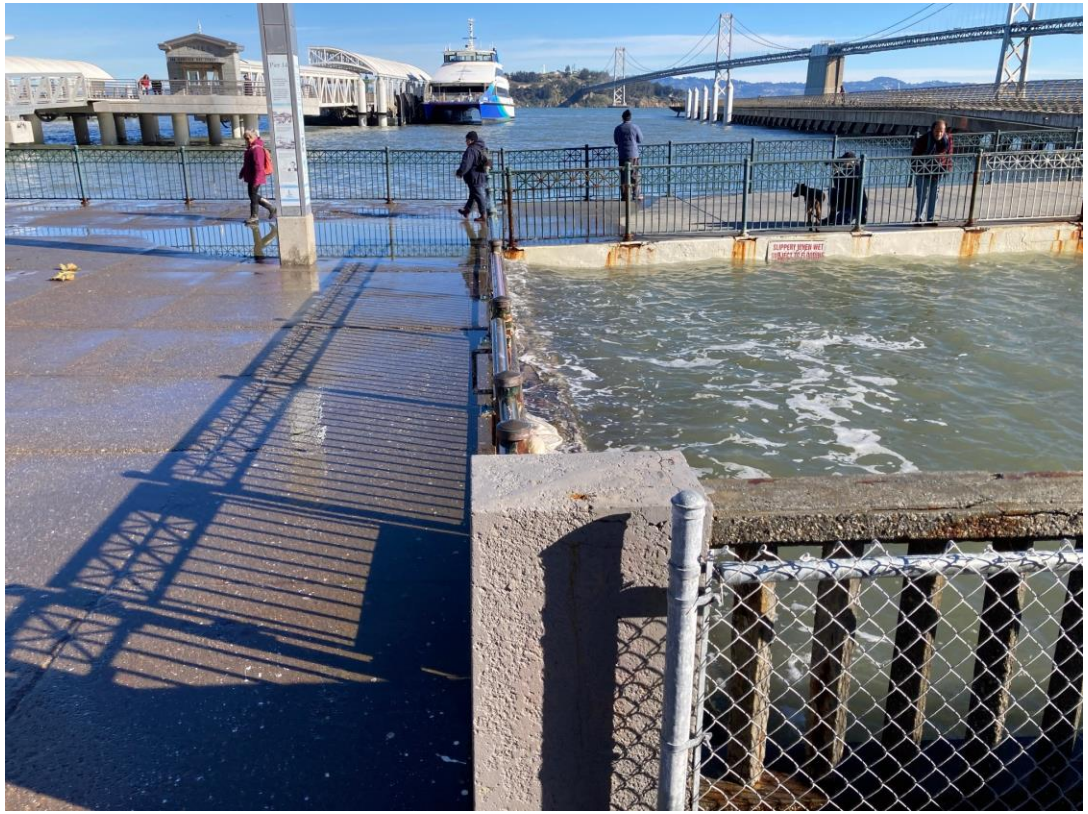
CONSIDERATION OF LEVEE AND FLOODWALL SAFETY

Jenn Hyman, P.E., Senior Engineer

August 21, 2024

PRESENTATION AGENDA

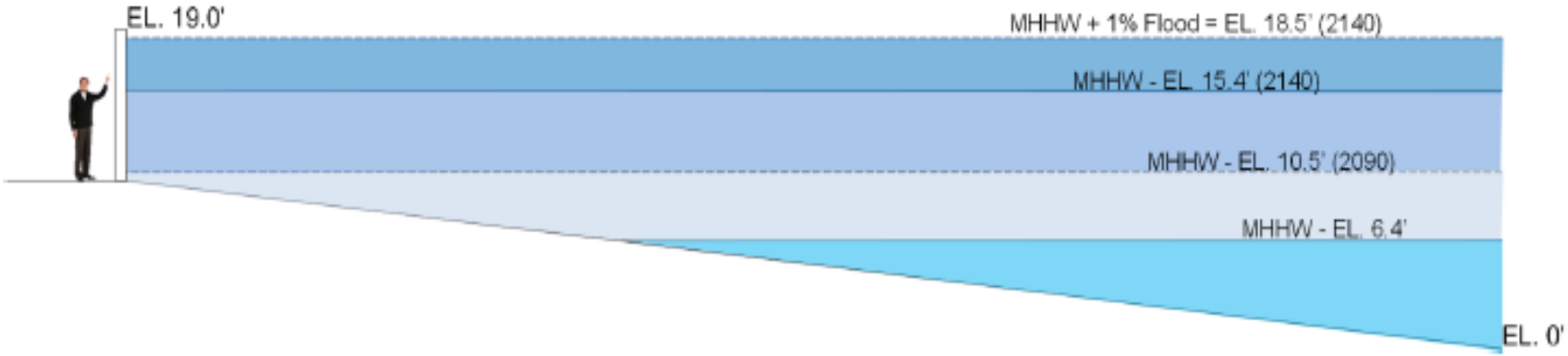
1. Why is Levee and Floodwall Safety Important?
2. BCDC Policies Guiding the ECRB
3. Typical Levees and Floodwalls
4. Lessons Learned from Hurricane Katrina
5. FEMA Accreditation of Levees and Floodwalls
6. USACE Levee and Floodwall Standards
7. Questions for ECRB and Discussion
8. Public Comment



King tide photo of the SF Embarcadero by Jenn Hyman, Jan 11, 2024

WHY IS LEVEE AND FLOODWALL SAFETY IMPORTANT?

