

Levee Threat Monitoring Guidelines



State of California
Department of Water Resources
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Levee Threat Monitoring Guidelines

State of California
California Natural Resources Agency
Department of Water Resources



Division of Flood Management
Flood Operations Branch
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Introduction

The purpose of the Levee Threat Monitoring Guidelines is to establish a set of “Best Practices” based on field-tested techniques used by Levee Maintaining Agencies, their engineers, flood fight specialists, and levee inspectors to mark and monitor a levee threat.

These guidelines seek to “standardize” levee threat monitoring techniques and are NOT to be taken as requirements. This standardization will help ensure the threat is properly communicated to the appropriate groups such as emergency responders and the Flood Operations Center. Particularly when there are multiple threats during a high water event, the ability to communicate effectively becomes especially important when the number of potential threats exceeds the available (limited) resources to respond, and a priority must be placed on which threat to mitigate first.

The Levee Threat Monitoring Guidelines presented in this field book were developed by the Department of Water Resources Division of Flood Management in cooperation with the local maintaining agencies, experienced consultant engineers, and DWR Maintenance Yards.



Levee and Embankment Threats

The main causes of levee failure or flood related problems due to high water are:

- **Seepage** of water carrying material through or under the levee heavy enough to cause a “boil”.
- **Erosion** of the levee or embankment due to swift moving water or wave action.
- **Overtopping** resulting from water-surface elevations higher than the levee or embankment.

Patrolling

The best defense against flood related issues and/or levee failure is to identify problems early and repair them immediately. Bi-annual levee inspections and effective high water patrolling make this possible. The following suggestions will help in organizing patrol teams for this work.

- Operate under the SEMS/ICS system and report to the appropriate section chief.
- Provide a sufficient number of workers for two 12-hour shifts.
- Provide each worker with a copy of the DWR “Flood Fighting Methods” handbook.
- Assign two people to each mobile patrol.
- Advise the officials of the district or agency responsible for emergency assistance in the area, and if necessary request their help, i.e. local emergency services office.



Terminology

Boil	Also known as “sand boil”, is caused by water flowing through or under a levee, possibly carrying eroded levee material, and surfacing on the land side of the levee.
Cracking	Fracture on the top or slope of a levee caused by displacement of the embankment material. Excessive cracking can lead to slipping/sliding (clay soils) or sloughing (silty or sandy soils).
Erosion	Removal of levee material from the toe or slope of the levee due to swift moving water or wave action possibly resulting in bank caving, section loss, or levee break.
Flood Fighting	An effort made to prevent or mitigate the effects of flood waters.
Hub	A 1.5”x1/5”x4” wooden stake that is pounded into the ground as a place-holder (option) for lath with only a few inches exposed and sprayed at the top with orange fluorescent marking paint for extra visibility.
Lath	Long, narrow wooden stakes (4 feet long by 1-1/2 inches wide) used to mark problem areas during high water patrolling. A brief description of the problem along with the date, time, and patroller’s initials are written on the lath with a permanent ink marker. Brightly colored survey ribbon is attached to the lath for easy identification.
Levee	An earthen structure that parallels a river or stream designed to prevent high water flows from inundating urban and/or agricultural land.
Levee Break	A point in the levee system that has failed to perform its designed function, has eroded away and is allowing water to inundate land.

Levee Breach	The same as “Levee Break” but can sometimes describe a section of levee that has been intentionally broken. If intentional, also known as a relief cut.
Overtopping	When water has risen higher than the banks of a waterway or the top of a levee.
Plastic Sheeting	Made of polyethylene; these 100’x20’x10-mil rolls are sometimes referred to as visquine and are used for erosion control.
Relief Cut	Intentionally removed section of levee to relieve hydrologic pressure upstream and downstream of the levee section.
Sack Ring	Multiple sandbag rings used to encircle a boil, slow the flow of water, and stop the erosion of levee material.
Sandbag	An 18”x30” bag (burlap or plastic) filled with sand or other appropriate material intended for use as a temporary flood fighting measure.
Scarp	A steep slope or long cliff that occurs from erosion or faulting and separates two relatively level areas of differing elevations.
Seepage	Water traveling under or through a levee in the void spaces of the soil.
Sloughing	Soil movement or slides often caused by over-saturated levee or hillside slopes. Can also be referred to as “mud slides”.
“U” Shaped Sack Ring	A sandbag structure used on levee slopes to control boils.

