is a course offered in FEMA's Advance Professional Series. This series may be accessed through FEMA's website and offers "how to" training focused on practical information and emphasizes applied skills in disaster operations, management, and coordination.

Greater Impact: How Disasters Effect

People in Low Socioeconomic Status is a Supplemental Research Bulletin developed by the Substance Abuse and Mental Health Services Administration that is focused on how people in poverty, with low incomes, and of low socioeconomic status experience disasters. Among other topics, it addresses people who may have a lower likelihood of receiving warnings, of having the ability to evacuate, and of accessing post-disaster aid (SAMHSA, 2017).

It is necessary to identify and plan for all evacuation challenges. Tools that may be helpful include issuing emergency notification in multiple languages, providing transportation and shelters, and door-to-door direct notifications. For additional information regarding evacuation planning, see **Chapter 12**.

2.7.3 Pre-Planned Floodfight Actions

Floodfight is the implementation of measures before and during a flood to maintain functionality of a levee or reduce flood damage. Floodfight actions range from routine, pre-planned actions to non-typical, emergency actions that are required to prevent progression of an issue that could lead to levee breach.

Understanding what actions may be required to maintain the levee during a flood event is integral to effective preparedness. This requires a clear understanding of what performance concerns are likely to arise and the techniques that will be used to address them. It is a best practice to develop pre-planned floodfight actions for all likely potential failure modes that are incremental in nature, providing for escalating levels of response based on the severity of the

performance concern. Incident classifications are useful for communicating the severity of performance concerns and determining appropriate floodfight actions. An example of preplanned floodfight actions targeted at dams is provided in Chapter 6 of the Federal Energy Regulatory Commission's Engineering Guidelines, Table 6-K-1 (FERC, 1987).

Examples of floodfight actions for various incident classifications were developed for levees based on the Federal Energy Regulatory Commission's table and are provided in Table 10-3 for demonstrative purposes. This table contains general examples that likely do not address all of

the unique physical and risk characteristics of a specific levee.

The highest level of floodfight planning should be implemented when there is a population at risk and one or more failure modes have been identified that are likely to cause breach prior to overtopping. The scale of preplanned floodfight actions will inform pre-flood preparations including stockpiling floodfight materials and equipment (section 2.9.1) and floodfight staffing and training (section 2.10). Preparing to execute floodfight actions also includes:

- Ensuring adequate access to the levee considering:
 - Locked gates.
 - Issues associated with inclement weather and road flooding due to rainfall.
 - Businesses that operate adjacent to the levee.
 - Areas where the levee is used for grazing animals.
- Identifying sources for adequate lighting to ensure the ability to respond after hours.
- Identifying alternate systems of communication (section 2.9.2).
- Identifying alternate power sources (section 2.9.2).

2.7.4 Transference of Risk

Floodfighting activities are intended to mitigate the consequences of floods; however, some floodfight techniques, such as raising a levee to prevent overtopping, may transfer flood risk to others. This type of risk transfer can impact those behind levees and those within the floodplain that do not have levees.

Levee owner/operators should understand how actions on their levee impact the wider floodplain and ensure proper coordination when a levee is part of a broader flood risk management system involving other levee districts and communities. A best practice is to have a regional plan concerning how floodfight measures—such as emergency levee raises—are implemented throughout a basin.

REFERENCE MATERIALS

The following publications include floodfight techniques to inform incident/emergency planning and response.

- Evaluation Design and Construction of Levees, Engineer Manual (EM) 1110-2-1913, Appendix I, (USACE, 2000).
- International Levee Handbook, Section 6.5 (Eau and Fleuves, 2017).
- Emergency Flood Fighting Methods, State of California Department of Water Resources, Flood Management Flood Operations Branch (CaDWR, 2012).

2.8 Using Inundation Maps

Inundation maps are maps that show potential flooding that could result from a hypothetical breach of a levee. It is a best practice to incorporate inundation maps into the emergency action plan. This section provides a high-level overview of the significant concepts to consider when developing levee inundation maps for levee emergency management and identifies resources that contain more information on preparing inundation maps. The rigor required for inundation mapping is scalable based upon the flood and levee risks associated with the levee.

The NLD is a starting point for an inundation map. The NLD displays a shaded area behind all levees called the leveed area. The leveed area is the most conservative estimation of the area that could potentially be flooded due to a levee breach. Generally, the leveed area is developed by projecting the top of the levee back to high ground, with some exceptions based on topography. Viewing leveed area delineations (Figure 10-5) within the NLD can help determine where flooding is possible to inform evacuation planning. This level of rigor in inundation mapping is only appropriate for levees where there is no population at risk within the leveed area.

More detailed inundation mapping showing potential breach or overtopping locations is required for levees with life safety risk. Inundation maps showing worst case flood depths based on worst case inundation scenarios may be adequate for moderate risk levees. Inundation maps that include inundation scenarios tied to risk-driving potential failure modes with flood depths and arrival times are recommended for higher risk levees. It is a best practice, for emergency planning for levees with a potential for life loss to be guided by detailed inundation mapping that identifies flood depths and arrival times for likely breach or overtopping scenarios. Resources for developing and updating inundation maps are described in **Chapter 4**.



Figure 10-5: Leveed Area from the National Levee Database

Galveston County Water Reservoir inundation map delineates the specific geographical area(s) that would be flooded due to a hypothetical levee breach, overtopping, or malfunction/misoperation of a levee feature.

Developing or updating inundation maps prior to an actual emergency is an essential step in levee emergency management as the data, models, and maps can be used for:

- Understanding if there is potential for loss of life, including location and severity.
- Developing emergency action plans and evacuation planning to reduce risks to life and property.
- Communicating flood and levee risks.
- Identifying inundation impact zones to support flood warning systems.

Inundation mapping can also be developed during a flood to show the extent of flooding that could occur based on real-time observed conditions to depict the potential flood hazard more accurately.

2.8.1 Hypothetical Scenarios

Developing inundation maps for a range of hypothetical scenarios could help prepare for a future emergency. Typical scenarios include an overtopping with breach event, in which flood

waters exceed the levee height and breach the levee, as well as scenarios in which the levee has failed before it overtops, or the levee overtops but does not breach. Scenarios with prior to overtopping breaches may consider a range of hydrologic loadings, including the design flood level, a historic flood level, or a level which was analyzed in recent risk assessments. In addition to considering various hydrologic loadings on the levee, breach scenarios may also consider the effects of various breach locations. Breach locations may be selected based on known levee vulnerabilities or locations where a breach could have particularly harmful or worst-case consequences. If available, risk assessment results can also be referenced to reveal where overtopping would likely occur or areas most likely to experience a breach prior to overtopping.

Breach parameters specific to the levee are needed to estimate the discharge into the leveed area. Breach parameters include width, depth, and shape of the breach; rate of breach formation; hydraulic head; and anticipated flood flow.

2.8.2 Inundation Map Key Characteristics

The most effective inundation maps include the extent and depth of flooding and the expected travel times to critical locations. Additional information that may be useful includes flow velocities and duration of inundation. Highlighting key locations, such as population areas, recreation areas, and any other significant features within the inundation zone can aid evacuation and rescue actions (Figure 10-6).

Key characteristics of an inundation map typically include:

- Inundation zones/polygons (extent and depths of flooding).
- Detailed information at key locations:
 - Flood wave travel times (in hours and minutes).
 - Expected peak water surface elevations or depths.
 - Expected peak velocities.
- Map collar information (map legend, notes to users/disclaimers, map scale box, panel locator diagram, tables, and title block).

Additional information which may be displayed on inundation maps include:

- Incremental rises in water levels.
- Estimated duration of inundation.
- Direction of flow.
- Critical infrastructure, residential and commercial developments, recreation areas, roads, railroads, bridges, and other significant features within the inundation zone.
- Base map data with a scale of at least 1:36,000.



Figure 10-6: Hypothetical Sacramento River Inundation Maps



2.8.3 Partner Coordination

Local emergency management agencies and community officials will rely heavily on inundation maps to effectively warn and evacuate people in the event of a potential levee emergency. Including those who will use the maps in map development and coordination can improve understanding and help to ensure proper implementation.

Emergency communication and actions can be expedited when applicable emergency management agencies retain current copies of the maps, ensure all team members understand how to interpret the maps, and verify the maps contain sufficient and current information.

Having partners review inundation maps to validate terrain data, such as identifying where bridges may block flow, where channels are blocked, where culverts exist under roads, and other items that may impact how the area would inundate can improve map quality.