1. With sea level rise (SLR), Bay levels will be higher than the ground levels behind levees and floodwalls, and failure could result in mass drowning fatalities.
2. Levees and floodwalls installed today will be old decades from now when SLR risk is much greater
3. Segments of levees and floodwalls must be continuous to function, and are only as effective as their weakest segment
4. BCDC's Safety of Fills policy charges the ECRB with confirming not just levee/floodwall design criteria for in-Bay projects, but also **"placement" (construction) and "maintenance".**



From USACE and Port of SF, SF Waterfront Coastal Flood Study, App B.2 – Coastal Life Safety

POLICIES RELEVANT TO ECRB REVIEW

- SF Bay Plan, Safety of Fills Policies
  - 1. The Commission has appointed the ECRB … to: (a) establish and revise **safety criteria** for Bay fills and structures thereon; (b) review all except minor projects for the adequacy of their specific **safety** provisions, and make recommendations concerning these provisions; (c) **prescribe an inspection system** to assure **placement** and **maintenance** of fill according to approved designs; …These activities would complement the functions of local building departments and local planning departments, none of which are presently staffed to provide soils inspections.
  - 2. Even if the Bay Plan indicates that a fill may be permissible, no fill or building should be constructed if **hazards cannot be overcome adequately** for the intended use in accordance with the criteria prescribed by the Engineering Criteria Review Board.
  - 4. **Adequate measures should be provided to prevent damage from sea level rise and storm activity** that may occur on fill or near the shoreline **over the expected life of a project**.

WHY IS THIS IMPORTANT NOW?

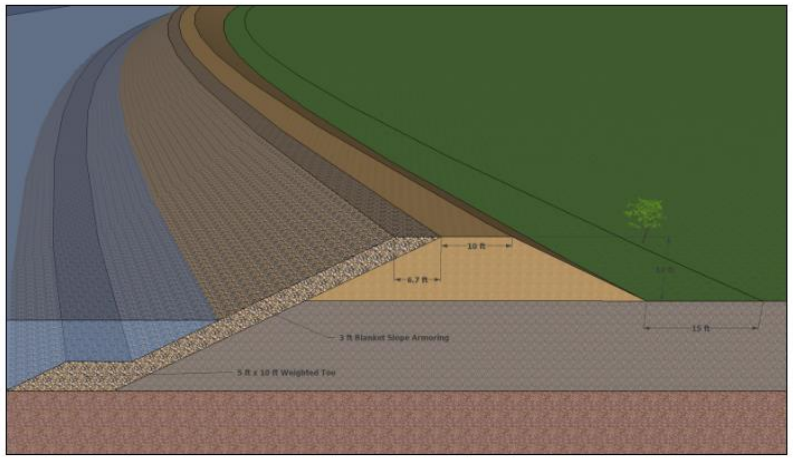
1. The ECRB is reviewing design criteria for a proposed floodwall project around critical infrastructure later this year and many levee/floodwall projects are in the planning stages
2. There is no regional agency responsible for levee/floodwall safety in the Bay Area
3. BCDC seeks ECRB input on possible permit conditions to track levee/floodwall project safety during construction and maintenance, including:
    1. Reporting on construction & maintenance
    2. Performing future condition assessments and updated stability assessments
    3. Modeling consequences of failure of the floodwall/levee

A levee protects a home surrounded by floodwater from the Yazoo River, near its confluence with the Mississippi River, on May 18, 2011 near Vicksburg, Mississippi. (Photo: Scott Olson) (Mississippi Island Homes Are Just Class Apart | How Did They Do It ? | Reckon Talk)

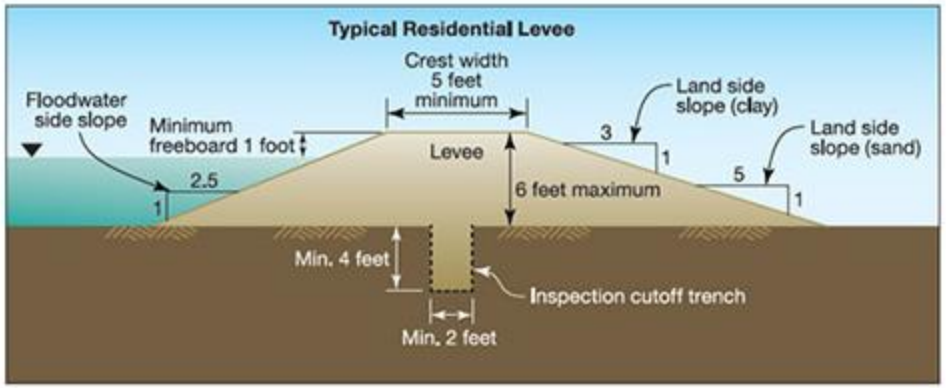
TYPICAL LEVEES

1. Made from special earthen layers
2. Generally built on existing grade
3. Can be strengthened with sheet piles

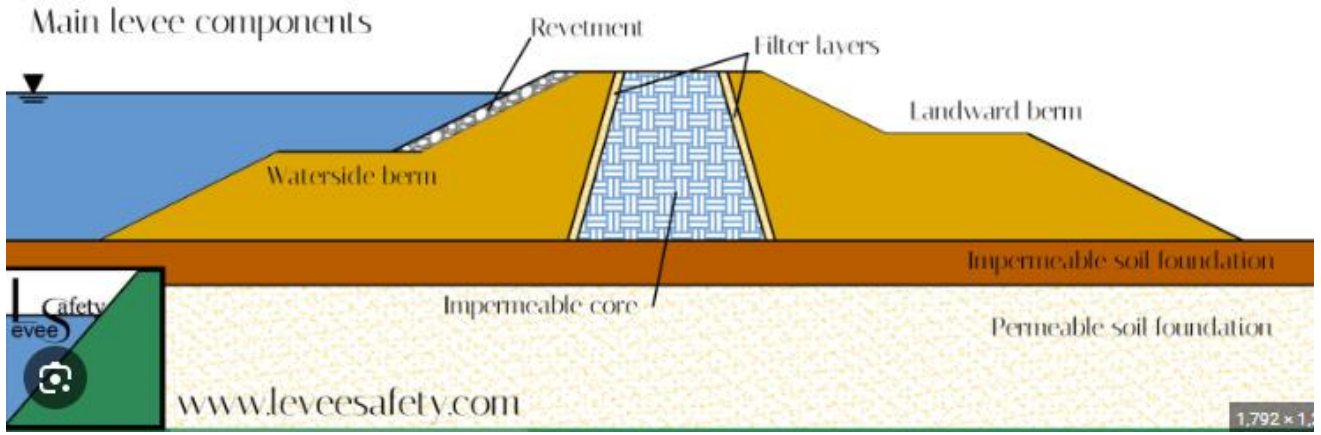
A Typical Levee Embankment Design:



https://www.nws.usace.army.mil/About/Offices/Engineering/Levee-Safety/



https://emilms.fema.gov/is_0280/groups/185.html



TYPICAL FLOODWALLS

1. Concrete
2. Steel sheet piles – also used as cofferdams

https://orientalsheetpiling.com/flood-protection-system/

USACE/TVA Slideshow titled “Floodwalls; Best Practices in Dam and Levee Safety Risk Analysis” June 2017.

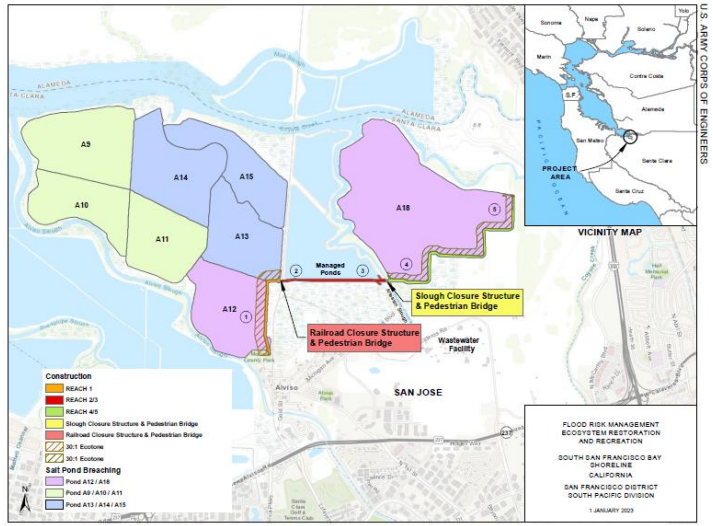
WITH SEA LEVEL RISE, COASTAL FLOODWALLS ARE SIMILAR TO BOTH DAMS AND RIVERINE FLOODWALLS

- Floodwalls on Rivers
  - Are exposed to 100-year flood events, similar in concept to 100-year tides
  - However high tides happen all year while dry seasons have low flows
  - Both are likely to contain rainwater behind it so drainage behind the wall is critical
- Dams
  - With SLR, floodwalls will eventually hold back water almost continuously, like dams
  - Unlike coastal floodwalls, dams can release excess flows over their spillway and outlets to avoid overtopping or lower water levels
- Both:
  - Failure with high water levels could result in inundation of large populated urban areas, threatening public safety
  - Maintenance and inspections are critical

Oroville Dam and Spillway from https://water.ca.gov/News/Blog/2023/June-23/Oroville-Update-6-16-2023

AGENCIES MANAGING DAM & FLOODWALL SAFETY IN SF BAY

- **FEMA** can provide accreditation based on their criteria; operation & maintenance (O&M) done by a local agency (using USACE standards)
- **USACE** sets design and O&M standards for floodwalls they fund; O&M responsibility transferred to the local municipality (e.g. Valley Water and the South SF Shoreline Levee)
- Some **County Flood Control Districts** set standards and maintain levees (e.g. Valley Water)
- In Solano County there are some **special districts** formed to maintain levees for land reclamation (e.g. https://www.solanolafco.com/documents/collinsville-levee-district-map-2014/)
- BCDC **ECRB** – only reviews major projects with Bay Fill; minor and upland projects are not reviewed



The US Army Corps of Eng South Bay Shoreline Levee Project. Valley Water is a partner in the project.

WHICH SF BAY FLOODWALLS/LEVEES ARE NOT REVIEWED BY FLOOD DISTRICT, FEMA, USACE?

1. Flood protection that is Not FEMA accredited (they may be too small a project or the owner decided not to) or USACE-funded do not need to meet FEMA/USACE standards.
2. Privately funded flood control on private property
3. Some Flood Districts have ceded oversight to cities (e.g. San Mateo County)

Moffat & Nichol, Treasure Island Development Project, Sea Level Rise Risk Assessment and Adaptation Strategy for Rising Sea Levels, Aug 1, 2016

LESSONS LEARNED BY HURRICANE KATRINA (USACE)- CAUSES OF FLOODWALL FAILURE

Floodwalls with deep foundations (I-walls) failed mainly for two reasons:

1. Overtopping of wall caused scour and loss of wall support on the inboard side (Lower 9thWard);
2. Formation of a flood side gap against the wall causing fully hydrostatic head along the face of the wall down to the depth of the crack (London Avenue wall failure).

From USACE, US BurRec, DOE, TVA Slideshow on Floodwalls, Best Practices in Dam and Levee Safety Risk Analysis, prepared June 2017, presented July 2019.

FLOODSIDE GAP CAUSES FLOODWALL FAILURE

Gaps can form on the flood side of sheet pile walls, causing significantly higher loading on the walls, causing the wall to deflect. This effect causes rotational instability, leading to failure.