Material Supplies Checklist:

- Lath (Bundle of 50)
- Wooden Stakes (1"x3"x24")(Bundle of 25)
- Hubs (10)
- 6' Rebar (2 No. 2 Rebar)
- Bailing Wire
- Pliers
- Tape Measure (100')
- Survey Ribbon (Bright Colors, Multiple Rolls)
- Basic Plastic Protractor (5)
- 1/2" Nut/Bolt Washers (20)
- Batteries
- Shovels, Long Handle (#2 Mud Shovel)
- Sledge Hammer (10 lb)
- Sandbags (approximately 50 empty)
- Plastic Sheeting (1 roll)
- Box Twine (250lb tensile strength)
- Tie Down Buttons (approximately 100)
- Safety Cones (Fluorescent Orange) or Barricade
- Permanent Ink Markers
- Orange Fluorescent Marking Paint-sprays upside down (17.0 oz)
- Camera
- GPS
- Log Book

Safety Supplies Checklist:

- First Aid Kit
- Personal Flotation Device
- Directory of Flood Officials
- Flood Emergency Phone Card
- Rain Gear
- Rubber Boots
- Hard Hat
- Safety Glasses
- Gloves
- Boots
- Personal Safety Light
- Warm Clothing

Lath Labeling Example

Orange Fluorescent Marking Paint (top 6" minimum)



Survey Ribbon – use bright colors and double-up for extra visibility



Provide Date and Time (24-hr) as reference for determining rates (i.e. rate of decay, flow rate, etc.)



Date

Time

Provide Initials to reference patroller



Initials

Threat being monitored



BOIL

Pertinent information being used to describe threat (i.e. flow rate, offset distance, horizontal/vertical displacement, etc.)



1 cup/min.

Field Safety Measures

- **Check weather patterns:** Always know weather forecasts and how it affects the vulnerable areas.
- **Changing Water Patterns:** The rise and fall of water can occur gradually or very quickly. Knowledge of high water and how it relates to your sites/levees is essential. Continuous monitoring and communication of water level influences, (i.e. reservoir releases, tides, and drainage inflow) is very important. Always know your area and its flood history.
- **Swift Water:** High velocities of water are common during high water events. Extreme caution should be used when anyone is exposed to high water. Workers should have personal flotation devices, throw ropes, and lifelines in the immediate area. Each staking crew must be composed of at least two individuals when staking swift water areas. Use common sense and sound judgment around swift water. Know your resources and how to activate them prior to the event. Swift water rescue teams may be available.
- **Temperature Related Illness:** Weather patterns can change constantly. Changes in temperature present the potential for hypothermia and heat exhaustion/stroke. Levee monitors should know the signs of distress for these types of illnesses and how to treat them. During cold, wet weather, it is recommended that workers layer clothing to stay warm and dry. A dry blanket and warm clear fluids should be on the work site for emergency use. In warm/hot weather lightweight clothing is recommended. If skin is exposed, a sun block agent may need to be applied. Plenty of drinking water should be on site and consumed regularly. Headgear is recommended in both hot and cold situations.
- **Insect/Animal Exposure:** Flooded areas force a variety of animals to evacuate to high ground. Workers in these areas should be aware of these animals and not handle them. If animal removal is needed, contact a local professional. Stinging and biting insects are prominent in certain flood-prone areas. Chemical repellents can be useful as a deterrent. A complete first aid kit should be on site.

- **Vegetation:** Noxious plants such as star thistle, stinging nettle, and poison oak are commonly found along rivers, streams, and levees. Avoid direct contact with this type of vegetation to prevent itching and rash. Consult medical personnel if symptoms persist. Individuals with history of allergic reaction should consider carrying an EpiPen.
- **Contamination:** Flooded areas can potentially carry high levels of contaminants. Common contaminants include fuel, sewage, and pesticides. Local Haz-Mat teams should be contacted if needed. Always wear protective clothing to help limit contact with water. Carry antibiotic hand soap and wash thoroughly after working around flood water.
- **Construction Equipment:** There are times when equipment and people will occupy the same work area. Workers should wear safety vests and hard hats and be aware of their surroundings. Safety warning devices (i.e. backup alarms and lights) should be intact and working on all equipment. Keep a battery-operated flashlight and radio on hand. Communication and alertness are vital! All operators must be certified for their equipment.
- **Boat Travel:** Materials and/or personnel will sometimes need to be transported to work sites by boat. Operators of the watercraft must be certified. Personal flotation devices must be available for every passenger. Extreme care should be taken while loading and off loading.
- **Patrolling:** Patrols will identify, mark, and monitor trouble spots in affected areas. Vehicle patrols should travel in two person teams with dependable communication devices. Lifelines, personal flotation devices, and a blanket should be in the vehicle for possible water-related accidents. Foot patrols should also have the same considerations. Extreme caution should be exercised when travelling saturated, cracked, or sloughing areas. Learn first-aid and have a first-aid kit with you at all times. Never turn your back on the water - work facing the water whenever possible or have a spotter monitor it for you if necessary. Do not take actions that would put an individual in harm's way.