2.8.4 Updating Inundation Maps

Levee owner/operators and emergency management agencies can keep inundation maps current through reviews to determine if any new developments, buildings, or recreation areas are constructed within inundation zones or if a known change in the levee (e.g., increased/decreased elevation, removal of structures or change in vulnerabilities) occurs. It is a best practice to review and update inundation maps every 10 years in conjunction with updating the levee risk assessment.

It is important to update inundation maps immediately if there are significant changes to development behind a levee that are not displayed on the existing inundation maps and more current base map information is available. Changes in the levee may trigger an update to the levee risk assessment, which may include updates to inundation mapping.

2.8.5 Digital Inundation Mapping

2.8.5.1 Interactive Use of Maps and Geospatial Data within a Digital Environment

Displaying inundation extents and other datasets within a digital geospatial environment provides many potential benefits to emergency responders. Inundation data, including arrival times, duration, and depth of flooding, are not easily annotated on a hard copy map. Multiple datasets can be displayed, and users may query the database for points of interest within the leveed area. Additionally, base map features not shown on an emergency action plan map, such as road centerlines, building footprints, and tax parcels, may provide additional critical information during an emergency.

There are currently numerous geospatial applications available that are fully compatible with mobile devices and allow users to access geospatial data through either locally stored data or web-based mapping systems including online map sites or cloud computing. These applications cater to a wide variety of user abilities—ranging from basic easy-to-use applications with limited functionality to highly complex and flexible applications suited to expert users.

Although mobile geospatial is not a solution suitable for all users and situations, the use of an inundation database—in combination with local and regional geospatial information in the digital environment—can potentially enhance a user's ability to respond when an emergency occurs

and unanticipated circumstances are encountered. Mobile geospatial will likely never completely replace hard copy inundation maps since the geospatial abilities of emergency responders likely vary considerably and there is always the potential for technical complications including power failure, overloaded communication systems, equipment damage, and software failure.

2.8.5.2 Animation

Animation can be another valuable tool for communicating the magnitude of flooding and response time needed in the event of a levee breach. Many software applications used for levee breach modeling provide varying degrees of functionality for plan view animation. Numerous online map applications also support the creation of animations, including flyovers. Although animations may rarely be used during an emergency, unless given a large



lead time, they can be valuable tools for training staff identified within an emergency action plan as responders. They can also be an important visualization tool for use in training and in public outreach efforts.

2.8.5.3 Innovative Solutions

Three-dimensional visualization does not always require geospatial data and graphic software applications. A simple, yet very effective, means of communicating the magnitude of inundation in three dimensions can involve the simple annotation of known landmarks with modeled high-water marks associated with a levee breach. Such annotations can help bring the severity of a potential event into context for those not familiar with the potential consequences of a levee breach. This type of visualization can be executed with a minimum of resources; all that is needed is an inundation elevation or depth, an image of a landmark, and a means of referencing the elevation or depth onto the image.

REFERENCE MATERIALS

There are several publications detailing the process of developing inundation maps that contain information applicable to levee owner/operators:

- Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures, FEMA P-946 (FEMA, 2013):
 - Provides guidance on how to prepare dam breach inundation modeling studies and generate maps that can be used for multiple purposes, including dam safety, hazard mitigation, consequence evaluation, and emergency management including developing emergency action plans.
- International Levee Handbook (Eau and Fleuves, 2017):
 - Chapter 8 covers topics pertaining to inundation and mapping including: input parameters and data requirements, types of inundation models, modeling approaches, model outputs, and treatment of uncertainties.
- Federal Energy Regulatory Commission Engineering Guidelines, Chapter 6 Emergency Action Plans (FERC, 2015):
 - Provides the Federal Energy Regulatory Commission's requirements for inundation mapping including information surrounding the topics of determining downstream impacts, preparing inundation maps, contents of inundation maps, cross-sectional information, additional information, sample inundation maps, coordination, and updating maps.
- Inundation Maps and Emergency Action Plans and Incident Management for Dams and Levees, Engineer Circular (EC) 1110-2-6075 USACE (USACE, 2002):
 - Provides requirements for inundation mapping for USACE operated and maintained dams and levees.

2.9 Managing Critical Resources

Preparedness activities, including the management of critical resources, should be scaled to be commensurate with levee risk and focused to address identified risk drivers. Levee with a population at risk and potential failure modes that are likely to cause breach prior to overtopping will have the most rigorous incident response planning, including floodfight actions to address risk driving failure mode. Preparedness activities should be tailored to support the scope and rigor of planned floodfight actions.

2.9.1 Stockpiling Floodfighting Materials and Equipment

It is best practice to document and maintain an adequate stockpile of floodfighting materials and equipment in a location that is easily and quickly accessible during flood operations. The quantity and type of materials to be stockpiled depends on the size of the levee, those used in previous floodfights, and anticipated flood operations based on previous risk assessments or evaluations of levee vulnerabilities. Good resource management includes regularly inventorying, inspecting, and maintaining floodfight materials and equipment to prevent degradation and replenishing resources found to be degraded. Resource inventory documentation typically includes the location, quantity, and type of material and equipment on hand.

A readily available and regularly updated directory of local vendors and suppliers for floodfighting materials and equipment including contact information and location is extremely helpful during floods. Contacting local vendors during the initial development of the emergency action plan and annually thereafter helps ensure they are available to provide the necessary materials and labor in the event of an emergency.

When selecting which type of floodfighting material to use, environmentally friendly choices that can be reused for future floods instead of one-time use products, such as reusable sandbags, or water-filled tubes instead of single use sandbags can help reduce waste.

2.9.2 Alternative Sources for Communication and Power

Preparing and training for communication outages concurrent with power outages, as well as identifying and practicing emergency response roles to be performed if communication and power are down during an emergency, improves readiness and resiliency.

Flood preparation activities that include identifying alternative sources of power for automated levee features help to ensure the levee can be operated under a wider range of circumstances. For example, generators can be obtained to provide backup power for electric powered features or multiple sources of fuel can be identified for diesel power pump stations.

Having alternative sources to supplement standard communication processes helps ensure communication can occur during emergency conditions. Many levees are located in remote locations with unreliable cell phone service. To complicate matters, it is common for cell towers to become overloaded during emergency situations. To ensure issues on the levee can be quickly and reliably reported to decision makers, secondary means of communication, such as radios, are imperative.

2.10 Training and Exercises

A plan for emergency response will provide limited value if it has not been practiced and communicated to those who will execute the plan's procedures. Training and exercises help ensure readiness by providing responders an opportunity to practice specific actions that typically occur during a levee emergency, such as removing debris, responding to sand boils, and performing flood inspections. Training and exercises also inform personnel about the time and resources necessary to complete certain tasks (Figure 10-7). Important practical considerations and physical limitations that could be easily overlooked in a plan are often identified during an exercise.



Figure 10-7: Emergency Responder Floodfight Training Session

Responders training to perform an emergency levee raise in California.

Generally, basic training and exercise activities include:

- Physical operation of project features (e.g., sluice gates, pumping stations, closure structures).
- Notification of emergency response personnel and verification of contact information.
- Testing of communication/backup communication systems.
- Mobilization of inspection teams and inspecting levee features.
- Floodfighting techniques.
- Data collection.
- Activation of rostered emergency teams and operation centers.
- Methods of coordination (e.g., between volunteers, patrols, nearby levee owner/operators, highway departments, state emergency operations center).
- Dissemination of information to the community.

Training and exercises can better inform future actions when they are documented, and the records maintained in a location that is easily accessible to personnel. Documentation typically

includes the names and roles of the participants involved, activities performed, and lessons learned.

2.10.1 Training

It is a best practice to create a dedicated incident response team that is continually trained and available for activation, described in section 2.5. An effective incident response team includes a sufficient number of trained people to ensure adequate coverage of the levee at all times. Team members who receive annual training in incident management, including detection, evaluation, classification, notification, and appropriate response actions are better prepared to act during emergencies. Cross-training of personnel in more than one role provides redundancy and flexibility in staffing response efforts.

Staff training for levees with a population at risk within the leveed area should be done on an annual basis. Staff for levees with a potential to breach prior to overtopping should be trained to recognize and respond to risk driving failure modes. The frequency and scope of training for levees with no life safety risk should be based upon the complexity of the levee, the scale of anticipated response actions, and the consequences of levee breach.