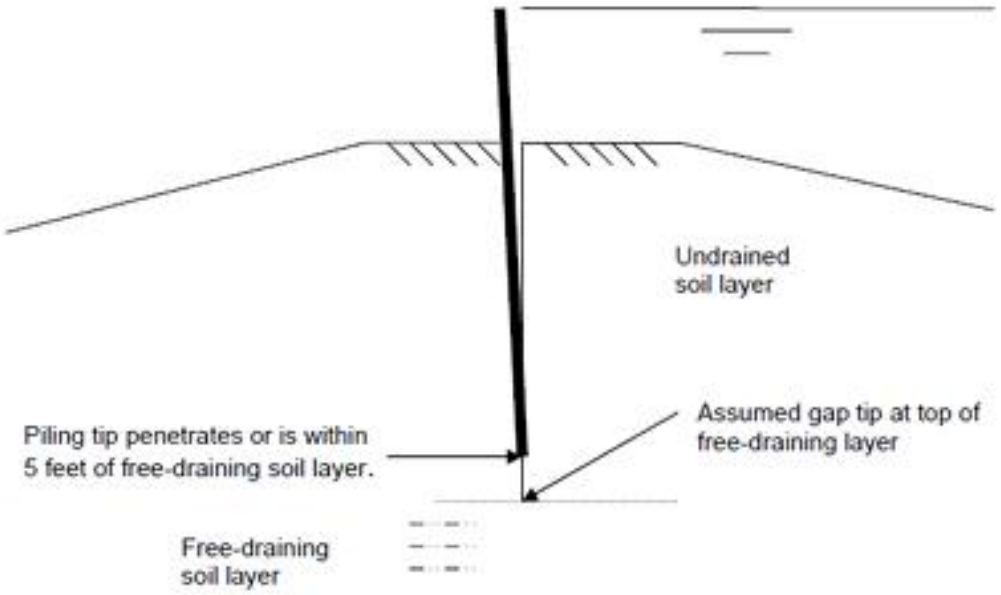


Figure B-1. Potential crack propagation below flood-side gap assumed for seepage analyses

From USACE, US BurRec, DOE, TVA Slideshow on Floodwalls, Best Practices in Dam and Levee Safety Risk Analysis, prepared June 2017, presented July 2019.

CONTRIBUTING CAUSES OF THE FAILURE OF THE HURRICANE PROTECTION SYSTEM (HPS) IN HURRICANE KATRINA

Contributing causes

- The HPS was a system in name only
- The management of the HPS was chaotic and dysfunctional
  - Multiplicity of jurisdictions
  - No one person or entity was in charge
- Questionable land use decisions allowed building homes up to 10 feet (3 m) below sea level
- Broader protection strategies were blocked by court orders and local opposition
- Pressure at all levels to cut costs ended up compromising safety
- Numerous penetrations were left "open" during the storm

Contributing causes

- Most levees were >2 feet too low
  - The vertical datum was inaccurate and never updated
  - Regional subsidence was ignored
- The margin of safety was too low at each step of the way
- There was no independent review
- The pumping system, designed for rainfall events, was useless
- Construction was piecemeal over 40 years leaving some sections too low, or incomplete
- Risk was never quantified, communicated, or taken into account in a rigorous way
- By omission or commission, the HPS was not considered a critical life-safety system

ASCE Presentation. /https://biotech.law.lsu.edu/climate/ocean-rise/against-the-deluge/01-new_orleans_levees.pdf

SOME PRIMARY CAUSES OF LEVEE BREACHING

- Levee overtopping, causing erosion of the unprotected backside
- Structural failure caused by inadequate foundations or foundation defects, subsidence, seepage, erosion, and borrowing animals
- Illegal contractor construction methods
- Earthquakes

Erosion on the backside of a levee.
https://biotech.law.lsu.edu/climate/ocean-rise/against-the-deluge/01-new_orleans_levees.pdf.

FEMA ACCREDITATION OF FLOODWALLS/LEVEES

A sheetpile wall on a levee in Foster City: Fostercitylevee.org

- Purpose is to revise the flood insurance map and reduce insurance costs.
- Must address flood hazards from a “base flood” or 100-year flood (fluvial flooding is considered; groundwater and sea level rise not considered)
- Floodwalls/levees must be a complete system; water cannot go around it
- Can apply to areas where the whole site is raised up
- Has strong safety standards through the use of USACE Engineering Manuals
- A very long process that is not complete until years after the system is constructed.
- Bay Area examples:
  - Foster City Sea Wall
  - USACE South SF Shoreline Levee (under construction)
  - USACE Colma Creek Floodwall (under design)

PROPOSED FEMA FLOODWALLS/LEVEES (IN PRE-APP)