2.10.2 Emergency Action Plan Exercises

An emergency action plan exercise is an activity designed to promote emergency preparedness; test emergency action plans, procedures, or facilities; train personnel in emergency response; and demonstrate operational capability. Exercises consist of the performance of duties and operations similar to the way they would be performed in a real emergency. However, the exercise performance is in response to a simulated event.

Exercises play a vital role in emergency preparedness. A well-designed exercise provides a low-risk environment to familiarize personnel with roles and responsibilities; fosters meaningful interaction and communication across organizations; and assesses, validates, and identifies strengths and areas for improvement. Exercises can bring together partners and strengthen the community to reduce impacts of levee emergencies.

The Department of Homeland Security's Exercise and Evaluation Program provides in-depth information for planning, conducting, and evaluating individual exercises. A high-level overview of the program's guidelines is provided below (FEMA, 2020).

These can range from simple and informal discussion-based exercises for low complexity, lower risk levees to more formal operations-based exercises for higher risk levees.

Selecting which type of exercise is most appropriate for a particular levee will depend on the specific circumstances of a levee, such as the type and complexity of features which make up the system, the level of levee risk, and identified levee risk drivers. There may also be specific exercise requirements that will be defined by applicable regulating agencies.

2.10.2.1 Discussion-Based Exercises

Discussion-based exercises include seminars, workshops, and tabletop exercises. These types of exercises familiarize participants with existing plans and may result in development of new plans.

2.10.2.2 Operations-Based Exercises

Operations-based exercises include drills, functional exercises, and full-scale exercises. These exercises validate plans, policies, procedures, and agreements; clarify roles and responsibilities; and identify resource gaps. Operations-based exercises include a real-time response, such as initiating communications or mobilizing personnel and resources.

2.10.3 Exercise Development

Effective design of an exercise starts with the development of a realistic scenario that can lead exercise participants through the various elements of an emergency action plan. Exercises are more effective and efficient when they are designed to match the size and complexity of the levee and the level of risk the levee poses to the community.

Scenarios for a levee emergency exercise based on risk drivers identified in the risk assessment make the exercise as realistic as possible. Scenario development requires collaborative and deliberate sequencing of events that is best completed through

TYPES OF EXERCISES

Discussion-Based Exercises

- <u>Seminar</u>: An informal discussion of roles and responsibilities that may include plan training or review.
- <u>Workshop:</u> Seminar to develop plans or procedures.
- <u>Tabletop Exercise:</u> Exercise that employs discussion to simulate a response to a simulated emergency to test plans and procedures.

Operations-Based Exercises

- <u>Drill</u>: An activity to test a single operation within a single organization, such as testing warning systems or conducting a call-down drill of a notification flowchart.
- Eunctional Exercise: Exercise to evaluate coordination, command, and control between various multi-agency coordination centers. Does not involve first responders or emergency officials responding in real time.
- <u>Full-Scale Exercise:</u> A multi-agency, multijurisdictional, multi-discipline exercise involving all participants role-playing a 'boots on the ground' response to a simulated emergency.

an exercise planning process prescribed in detail in the Department of Homeland Security Exercise and Evaluation Program (FEMA, 2020).

Exercise scenarios based on compound events and discussing the different types of likely compound events with stakeholders can help address climate change trends.

2.10.4 Exercise Evaluation

Thorough exercise evaluation requires planning, documentation, observation, data collection, and data analysis. Proper exercise evaluation recognizes the strengths of the emergency management program and identifies areas for improvement.

Evaluation documentation includes handbooks for evaluators, an evaluation plan, exercise evaluation guide, and participant feedback from wherein all participants can provide feedback regarding their observed strengths and areas for improvement.

After analyzing the data collected from the exercise, an after-action report/improvement plan can be developed which documents exercise results and tracks any action items resulting from the exercise. Additional information on after action reports is provided in section 4.6.5.

2.10.5 Exercise Participants

The effectiveness of an exercise in preparing for an event depends on having the right people at the table. Involvement of relevant levee owner/operator personnel, emergency management

agencies, subject matter experts, and other partners will assure plans or procedures being discussed or tested are adequately and thoroughly vetted. It can be particularly valuable to engage leaders or other trusted messengers of traditionally underserved communities and socially vulnerable populations to increase trust and identify possible barriers to effective emergency notifications. These individuals can also help develop solutions to overcome these barriers. Participants may vary depending on the type of exercise conducted.

2.10.6 Exercise Frequency

For levees with a population at risk, it is a best practice to perform seminars and drills with partners at least once a year to maintain optimum preparedness, replaced by a tabletop exercise, functional exercise, or full-scale exercise every fifth year. Exercises are not necessary during years in which an actual emergency occurs.

For levees that do not pose a risk to life, annual call-down drills of notification flowcharts and/or seminars may be sufficient.

3 Managing a Levee Emergency

Levee emergencies can cause rapidly changing conditions that impact people and property in multiple counties and geographical areas. Emergency response often involves a range of personnel and organizations that must coordinate efforts to save lives, stabilize the incident, and protect property and the environment. Incident management is more effective when all partners work together to share resources, communicate information, and act collaboratively. Poor incident management can result in the loss of life, increased damage and costs, and permanent harm to a levee owner/operator's

reputation.

Response actions are more effective when the partners involved in managing a levee emergency have a shared understanding of the situation, their roles and responsibilities, available resources, current and potential impacts, and the incident timeline. Timely, consistent, and clear communication by levee owner/operators throughout the duration of the emergency can help ensure a high-level of situational awareness for both those internal to their organization and external partners.



3.1 Incident Management System

Federal Emergency Management Agency's (FEMA) National Incident Management System provides a standard and consistent, systematic, proactive approach to guide all levels of governmental and non-governmental entities with a role in emergency management to work seamlessly in responding to emergencies (FEMA, 2015). This approach is effective for any situation that involves coordination among multiple agencies or partners.

The Incident Command System is a fundamental element of FEMA's National Incident Management System. Incident Command System is a standardized, on-scene, scalable, allhazards incident management approach that provides methods for team organization and inthe-moment response planning, including:

- A standardized approach to the command, control, and coordination of on-scene response (Figure 10-8).
- A common structure within which personnel from different organizations can work together.
- A structure for incident management that integrates and coordinates procedures, personnel, equipment, facilities, and communications.

It is a best practice for levee owner/operators to coordinate with appropriate emergency management agencies to incorporate, implement, and regularly train and exercise the Incident Command System and National Incident Management System principles.

It can be helpful to realize that each entity involved in emergency response is managing an incident from their own perspective. For example, a levee owner may be managing an incident related to a performance concern on the levee structure that includes floodfight actions and notifying and coordinating with others. The local emergency management agency may be managing an incident related to the larger flood event, that includes understanding levee conditions and making flood warning and evacuation decisions. Each entity responsible for some aspect of incident response can implement National Incident Management System, and Incident Command System in particular, to organize and guide their efforts. National Incident Management System training courses, Incident Command System forms, and Incident Command System resources can be found on FEMA's website (FEMA, 2015).



Figure 10-8: Incident Commander During an Exercise

Incident commander communicates from the levee using a radio during the Twitchell Island Exercise in Isleton, California. The annual exercise, led by the California Department of Water Resources in conjunction with the Sacramento County Office of Emergency Services and Reclamation District 1601, is designed to improve communication and cooperation among partner agencies during flood emergencies in the Delta.

3.2 Unified Command

Levee emergencies often involve a response from multiple organizations, each managing an incident from their own perspective. Bringing these organizations together to form a unified command may be appropriate when no one agency or organization has the primary authority or the resources to manage the emergency. Unified command is an authority structure in which the role of incident commander is shared by two or more individuals, each already having authority in a different responding agency. When all organizations agree, establishing a unified command can be an effective approach to establish unity of effort to respond to what would then be managed as a single incident. A benefit of unified command is that it allows resources to be applied regardless of ownership or location.

In unified command, there is no single incident commander. Instead, the unified command manages the incident using jointly approved objectives established during the incident. A unified command allows the participating organizations to retain their own authorities and control their own resources while jointly addressing incidents. Figure 10-9, Figure 10-10, and Figure 10-11 demonstrate the different ways a unified command can be organized, depending on the organizations involved in the response.

INCIDENT ACTION PLANNING

National Incident Management System incident action plans are central to managing incidents and help synchronize operations and ensure that they support incident objectives.

Incident action plans document what needs to be done, who is responsible for doing it, what resources are needed, and how communications should occur. Incident action plans also:

- Record and communicate incident objectives, tactics, and assignments for operations and support.
- Are recommended for all incidents.
- Are not always written but are increasingly important to be in writing when an incident is likely to extend beyond one operational period, becomes more complex, or involves multiple jurisdictions or agencies.

Hamilton County Emergency Management in Indiana requires the creation of an incident action plan for each operational period (generally 12 to 24 hours) during flood operations and includes a sample incident action plan within their floodfight plan (HC-EMA, 2018).

INCIDENT OBJECTIVES			1. Incident Name	2. Date 09/06/2018	3. Time 0700-
		CIDENT OBJECTIVES	Tropical Storm Gordon Flood Fight		1900
4. 0	4. Operational Period: First Operational Period				
5. G	ene	ral Control Objectives			
	1.	Provide for the safety of all person	nnel working at the sand barn		
2. Ensure all personnel follow safety standards					
3. Manufacture sandbags in an efficient manner to meet throughput demands					
4. Ensure supply chain management by ordering supplies before they are needed					
5. Assist public by answering questions and providing sandbag information					
	6.	Maintain open traffic to allow for	continued recycling operations		

By requiring incident action plans for each operational period during a flood, Hamilton County, Indiana, promotes effective and efficient incident operations, as well as accountability.

Figure 10-9: Unified Command—Multiagency/Multijurisdictional Incident

SAMPLE ORGANIZATION CHART



Figure 10-10: Unified Command—Multiagency/Single Jurisdiction Incident



Figure 10-11: Unified Command—Multijurisdictional Incident

SAMPLE ORGANIZATION CHART



3.3 Emergency Operations Centers

An emergency operations center is a physical or virtual location from which coordination and support of incident management activities is directed. Typically, those staffing the emergency operations center during an emergency collect, gather, and analyze data; make critical decisions about the management of an emergency; disseminate those decisions to all partners; and maintain continuity of the response efforts. A key function of the emergency operations center is to ensure those who are performing notification and floodfight actions have the information and resources they need.

It is a best practice for levee owner/operators to establish an emergency operations center from which levee operations and emergency response can be managed. The size and technical sophistication of levee owner emergency operation centers will vary dependent upon the size and complexity of the levee and the level of associated risk.

Once notified of an incident on the levee or a forecasted flood that is expected to impact the levee, local emergency management agencies may also activate an emergency operations center to serve as a central coordination center for emergency response, warning, and evacuation activities. By participating in the emergency operations center, they can help agency personnel better understand the project-specific information and inundation maps and increase efficiency and effectiveness of response efforts.

DISASTER DECLARATIONS

A disaster declaration is a formal statement by the jurisdiction's chief public official (i.e., mayor, county judge, governor, or president) that a disaster or emergency situation exceeds their response capabilities and allows public officials to exercise emergency powers to preserve life, property, and public health.

Emergency declarations can confuse organizations and individuals. All agencies need to understand the implications of operating under an emergency declaration.

	Local
Local governm within their jur or federal eme	nents may have the authority to declare an emergency and activate emergency agencies isdiction. Local emergency declarations can also potentially allow agencies to receive state ergency funding, if such funding becomes available.
	State
While unique order or other declaration, ge agency or age regulations that triggers an arr	to each state, generally the governor may declare an emergency by issuing an executive declaration to that effect. The declaration addresses the effective dates and duration of the eographic areas of the state covered, conditions giving rise to the emergency, and the incies leading the response activities. The declaration may also identify state rules and at are waived or suspended during the emergency. The declaration of a state emergency ay of authorities and actions by state and/or local governments.
	Federal
Emergency Declaration	Upon the request of the state, tribe, or territory, the President of the U.S. can declare an emergency for any occasion or instance when the president determines federal assistance is needed. Federal emergency declarations supplement state and local or Indian tribal government efforts in providing emergency services, such as the protection of lives, property, public health, and safety, or to lessen or avert the threat of a catastrophe in any part of the U.S. The total amount of assistance provided for a single emergency may not exceed \$5 million.
Major Disaster Declaration	Upon the request from the state, tribe, or territory, the President of the U.S. can declare a major disaster for any natural event, including any hurricane, tornado, storm, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, mudslide, snowstorm, drought, fire, flood, or explosion that the president determines has caused damage of such severity that it is beyond the combined capabilities of state and local governments to respond. A major disaster declaration provides a wide range of federal assistance programs for individuals and public infrastructure, including funds for both emergency and permanent work.

Dually as important as the issuance of an emergency declaration, levee owner/operators should also familiarize themselves with the process for how different jurisdictions decide when to declare an emergency is over, which ultimately will affect the availability of additional resources.

4 Operating a Levee During an Emergency

Time is of the essence during a levee emergency. A levee emergency can occur within minutes or over a long period of time and may last days, weeks, or longer, which creates a variable window of opportunity to reduce the impacts of the emergency on the levee and the affected community. Levee owner/operators who have planned and prepared for an emergency and implement appropriate emergency response actions have a better chance of fulfilling their role in avoiding a levee breach and preventing loss of life when a breach is unavoidable.

Constant observation of levee conditions, early detection, communication, proactive floodfighting measures, and an effective emergency notification process can help reduce the likelihood and impact of a levee emergency. The following sections detail common activities to identify and respond to a flood-related levee emergency. Though levee emergencies typically happen during floods, they can occur prior to a flood and the principles and best practices of this section apply to any levee emergency situation.

4.1 Incident Detection

An incident at a levee may be detected by:

- Monitoring the status of the flood source or flood source predictions.
- Monitoring the weather forecast.
- Inspecting and observing the levee.
- Evaluating levee instrumentation data.
- Identifying suspicious activity or security threats.

When a levee-related issue is detected, the incident can be classified to streamline communication and aid in implementing the appropriate response actions, as discussed in section 2.6. Once the incident is classified, the appropriate notifications can be made, and all necessary actions can be taken in accordance with the pre-planned actions that are discussed in section 2.7.

4.1.1 Preliminary Response Activities

When a flood is forecasted, performing activities outlined in the O&M manual such as closing gates, performing inspections, and other tasks will help make sure the levee and those responsible for its operation are ready for the flood. Other important pre-flood actions include partner coordination, especially between the levee owner/operators and local emergency management agencies and activation of emergency operations centers, if warranted. Ongoing communication between emergency management agencies and emergency operation centers through regular situational updates ensures awareness of the response activities and levee condition.

Other important activities to perform when preparing for emergency response include:

- Reviewing the emergency action plan and lessons from previous incidents and exercises and identifying problem areas.
- Verifying that response personnel have access to gate keys, current rosters, contact numbers, staging areas, listing of project features, feature operation plans, and other critical items.
- Coordinating efforts with communities and levee owner/operators in the floodplain.
- Alerting communities within the leveed area to the potential for flooding in coordination with the appropriate emergency management agencies.
- Beginning documenting the situation and sending situation reports to the emergency operations center, appropriate emergency management agencies, or others, as appropriate.

4.1.2 Flood Source Monitoring

Knowing flood source conditions and predictions is invaluable to effective flood operations. It is a best practice to assign an individual the responsibility of monitoring flood source and weather data both before and during a flood event. Before a flood event, monitoring frequencies that provide the levee owner/operator sufficient warning time to execute pre-flood preparation activities can be developed by considering the characteristics of the flood source, the levee, and available resources. During flood events, monitoring frequencies that allow adequate time to respond to changing flood source conditions can be developed by considering the characteristics of the flood source time to respond to be taken if an emergency occurs, such as evacuating the leveed area or performing floodfight actions. There are a number of sources with flood information, a few are discussed below.

4.1.2.1 River Gages

Many of our nation's rivers and streams are monitored by gages. Knowing if a gage is available to inform response actions at a levee and being able to relate gage readings and forecasts to levee loadings is a powerful tool to aid proactive floodfight actions and emergency notifications. The U.S. Geological Survey and the National Weather Service maintain gages in many locations across the nation. There are various other sources of gage information including the U.S. Army Corps of Engineers (USACE) and the Bureaus of Reclamation.

The National Oceanic and Atmospheric Administration's National Weather Service provides river gage observations and forecasts for major rivers and streams across the nation. For some locations, the National Weather Service issues daily forecasts that extend out for seven to 14 days. For other locations, forecasts are only issued during floods.

4.1.2.2 National Weather Service Flood Warnings and Weather Forecasts

The National Weather Service has the primary responsibility for issuing flood warnings and providing weather forecasts. It is of utmost importance that those responding to a flood stay apprised of flood warnings and current weather conditions and forecasts. Understanding how various flood stages and/or flows and weather events impact levee operations and performance

and what activities are triggered by current or predicted conditions can help prepare for and execute flood operations.