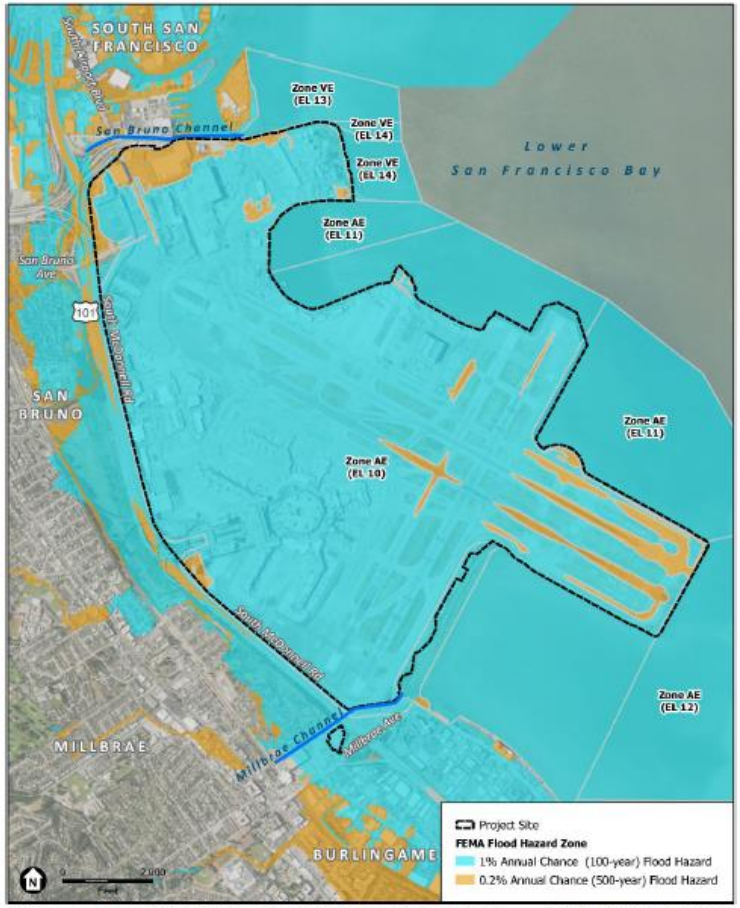
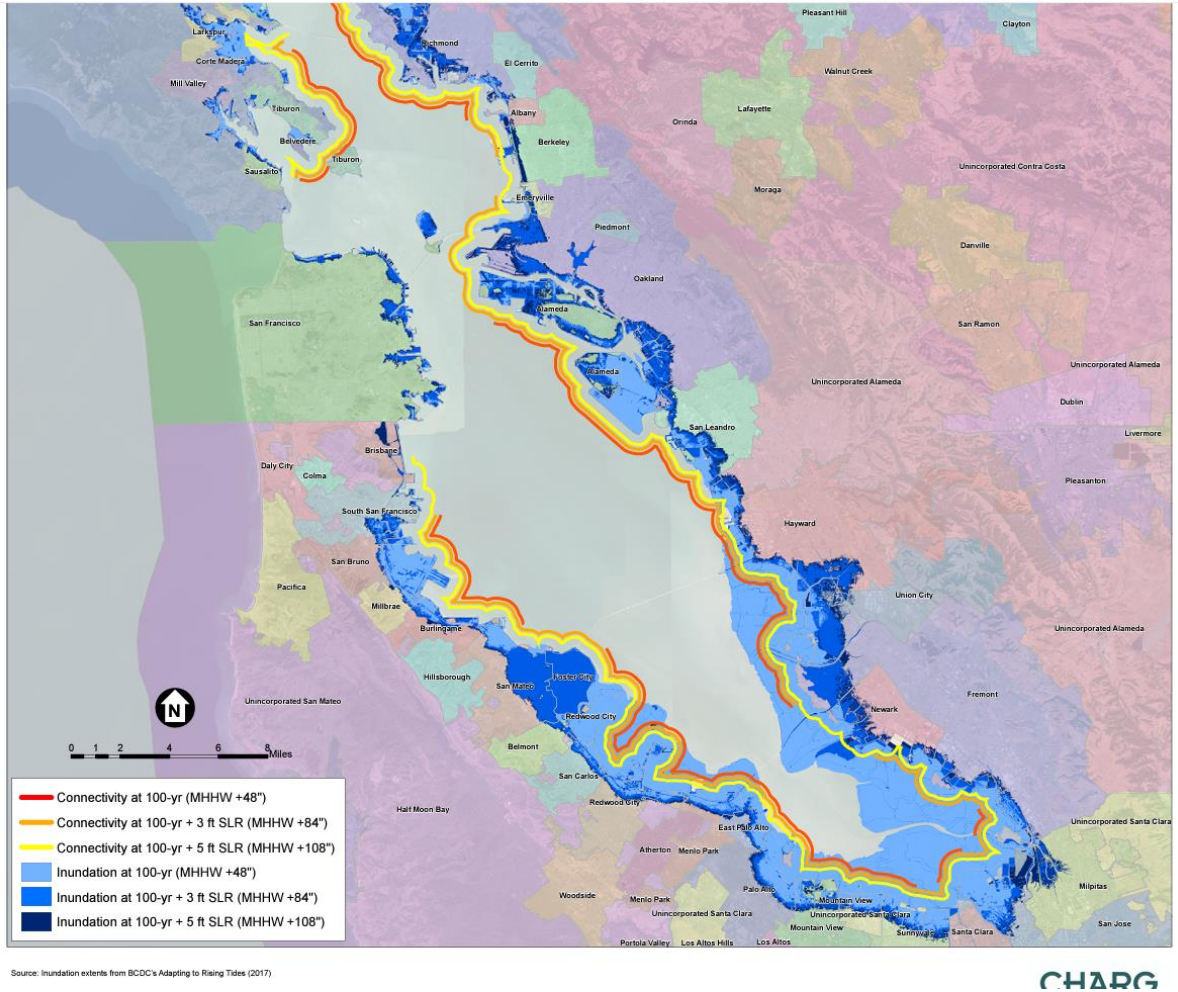


Figure 1
FEMA Flood Insurance Rate Map

- SFO-SPP Sea Walls (7 miles)
- USACE/Port of SF Flood Study raised shorelines and floodwalls (7.5 miles)
- SAFER levees? (11 miles)
- First Mile Horizontal Levee?
- OneShoreline Millbrae-Burlingame Barrier Project? (3 miles)
- OneShoreline Redwood Shores SLR Protection Project (3 miles)
- North Richmond Living Levee (0.7 mi) will be built to FEMA standards and raised and accredited later
- Many more are coming

FEMA Flood Insurance Map from ESA, SF International Airport Shoreline Protection Program Flooding Hazards, August 2023

WHAT IS A "COMPLETE SYSTEM"?