Just as National Weather Service warnings and notifications can inform levee operations, information concerning levee conditions can help inform National Weather Service communications. Including the National Weather Service in planned notification procedures (section 2.7.1) can help ensure proper information exchange between the levee owner, the local emergency management agency, and the National Weather Service during floods. This in turn helps to ensure the public receives timely and accurate notifications and warnings.

FLOOD STAGES VS. INCIDENT CLASSIFICATIONS

The National Weather Service uses various flood stages to describe the level of a watercourse at a given location. These levels do not necessarily correlate to an incident at a levee nor classify the severity of a levee incident.

Flood stages are often used to describe river flooding conditions where gages exist. The levee incident classifications discussed in this chapter are different from flood stages. The incident classifications describe the condition of a specific levee. The incident classifications also provide a basis for the development of pre-planned floodfight actions and notification procedures that correspond with each incident classification so that response can happen quickly when an incident occurs.

4.1.2.3 Flood Warning Systems

Automated flood warning systems can be installed along waterways or bodies of water. These supplemental systems can provide advanced warning of potential flood conditions, particularly in locations where ungaged waterways present a primary hazard. Early warnings can provide valuable time for responding to possible overtopping events or flood loadings that are known to induce seepage or other failure modes. Knowing when these loadings are predicted can expedite emergency notifications and floodfight actions.

4.1.3 Flood-Related and Event-Driven Inspections

Flood-related and event-driven levee inspections allow for early detection and response to potential levee concerns. Inspecting levees at frequent intervals throughout an emergency, with the frequency of inspections increasing as the threat to the levee increases will enable earlier detection of possible emergency situations. It is a best practice to establish pre-determined triggers tied to inspection frequencies in the levee O&M manual or emergency action plan. **Chapter 9** discusses considerations for establishing these types of thresholds.

Effective flood inspections include observation of the entire levee throughout the flood, as any part of the levee can suffer distress that requires immediate attention. However, some locations may warrant closer observation based on the design of the levee, previous performance, and/or areas of known deficiencies. It may be beneficial to assign personnel to specific levee reaches, to ensure adequate coverage.

Important safety considerations include having personnel travel in two-person teams equipped with dependable communication devices and adequate safety and floodfighting equipment. Traveling in and around saturated, cracked, or sloughed/sloughing areas can worsen the levee condition or lead to injury. Using objects, including arms or legs to investigate holes in or around a levee may also pose a threat to the inspector(s).

It is a best practice to perform flood-related inspections prior to an expected flood, during a flood, and shortly after a flood.

4.1.3.1 Initial Flood-Related Inspections

Initial inspections occur after a flood has been predicted and before the levee is loaded. Monitoring of flood source data as described in section 4.1.2 can provide the warning required to accomplish these inspections. Thorough initial inspections can avoid many common issues that consume valuable response resource, such as faulty culvert gates and access issues. In addition to the items that are typically observed during routine inspections, it is also important to consider the following items during the initial inspection prior to a flood or emergency:

- Levee conditions:
 - Condition of any recent levee repairs.
 - Flood conditions and any accumulation of trash, debris, ice, etc.
- **Condition of transportation routes**: Levee access roads, rail and roadway crossings, and access to the levee through the leveed area.
- **Closures**: Ensure closure seals are in good condition and prepared for closure installation; verify material, equipment, and manpower is available to install the closures at the pre-established closure thresholds.
- **Instrumentation**: Ensure instrumentation is in good condition and producing reasonable readings.
- Floodfighting materials:
 - Confirm availability of all necessary tools and materials (e.g., sacks, sandbags, lumber, and lights).
 - Identify location, quantity, and condition.
 - If necessary, distribute or store the materials at locations that will facilitate movement to where they will likely be needed.
- **Communication**: Locate and check all two-way radios and telephones.
- **Interior drainage systems**: Inspect outlet structures, gates, and other components that might not be accessible later. These structures are typically subject to inundation at lower stages than other levee features.

4.1.3.2 Inspections During a Flood

The criteria for determining when inspections are necessary, and the appropriate frequency of inspections during a flood, are detailed in **Chapter 9.** Thoroughly viewing and assessing all levee features during these levee inspections helps ensure issues will be identified before emergency conditions develop.

Additional methods that can be used to conduct inspections when foot and/or vehicle patrols are not possible include boat patrols to detect riverward scour or sand boils in inundated landside areas, aerial surveillance using rotary and winged aircraft, and aerial unmanned drone surveillance. These additional methods of inspection, while often costly, can provide early detection and identification of levee distress. Early detection may allow the distress to be addressed before levee breach is imminent. The tasks typically accomplished during flood related inspections are provided in Table 10-4.

Feature	Typical Tasks	Operating and Maintaining a Levee Chapter Reference
Embankment	 Look for sand boils or unusual wet areas on the landside levee slope and landward of the levee toe, denoting size, location and characteristics of the flow and mark accordingly (see Figure 10-12). Look for slides or sloughs on levee side slopes. Look for wave wash or scouring on the waterside and landside. Look for low areas in levee crest. Inspect managed overtopping sections for obstructions to flow, erosion, and missing erosion protection. 	Chapter 9, section 3.1
Floodwalls	 Look for saturated areas, wet areas, soft areas, seepage, sink holes, or sand boils landward of the toe of the floodwall and mark accordingly. Look for settlement of the floodwall or movement between monoliths. Look for bank caving that may affect the structural stability of the floodwall. Inspect toe drain risers/manholes (discharging/non-discharging). Inspect for any leakage, especially around the monolith joints. 	Chapter 9, section 3.2
Closures structures	 Check gap closures for damages or leaks (i.e., stoplog/sandbag). Ensure alarms are functional. Look for debris blockage. Check for missing or damaged parts (pins, bolts, nuts, washers). 	Chapter 9, section 3.3
Transitions	 Look for surface erosion at transition locations caused by water movement. Look for leaks at interfaces between hard surfaces and earthen materials. 	Chapter 9, section 3.7
Seepage control features	 Monitor relief wells (flowing/non-flowing) and document when flows begin/rate of flow. Check for vegetation that may prevent the system from functioning as intended. Check for debris. Inspect collector systems and manholes. 	Chapter 9, section 3.4
Channels and floodways	 Look for scours resulting from high velocities at waterside and landside toe. Check crest for signs of instability. Ensure any flood gates are operational. 	Chapter 9, section 3.9

Table 10-4: Flood-Related Inspection Tasks

Feature	Typical Tasks	Operating and Maintaining a Levee Chapter Reference
Interior drainage systems	 Check flap/sluice gates for proper closure. Look for depressions, sinkholes, soft spots or cracking immediately over pipes. Check for sand boils in landside ditches and ponding areas. Check for seepage emerging around pipes or from behind headwalls. 	Chapter 9, section 3.5
Pump stations	 Verify that assigned personnel are on duty as required. Run and monitor pumps. Look for sink holes or wet areas around the perimeter of the pumping plant, and/or settlement of the pump house. These conditions could be the result of separation in the conduits. If separation is suspected, shut down pumps and motors until an engineering review can be conducted to analyze the condition. Inspect trash racks to ensure they are clear of debris. Clogged trash racks can prevent water from reaching the pump station and cause erosion. Verify proper ventilation (e.g., fans, vents) of the pumping plant to prevent overheating of pump motors. Assess conditions and operability of communication and control systems. 	Chapter 9, section 3.6
Instrumentation	 Record gage readings (frequency based on rate of flood source change). Inspect fences on the waterside of the levee frequently to make sure they are free from debris. Clear debris, if possible. The fence may need to be cut to free the debris and decrease the possibility of damage to the levee. Verify all necessary access roads and ramps along the levee are accessible and usable. Take photographs of all significant issues (use date/time stamp feature on the camera, when possible). 	Chapter 9, section 2.3

Flood-related inspections should include viewing and documenting the entire levee without precluding areas based on adequate performance during past floods. However, special attention including more frequent and thorough inspections may be warranted for areas identified as vulnerable during previous inspections or risk assessments.

4.1.3.3 Inspection Documentation

Inspection findings are only useful if they are documented and shared with the appropriate personnel. Inspection documentation procedures are typically included in the O&M manual. More information on these strategies and the O&M manual is provided in **Chapter 9**.

Clearly and consistently marking distress points in the field helps ensure they can be easily located for future inspection and floodfight action if necessary. Wooden stakes and pin flags are typical tools used to mark distress points. It can be helpful to place a marker at the distress point and on the levee crown. An effective marker indicates the type of distress and the location of the distress point relative to the levee as shown in Figure 10-12.



Figure 10-12: Sandboil Marker

Wooden stake on levee crown indicating the presence of a sand boil near the landside levee toe.

4.1.4 Instrumentation Monitoring

Data collected from instrumentation during a flood gives indications of how the levee is responding to a flood loading. Professionals trained in analyzing the data can identify potential concerns that need further evaluation, remediation, or immediate floodfight action. Separate personnel from those performing flood-related inspections who are qualified to perform data collection and analysis may be needed. It is helpful to develop and document threshold instrumentation readings that trigger additional data collection or emergency response actions. Triggers established prior to a flood event will ensure that emergency conditions are quickly identified, allowing for a more effective response. Various types of levee instrumentation and considerations for installation on a particular levee are described in **Chapters 7 and 9**.

Frequencies for monitoring levee instrumentation during a flood are typically established by the designers of the instrumentation. These frequencies may be adjusted based on recent

performance or information from a risk assessment. Documenting the frequencies and procedures for reading and analyzing data in the O&M manual helps ensure these activities are performed correctly so that the data is available to inform response actions.

Abnormal or sudden changes in readings may indicate a potential issue at the levee. Good flood preparedness includes pre-planned processes to quickly evaluate these conditions and then communicate and address them.

Climate change can affect rainfall patterns, flood frequency, water levels, freeze/thaw cycles, and wetting/drying cycles, which can impact understanding of long-term levee performance data. Awareness of potential changes to the environmental factors affecting the levee can help levee owner/operators better evaluate and utilize levee performance data during emergencies.

4.2 Data Management

Data collected during flood events informs immediate flood operations, and identifies necessary long-term levee remediation measures. Good documentation of performance observations during the flood, formalizing the data in a report once the flood is over, and storing the report in the levee's data management system (**Chapter 9**) helps ensure this information is available to inform future actions.

Formal documentation may include incorporating performance observations and response methods into the emergency action plan, revising the O&M manual to address operational or maintenance concerns, or developing an after-action report, as discussed in section 4.6.5. Proper documentation will greatly assist future floodfighting efforts by providing awareness of potentially poor performing areas of the levee and how they have been successfully addressed in the past.

4.2.1 Criteria for Data Collection

Data is more useful when it is collected using consistent criteria and terminology that is universally understood. It is a best practice to develop a standard list of attributes to be documented for each failure mode along with standard language to describe levee conditions. Standardization will help ensure consistent data collection and improve understanding of levee conditions. For example, standard terms can be adopted to describe the size of a sand boil or seepage quantity. Table 10-5 provides a summary of some of the data that should be collected using standardized methods and language during a flood. Detailed best practices for collecting and documenting levee performance data, including an example of standardized terms and definitions, are provided as an appendix on floodfighting in EM 1110-2-1913 (USACE, 2000). It is a best practice to designate an experienced lead to coordinate and oversee performance data collection and ensure consistency.

Condition Type	Attribute	Description	
All conditions	Coordinate (points or lines) Date and time Name of person reporting	Preferably automated during collection	
	Photograph or video	Includes date stamp	
	Description	Standard language and detailed descriptions of performance	
Quard haile	Size	Measured diameter of sand boil throat or use standard descriptions (pin boil, small, medium, large)	
	Activity description	Description of the amount of soil material flowing from the sand boil (clear boil, low, moderate, high, or very high activity)	
	Location	Distance from levee toe	
	Contributing factors	Topography, features, environmental or human conditions which contribute to the condition, such as ditches, pipes, animal burrows, thickness of clay top stratum, pumping of landside water, etc.	
Underseepage	Quantity of seepage	Standard descriptions (no seepage, very light, light, medium, heavy)	
1 3	Contributing factors	Topography, thickness of clay top stratum	
	Quantity of seepage	Standard definitions (no seepage, light, medium, heavy)	
Inrougnseepage	Contributing factors	Levee embankment material, levee slopes, encroachments, transition zones	
	Size	Length, depth, width of erosion Rate of progression	
Erosion	Location	Location on embankment or relative to features	
	Contributing factors	Poor sod cover, high winds, concentrated flows, high velocity, existing erosion protection, etc.	
	Time of overtopping	Time and date that water started flowing over the top of the levee	
	Depth of overtopping	Maximum depth of water flowing over the levee (above pre-existing levee grade without erosion)	
Overtopping	Time of breach	Time the overtopping resulted in a rupture, break, or gap	
	Breach width	Approximate width of breach 15 min, 30 min, 1, 2, 4, 8, and 24 hours after breach	
Slides	Size	Width at widest extent parallel to levee Vertical displacement (scarp height)	
	Location	Approximate location on slope (distance from crown, landside, or waterside)	
	Contributing factors	Soil saturation, changes in slope, vegetation, encroachments, etc.	
Floodwall issues	Movement	Measurement of movement due to tilting, sliding, or settlement during loading	
	Waterstops	Description of flow and height of waterstop failure	
Popord of closure	Туре	Stoplog, swing gate, sliding gate, sandbag	
Record of closure operation and issues	Date and time closure started and completed	Start/stop time for closure installation	

Table 10-5: Conditions and Attributes to Record During a Flood

Condition Type	Attribute	Description
	Operational issues	Missing parts during installation, broken components during operation, temporary fixes
	Performance issues	Leaking stoplogs, leaking seals, misalignment
Gate closure issues	Effectiveness of closure	Issues experienced during gate operation Quantity of water leaking through gate
Pipe issues	Condition of surrounding soils	Location and size of sinkholes, depressions, or erosion over or near the pipe
	Leakage	Estimate flow through pipe due to leakage or around pipe due to seepage. Distinguish between gate leakage and leakage into the pipe due to pipe defects

It is important that levee inspectors that are collecting the data be able to recognize conditions that may lead to levee breach and know the terminology used to describe them. Ensuring that inspectors are aware of pre-planned actions (section 2.7) can speed response, should immediate action be required to address performance concerns.

4.2.2 Tools for Data Collection

Geographic information system-based data collection systems allow for efficient and consistent collection of performance data. The USACE Levee Inspection System is a mobile application designed by USACE to assist with the process of conducting inspections, documenting conditions, and generating reports. The Levee Inspection System can be obtained through the NLD website. Other commercial mobile collection tools can also be used to collect data.

The most effective tools used for data collection have the following capabilities:

- Collects recommended distress point attributes using standard terminology.
- Collects both line and point data.
- Provides GPS/camera/video capabilities.
- Is easy to carry (tablet or phone size).
- Provides remote connectivity to office using data network (wireless) or ability to offload data for email or external data transfer.
- Has user interface with dropdown menus to minimize typing.
- Has ability to append data daily as features change.

The NLD is the national repository for all levee performance data. The Levee Inspection System is integrated with the NLD, and data collected using this tool is automatically associated with the levee in the NLD; however, if manual data collection or other commercial tools are used, manual upload of that data would be needed. Users of the Levee Inspection System should be prepared for computer issues and lapses in internet service during an emergency. Non-electronic means of data collection will likely need to be used in these instances.

4.3 Floodfight Actions

There are a wide range of floodfight actions that can be implemented depending on the failure mode that has initiated and the location and severity of the incident. The appropriate response actions will also depend on the availability of materials, equipment, staff, volunteers, and time. Incident response consistency and efficiency can be improved by assigning a single individual the responsibility of evaluating incidents, determining their severity, and prescribing floodfight actions to address them. Best practices to help ensure adequate personnel and resources are available during floodfight events are included in section 2.9 and 2.10.

Failure to react in a timely manner and apply proven floodfight actions greatly increases the likelihood of levee breach. Although each flood is unique, there are many common elements from one flood to the next, and proper implementation of floodfight actions will improve response time and chances of successfully managing consequences. Pre-defined incident classifications with associated pre-planned response actions as discussed in sections 2.6 and 2.7 are an excellent tool for facilitating fast communication and decision making during an incident.

Coastal flooding is significantly different in that the wind and wave action make floodfight during a storm very difficult, so the best response for a coastal levee is to make preparations before the storm, and act once a storm is predicted but before it arrives. A list of references to help aid the development of pre-planned floodfight actions is available in the callout box titled "Reference Materials" in section 2.7.3. Typical incidents observed during a flood on a levee with typical actions to address them are provided in Table 10-6.