- Levee or flood wall segments cannot be accredited by FEMA, although they can be designed for future accreditation
- FEMA will only accredit (and change their map) for flood control systems that demonstrate no flooding onsite under current storm conditions
- Complete flood control systems today may not be complete in the future with sea level rise
- FEMA typically reassesses flood insurance maps every 25-30 years

SLR flood connectivity between jurisdictions, by CHARG

FEMA DESIGN CRITERIA

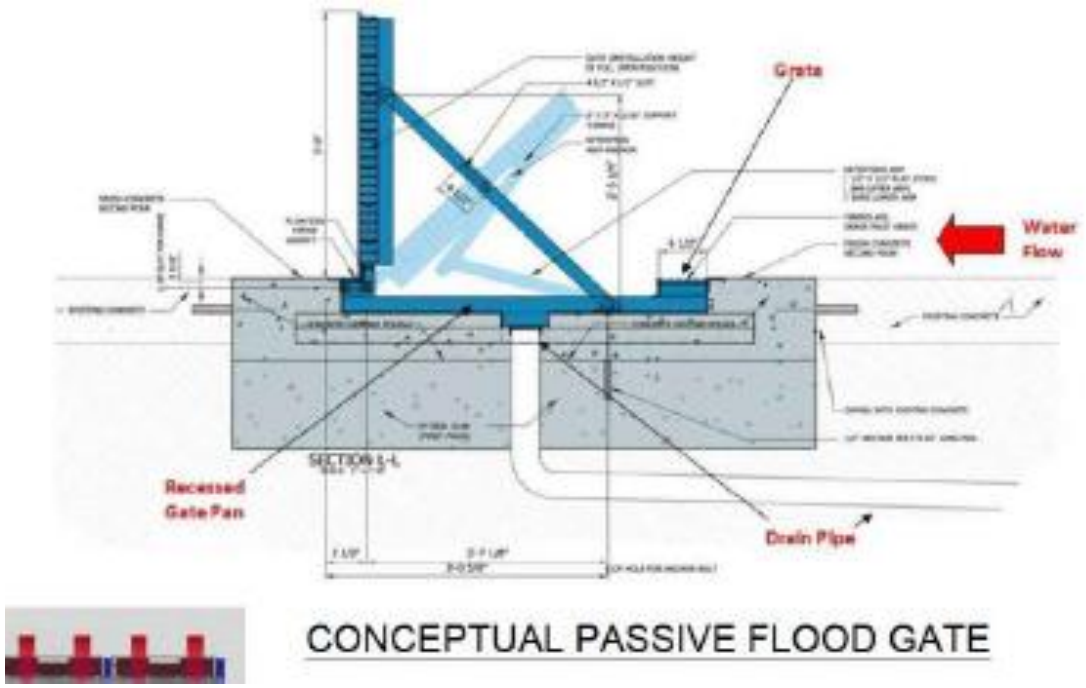
Table 10 Design Elevations. All elevations in ft-NAVD88.

Reach ID	FEMA BFE	1% SWEL + 2ft Freeboard	1% TWL (Rmax) + 1ft Freeboard	COWI Design Elevation Indicator	COWI Proposed Design Elevation
1	10	15.8	NA	15.8	16
2a	13	15.8	15.3	15.8	16
2b	14	15.8	19.3	19.3	19.5
2c	11	15.8	15.9	15.9	16
3	11	15.8	15.6	15.8	16
4	11	15.8	15.6	15.8	16
5	10	15.8	17.0	17.0	17
6	10	15.8	15.4	15.8	17
7a	11	15.8	16.8	16.8	20.2
7b	11	15.8	17.4	17.4	20.2
7c	11	15.8	17.3	17.3	20.2
8	11	15.8	17.3	17.3	17.5
9	11	15.8	16.5	16.5	17
10	11	15.8	16.6	16.6	17
11	11	15.8	17.1	17.1	17
12	12	15.8	17.3	17.3	17
13	10	15.8	15.2	15.8	17
14	12	15.8	18.0	18.0	18
15	10	15.8	NA	15.8	16

- Design height is the maximum of:
- the 1% Still Water Elevation Level (100-year storm tide) + 2 ft freeboard OR
- 1% TWEL (100-year storm tide + wave runup) + 1 ft freeboard
- SLR is often added on top of this, but not required by FEMA
- Embankments shall be designed to have no appreciable erosion during the base flood
- Demonstrate freeboard will be maintained with anticipated soil settlement during the accreditation period.

COWI Coastal Hazard Flood Study, SFO-SPP, August 2023

FEMA REQUIRED SUBMITTALS



Passive flood gate – the SFO-SPP includes 6 of these where the floodwall crosses a road. from COWI-Terra plans dated 7/19/23

- Calculations of design height
- Stability Analysis – Geotech and structural analysis reports
- Interior Drainage Plan- analyze capacity of storm drain system for evacuating interior floodwaters, have a flood warning system, operations plan, manual backup for activating automatic systems, inspection/testing plan
- Operation Plan- contains operation procedures and manuals for any closure devices, documentation of a flood warning system, and provisions for periodic operation/testing of closure structures

FEMA REQUIRED SUBMITTALS (CONTINUED)

Maintenance being conducted on Delta levees.