Incident	Typical Floodfight Actions		
Individual sand boils	 Raise water level over boil. Most common method is to build a ring of sandbags around the boil that stops soil migration out of the boils but allows water to continue to flow. 		
Large area with many sand boils	 Raise water level over area by building a water berm. Water berms are constructed by building a 1- to 2-foot-tall soil embankment around the seepage area and filling it with water. Reinforce the landside slope or the area landside of the levee by building an emergency seepage berm. Berm soils should be less permeable than levee and foundation soils. See the discussion on seepage berms in Chapter 7. 		
Landside slope failure	 Minor sloughs typically do not impact levee stability and can be covered with plastic sheeting or riprap to prevent erosion of exposed levee soils during the flood. These areas should be monitored for throughseepage. Deeper slides often require the placement of soil or rock on the levee toe to prevent additional slope movement. Monitor for seepage emerging from the slide as this can indicate a progressing failure mode. 		
Waterside erosion	 Wave wash can usually be managed by the deployment of plastic sheeting to protect the areas where wave wash is occurring. Sever wave wash or deeper erosion due to currents may require the placement of rock to protect the levee. 		

Table 10-6: Typical Floodfight Actions

Incident		Typical Floodfight Actions	
Overtopping – Outside of designed overtopping sections	•	Evacuate the leveed area. Overtopping can sometimes be prevented by raising the levee using methods for earthen assembled closures discussed in Chapter 7 . However, this action can transfer risk to other levee systems and areas outside of levees. Raising a levee also subjects the levee and its foundation to water levels greater than those used to design the levee.	
Leaking floodwall joints	•	Expanding foam can be used to stop moderate leaks. Extreme leakage may be a sign of a progressing failure mode and a structural or geotechnical engineer should be consulted.	
Leaking closure structure	•	Deploy plastic sheeting against the waterside of the closure. Place sandbags along the seals on the landside.	

4.4 Emergency Communication

It is important to ensure timely, consistent, and clear communication during an emergency. Specifically informing emergency management agencies and local jurisdictions of the condition of the levee and providing ongoing situational updates following the pre-developed notification flowcharts and messages discussed in section 2.7.1 keeps all partners aware, engaged, and ready to respond.

Throughout the U.S., the National Weather Service has the primary responsibility for issuing flood warnings to the impacted community. The National Weather Service will often decide when to issue flood warnings to the public based on the weather forecast and information from the levee owner or the emergency management agency concerning levee conditions. This makes timely and accurate delivery of information to the National Weather Service about levee conditions—particularly imminent breach, overtopping, or high flow conditions—very important.

It is critically important that proper coordination and communication occurs among personnel in the field, public information officers, and emergency personnel at the emergency operations centers to ensure a successful response to an emergency. Thoroughly testing these activities during emergency action plan exercises, and making necessary modifications, can help communication flow smoothly during an emergency.

4.5 Evacuation

If floodfight actions are not successful or if conditions worsen, it may become necessary to initiate an evacuation of the threatened area. Often, the levee owner/operator will not have the authority or resources to perform an evacuation. Evacuations are typically ordered and conducted by a local or state emergency management agency.

Typically, the levee owner/operator's role in an evacuation is to provide the information necessary for responsible entities to make an informed decision regarding evacuation. However, in some cases, the levee owner/operator may be a municipality or other organization with the responsibility to call for and/or execute an evacuation. It is a best practice for the levee owner to understand their role in the evacuation process and to assign a specific individual

within the levee owner's organization the responsibility to make and communicate decisions to fulfill that role. Additional information regarding evacuations is provided in section 2.7.2.

4.6 Termination

Once conditions have stabilized, emergency response will be terminated and a transition to the recovery phase will be initiated. Demobilization and termination are deliberate processes that include all partners in the decision-making process.

It is a best practice for the emergency action plan to describe the termination process, including criteria for determining an emergency at the levee has been resolved, as well as termination and follow-up processes for levee incidents and emergencies. Planned termination activities should include processes to ensure inspection and performance data, debriefings, and after-action reports are documented and organized within the levee's data management system (**Chapter 9**). Components of the termination phase are described in further detail below.

4.6.1 Communication

The first step in transitioning from the emergency phase to the termination phase consists of the levee owner/operator promptly notifying emergency management agencies and other partners that the condition of the levee has been stabilized or the incident classification severity has been lowered.

Government officials are responsible for declaring an end to a public emergency response if one has been previously designated. Emergency terminations will be issued by the level of government from which the emergency declaration was made.

4.6.2 Demobilization

The goal of demobilization is the orderly, safe, and efficient release and return of a resource to its original location and status. Once resources are no longer needed, they can be demobilized by the personnel responsible for the resources. Prompt removal will protect both the resources and the levee from damage.

The termination process can be improved when staff responsible for the planning and logistical functions collaborate prior to demobilization, in order to plan how resources are replenished, disposed of, or returned to operational condition. The management of resources is smoother when levee owner/operators begin planning and preparing for the demobilization process at the same time they begin mobilizing resources, or prior to flood events, if possible.

Demobilization policies and procedures will vary depending on the size of the incident and will be specific to the levee owner/operator based on their fiscal/legal policies, procedures, work rules, and other requirements.

Developing a demobilization plan can help ensure a controlled and cost-effective release process, eliminate waste, and eliminate potential fiscal and legal impacts. A demobilization plan contains the demobilization process, responsibilities for implementation, release priorities, specific release procedures, and travel information.

4.6.3 Transfer of Command

As the incident de-escalates, the size and complexity of the resources needed may be reduced and may lead to a transfer in command. The details of how to execute a transfer in command is thoroughly discussed in FEMA's Incident Command System training materials, which can be accessed through the FEMA website (FEMA, 2015).

4.6.4 Closeout/Debriefing

Incident management team demobilization may include a formal closeout meeting with the responsible agency or jurisdiction for managing the emergency. Including a debriefing as part of the closeout process can help identify areas for improvement. A closeout meeting should be documented and include a summary of the incident, discussion of major events, a discussion of the incident outcome, a voicing of concerns, and a final evaluation of incident management. Closeout meetings are important for major incidents that have attracted media interest, incidents that have drawn public scrutiny, incidents where there will be a need for longer term recovery efforts, and situations where there were important lessons learned for future responses.

4.6.5 After-Action Report

Following an emergency, it is valuable to reflect upon and evaluate the circumstances leading up to the emergency, all activities and actions that took place during the emergency, and the resulting outcomes. It is also beneficial to review the emergency action plan and O&M manual to determine if there are opportunities for improvement and make updates as appropriate.

Preparing an after-action report is the best practice for consolidating all information related to an incident, including response action and levee performance. Detailed information on how to prepare an after-action report along with the standard format is provided in the Department of Homeland Security's Exercise and Evaluation Program (FEMA, 2020).

Coordinating this effort with all organizations and individuals involved in the response efforts will result in a more holistic view of the situation from a variety of perspectives and assist in identifying lessons learned and opportunities for improvement. Depending on the extent of the emergency and partners involved, multiple organizations may produce their own documentation of the emergency.

Assigning the responsibility for implementing each corrective action identified in an after-action report to a specific person, as well as developing and tracking an implementation schedule, will help ensure lessons learned are used to improve future emergency response efforts. Incorporating changes in emergency response procedures into the emergency action plan as appropriate will ensure they are used to improve response during the next flood. Levee owner/operators should store after-action reports in an easily accessible location and upload them to the NLD linked to the respective levee system for ease of access to local emergency management agencies and other levee emergency management partners.

A comprehensive continuous improvement process applied before, during, and after an emergency action plan exercise or actual emergency will improve readiness by identifying and addressing weaknesses. Having an internal process in place to validate previous actions that were successfully implemented can also inform future planning and response.

4.6.5.1 Levee Performance Documentation

Valuable data can be obtained by closely inspecting levees during and after each levee emergency, as well as evaluating and documenting levee performance. Keeping organized records of locations where issues, emergency action, or breaches have occurred can inform O&M, flood operations, and levee rehabilitation projects.

Complete levee performance data includes photos, locations, type and severity of the distress, how the distress point changed during the flood event, and a description of floodfight actions and their effectiveness. The specific date, time, and river level when observations were made is important for levee performance projections for higher hydraulic loads and remediation of observed distress. Including levee performance data as an appendix to the after-action report can be an effective way to organize this data and make it available.

4.6.5.2 Emergency Management Lessons Learned

Lessons learned can provide emergency management agencies and levee owner/operators with valuable information to improve response and recovery actions. A thorough evaluation will include evaluating strengths and weaknesses of significant actions taken on the levee or within the community in response to a levee emergency including the incident management process, resourcing of materials, information sharing, equipment used, and leadership structure. A complete evaluation will result in needed corrective actions, opportunities to improve processes or tools, and a planned course of action to implement recommendations.

This information can also be used to inform public officials and residents about flood and levee risk and to assist in public policy discussions concerning other flood risk management options for the community. Other outcomes of an after-action review could produce either a more effective response during an emergency or improvements to the levee that would reduce the need for emergency response. **Chapter 12** discusses community-based flood risk management measures.

4.6.6 Transition to Recovery

Planning for the transition to recovery is particularly critical in large-scale incidents where an organization, such as an emergency operations center, may be required to assume responsibility for recovery actions and activities.

5 Recovering from a Levee Emergency

A levee emergency may result in impacts to levee infrastructure, critical infrastructure, people, housing, the economy, and the natural environment. **Recovery** of a levee after an emergency is the prompt restoration of the levee to a serviceable condition in the event of damage and/or prompt removal of excess flood water from the leveed area. Including recovery planning in preparedness efforts and starting recovery efforts as soon as the emergency has subsided and it is safe to do so will speed restoration of levee function, minimize economic losses, and minimize the extent of damage progression.

Recovery typically begins after the emergency has ended, but some short-term recovery activities may occur simultaneously with response efforts. This section focuses on the immediate operational actions following a levee emergency. Ensuring short-term recovery actions necessary to return the levee to its pre-flood condition are in the emergency action plan or O&M manual will help ensure a speedy and well-coordinated recovery.

5.1 Post-Flood Inspection

It is important to conduct a post-emergency inspection to document the extent of damage to the levee. Including an inventory of all remaining incident response equipment, sandbags, and other supplies as part of the post-flood inspection can document which materials need to be replenished and the need for equipment maintenance or repair.

A post-flood inspection that includes the type and extent of damage can help determine if shortterm repairs or long-term rehabilitation is needed to restore levee integrity. This data can guide the recovery process and help:

- Identify financial requirements for repairs (how much the repairs will cost and who will bear the cost of repairs).
- Determine the priority of necessary repairs.
- Identify key infrastructure that may need to be repaired in coordination with other agencies (e.g., roads).
- Support documentation for state or federal assistance and cost recovery activities.

Documenting the data collected, as well as the inspection findings, in a formal report helps to organize the data and facilitates sharing with appropriate personnel and partners, as further discussed in section 4.6.5.1.

5.2 Immediate Repairs

Once a post-flood inspection has been completed, it is a best practice to prioritize identified repairs based upon risk and to immediately address urgent issues (if safe to do so). Urgent issues are typically those most likely to cause a levee breach during future loadings and/or that have a greater potential to impact populated areas. Immediate repair of high-risk issues will help to prevent conditions from worsening or the occurrence of another levee emergency due to unaccomplished repairs.

The urgency of a repair is dependent upon the unique characteristics of the damage and how it impacts levee risk. The following issues may be urgent depending on what is driving levee risk.

- Levee crest levels: Fill any settlement, holes, voids, gullies, and washes in the levee crown with compacted fill material.
- Levee cross section or foundational damage: Repair any observed issues that could degrade over time if left unrepaired, increasing the chance for a breach during future floods (e.g., erosion, sloughing). (See Figure 10-13 for an example of a levee slope repair.)

- Interior drainage systems: Examine all drainage ditches on the landside of the levee and remove any obstructions. Manually check and repair any damaged gates and remove debris, sediment, or other potential obstructions. Examine the waterside of levee for debris.
- Access routes and staging areas: Restore access and repair any damages to transportation routes or locations that will be needed to stage equipment and materials for other levee repairs. Re-establish access security measures, as necessary (e.g., cameras, gates, and locks).
- **Instrumentation system:** Assess and restore levee monitoring systems impacted by incident (e.g., staff gages, stakes, flow meters, water level pressure transducers, and remote cameras).

In some cases, complete repairs will not be possible and **interim risk reduction measures** actions to reduce levee risk until more permanent repairs are completed—should be implemented. Care must be taken to ensure temporary measures do not block access for O&M, impact levee integrity, or complicate the design and construction of the needed levee rehabilitation project. Completing interim risk reduction measures before conditions worsen or another emergency occurs reduces levee risk until more permanent repairs and rehabilitations can be accomplished.



Figure 10-13: Workers Repair a Levee

Workers using a track hoe to repair levee damage and replace riprap in South Sacramento, California.

5.3 Long-Term Repairs and Rehabilitation

After the emergency has subsided and urgent repairs have been made, levee performance data and post-flood inspection data should be evaluated to determine if additional repairs or large-scale rehabilitation is needed.

In many cases, post-flood repair and rehabilitation needs will exceed immediate resources. It is a best practice for all required repairs identified by flood and post-flood inspections to be tracked and prioritized for action based upon risk. The prioritized list of flood recovery actions should be merged with any pre-existing prioritized list of levee risk management actions to ensure that resources are invested to reduce levee risk as quickly and effectively as possible, as discussed in **Chapter 9**.

In instances where significant performance concerns cannot be addressed immediately, an evaluation may be warranted to see if changes are needed to the O&M manual or emergency action plan. Adjustments to maintenance, operation, inspection, or floodfight procedures may be needed to manage levee risk until permanent repairs can be made. Adjustments to notification and evacuation procedures may also be warranted.

Risk assessment, as described in **Chapter 4**, is an effective method for understanding how damages and performance concerns impact levee risk. Risk assessments result in a list of recommendations to reduce and manage risk. Risk management, as discussed in **Chapter 5**, provides a method for choosing and prioritizing actions. Design and construction of levee rehabilitation projects are addressed in **Chapters 7 and 8**.

5.4 Removing Temporary Floodfighting Measures

Temporary measures deployed during flood emergencies are not permanent solutions. Temporary measures are intended to reduce the likelihood or consequences of an impending levee emergency and are not designed to support a levee in perpetuity. They can cause damage to the levee and increase the levee risk if left in place long term.

Once the emergency conditions have ended and it is safe to do so, it is a best practice to remove temporary measures (e.g., sandbags, flashboards, rock, plastic sheeting, emergency levees) and dispose of them properly to prevent damage and preserve access to the levee. Some temporary floodfighting measures may need to remain in place as interim risk reduction measures until a permanent solution can be designed and implemented.

Additionally, some flood waters impounded by the temporary floodfighting measures may be contaminated with fuel, pesticides, and other contaminants. Due care should be used when entering contaminated water to remove temporary measures. Measures should be taken to ensure the removal of the contaminated water, and the disposal of temporary floodfighting measures that came into contact with the contaminates.

5.5 Recovery Assistance

There are numerous state and federal recovery assistance programs available to levee owner/operators to aid in post-flood recovery efforts. The various programs are discussed in **Chapter 12**.

6 Summary

Emergency preparedness actions outlined in this chapter can reduce potential impacts of emergencies before they occur. Preparation requires communicating with the public, ongoing collaboration between stakeholders, developing and exercising emergency action plans, training levee personnel, and maintaining the appropriate materials, supplies, and operational readiness for when an emergency occurs.

Learning from previous emergencies, constantly revising plans and activities to adjust for changing conditions, and leveraging lessons learned will increase the ability of emergency management partners to navigate future levee emergencies as conditions continue to evolve and change.

Related content associated with this chapter is included in detail in other chapters of the National Levee Safety Guidelines as described in Table 10-7.

Table 10-7: Related Content

Chapter		Chapter Title	Related Content
	1	Managing Flood Risk	Sources of flood hazard
	2	Understanding Levee Fundamentals	Potential failure modes
	3	Engaging Communities	Flood-related communicationEmergency communication
0	4	Estimating Levee Risk	Risk assessmentPotential failure modesInundation maps
31	5	Managing Levee Risk	Levee risk managementRisk-informed decision making
	6	Formulating a Levee Project	
	7	Designing a Levee	Levee rehabilitation
	8	Constructing a Levee	Construction of long-term repairs
	9	Operating and Maintaining a Levee	Flood-related inspections and monitoringEmergency preparedness
	10	Managing Levee Emergencies	
V ·	11	Reconnecting the Floodplain	
	12	Enhancing Community Resilience	Community flood preparednessEvacuation planning