- Maintenance Plan – this plan must be implemented under the jurisdiction of a Fed or State agency or an agency participating in the National Flood Insurance Program.
- As-built plans

https://water.ca.gov/Work-With-Us/Grants-And-Loans/Delta-Levees-Maintenance-Subventions

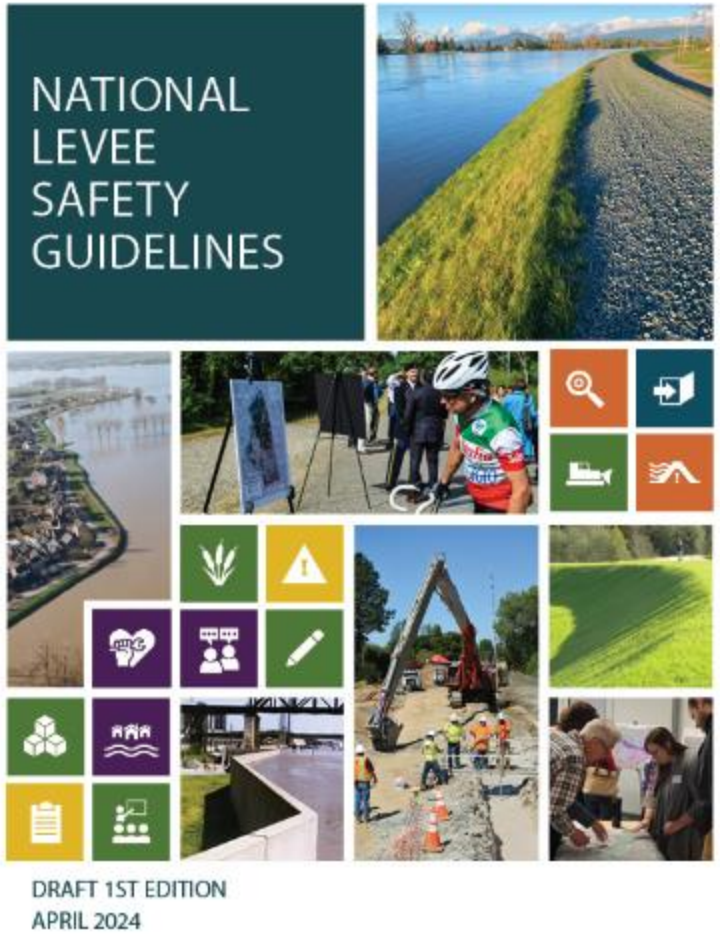
FEMA ACCREDITATION DOES NOT

Photo of sunny day flooding from groundwater rise, from Shallow Groundwater Response to Sea-Level Rise by Pathways Climate Institute and SFEI, 2022.

- Require consideration of sea level rise or groundwater rise
- Require minimization of environmental impacts or promote nature-based solutions
- Require backup power systems
- Have minimum standards for maintenance
- Review submittals in detail like the ECRB or a peer review
- Follow up with the project following accreditation unless they are redoing the flood map for that region, which typically happens every 20-30 years

US ARMY CORPS OF ENGINEERS LEVEE & FLOODWALL SAFETY

- New National Levee (& Floodwall) Safety Program
- Draft Safety Guidelines out for public comment



https://orientalsheetpiling.com/flood-protection-system/

https://www.leveesafety.org/pages/nlsg

US ARMY CORPS OF ENGINEERS LEVEE & FLOODWALL SAFETY GUIDELINES CHAPTERS

- Estimating and Managing levee risk
- Designing a levee
- Constructing a levee
- Levee O&M
- Managing levee emergencies

NATIONAL LEVEE SAFETY PROGRAM

www.leveesafety.org

NATIONAL LEVEE SAFETY GUIDELINES – *WHICH CHAPTERS SHOULD I READ?*

Learn which chapters may be of most interest based on your role in levee safety, floodplain management, and community resilience.

	LEVEE OWNER/ OPERATORS	EMERGENCY MANAGERS	LOCAL COMMUNITY OFFICIALS	TECHNICAL PROFESSIONALS	ENVIRONMENTAL AND OTHER INTERESTS
PREFACE AND NAVIGATING THE GUIDELINES *High-level information on Guidelines development and descriptions of visual tools to assist readers with navigation and readability.*	✓	✓	✓	✓	✓
CHAPTER 1: MANAGING FLOOD RISK *Basic decision-making framework for communities to align goals with flood risk management, flood risk tolerance, and resilience and if levees fit into those goals. Also includes different flood hazards and consequences of flooding.*	✓	✓	✓	✓	✓
CHAPTER 2: UNDERSTANDING LEVEE FUNDAMENTALS *Basic terminology and related information that focuses on levee features, functionality, and common ways that levees can fail.*	✓		✓		
CHAPTER 3: ENGAGING COMMUNITIES *Approaches for engaging communities during each phase of the levee lifecycle.*	✓	✓	✓		
CHAPTER 4: ESTIMATING LEVEE RISK *Technical procedures for estimating levee risk to include estimating hazards, performance, and consequence and understanding risk assessment results.*	✓	✓		✓	
CHAPTER 5: MANAGING LEVEE RISK *Risk management principles and guidance on key decisions and management actions for each phase of the levee lifecycle (i.e., how to prioritize and scale the level and frequency of routine activities).*	✓				
CHAPTER 6: FORMULATING A LEVEE PROJECT *Principles and practices of formulating a new, modified, or rehabilitated levee to include considerations when choosing alternatives and realizing the benefits of incorporating adaptive management into the planning process.*	✓		✓	✓	✓
CHAPTER 7: DESIGNING A LEVEE *Design process for a new levee or one to be rehabilitated or modified, including common challenges associated with levee design and solutions to address those challenges.*				✓	
CHAPTER 8: CONSTRUCTING A LEVEE *Levee construction process including best practices to use prior to, during, and at the end of levee construction – emphasizing practices that promote good levee performance, resilience, and serviceability.*	✓			✓	✓
CHAPTER 9: OPERATING & MAINTAINING A LEVEE *Practices for operating and maintaining levee features, developing an operations and maintenance plan, and identifying and resolving common operations and maintenance challenges.*	✓				
CHAPTER 10: MANAGING LEVEE EMERGENCIES *Preparing, managing, operating, and recovering from a levee emergency to include best practices for developing emergency plans, effectively utilizing inundation maps, and monitoring, collecting, and storing levee performance data during floods.*	✓	✓	✓		
CHAPTER 11: RECONNECTING THE FLOODPLAIN *Principles for levee setback or removal and considerations during the planning, design, and construction phases. Also includes floodplain restoration benefits and impacts of levee removal within the floodplain and watershed.*	✓	✓	✓	✓	✓
CHAPTER 12: ENHANCING COMMUNITY RESILIENCE *Actions to mitigate damages from flooding in the event of levee overtopping such as warnings, alerts, evacuation planning, public health and safety considerations, and consideration of underserved communities.*		✓	✓		✓

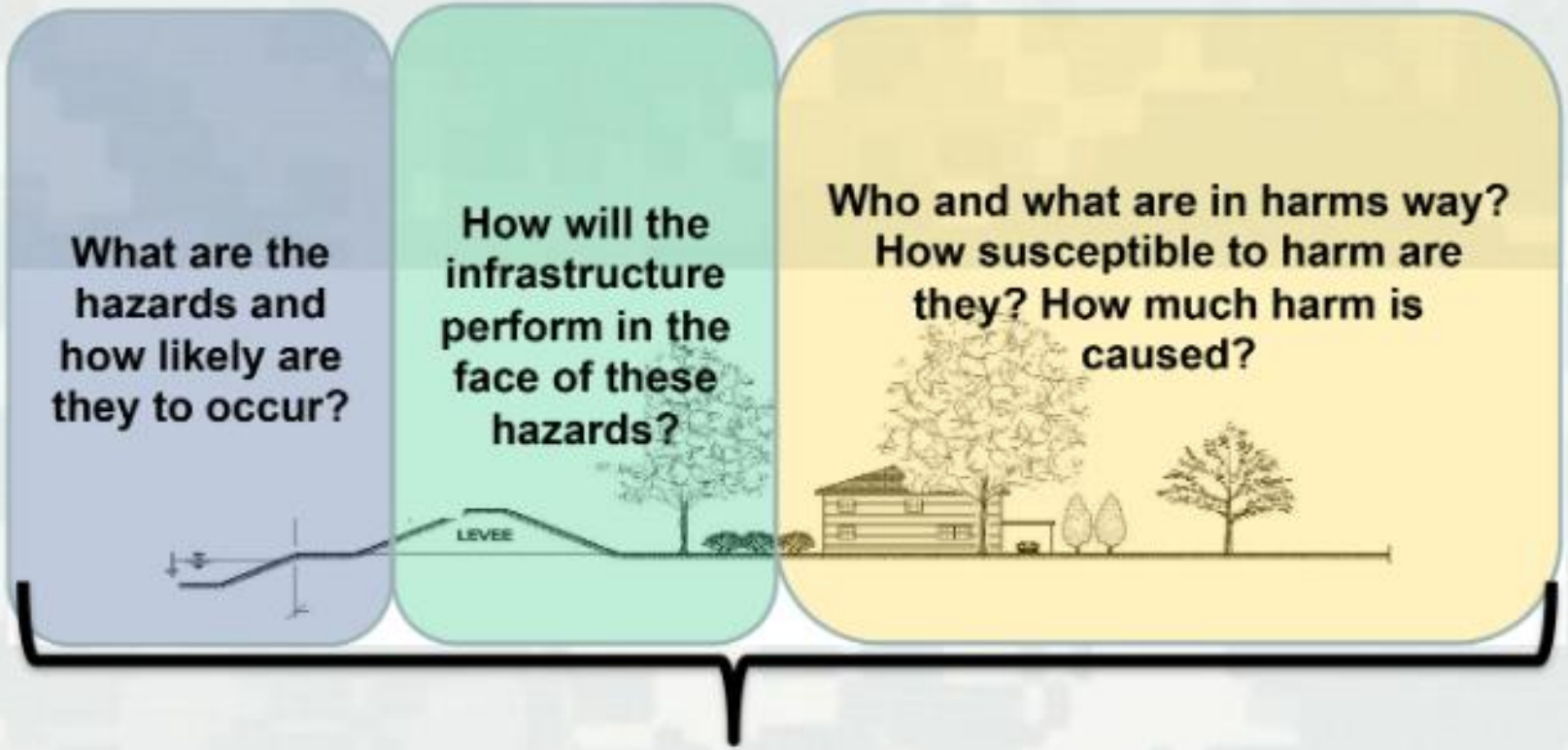
4 / National Levee Safety Guidelines: Roadmap / March 2024

FEMA

https://www.leveesafety.org/pages/nlsg

Risk Informed View of Infrastructure Safety

Risk = f(Hazard, Performance, Consequences)



Infrastructure Safety Program: Focused on People, Performance, and Risks

BUILDING STRONG®

https://www.nws.usace.army.mil/About/Offices/Engineering/Levee-Safety/

QUESTIONS FOR THE ECRB TO CONSIDER FOR FLOODWALL/LEVEE PROJECTS ON BAY FILL

1. Should the ECRB provide extra scrutiny of the safety of levees and floodwalls in certain projects: i.e. above a certain height, above a certain height of water retained above the internal grade, no compliance with USACE standards, or high criticality of the resource protected?
2. What construction submittals for floodwalls and levees are important to review and have in BCDC files?
3. Should BCDC require an approved maintenance plan or reporting on long-term maintenance?
4. Due to anticipated material corrosion, increase frequency of storms, and rising sea levels, should BCDC have a permit condition requiring future condition assessments and an updated stability study? If so at what frequency?
5. Should a failure scenario(s) be modeled to better understand safety? What scenarios should applicants model?

QUESTIONS?

Steel sheet pile flood walls in New Orleans after Hurricane Katrina. /https://biotech.law.lsu.edu/climate/ocean-rise/against-the-deluge/01-new_orleans_levees.pdf