- **Safety Gear:** Rain gear, warm clothing, handheld lights, gloves, goggles, hard hat, boots, ropes, personal flotation devices, hip waders, etc. as needed.
- **Structure Considerations:** When working around structures be aware of downed power lines, natural gas or propane leaks, and unstable structure supports. Communicate with the structure owner if possible.
- **Vehicle Considerations:** Vehicles along the levee should remain parked on high ground— this is usually the crown of the roadway. Vehicles should also be parked facing their access point to allow for a quick exit (if needed). An escape plan should be communicated to all flood workers. Do not drive through floodwaters during high water events. Remember, two feet or less of water can cause a car to be swept away.



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Considerations Around Boil

1. Do not park directly above the boil.
2. Do not tread unnecessarily near the boil.
3. The sensitive zone may be saturated—do not walk directly from the road straight down to the boil.
4. Confirm the boil is NOT an irrigation pipe.

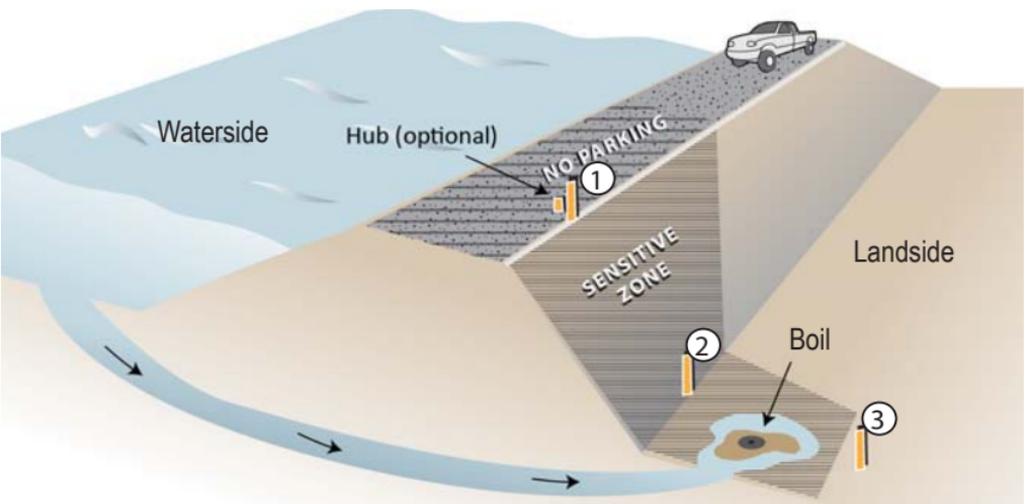
What to Measure and Record in Log Book:

Monitor changes in width, depth, and water clarity.

- Date, Time, Person's Name
- Location along levee (GPS coordinates, levee mile, or approximate description), location relative to levee crown (is it on slope?) – use Lath ① for reference
- Threat and description of threat
 - » Located on the levee slope or the ground adjacent to the slope
 - » Water is flowing clear or carrying material
 - » Approximate flow rate (i.e. 1 cup/min, 1 coffee can/min, 5-gallon bucket/min)
 - » Total number of boils
 - » Approximate waterside elevation relative to crown
 - » Note if raining heavily or if there are signs of poor drainage
- Take photos for records



How to Mark a Boil



- ① Mark what the diameter is of the Boil, and the approximate flow rate of the Boil. Stake an (optional) "Hub" at the base of the lath for extra location identification protection from lath being lost or stolen.
- ② Measured from the levee toe mark the distance to the edge of the boil, and the distance to the center of the Boil.
- ③ Lath Alternative: Place an additional lath in the landside field at a minimum distance of 10' from the Boil to show extent ponding.
Optional Measure: Use blue (environmentally safe) dye to track water flow.

①		Date	Time	Initials	BOIL 10' Diameter
②		Date	Time	Initials	BOIL 8' Offset
③		Date	Time	Initials	BOIL Extent

****Replace lath if lost or stolen****

SINK HOLE

Considerations Around Sink Hole

1. Do not park directly adjacent to sink hole.
2. Be cautious of collapse around sink hole.
3. Be cautious around toe of levee slope.
4. Confirm sink hole has not been created by an irrigation pipe.

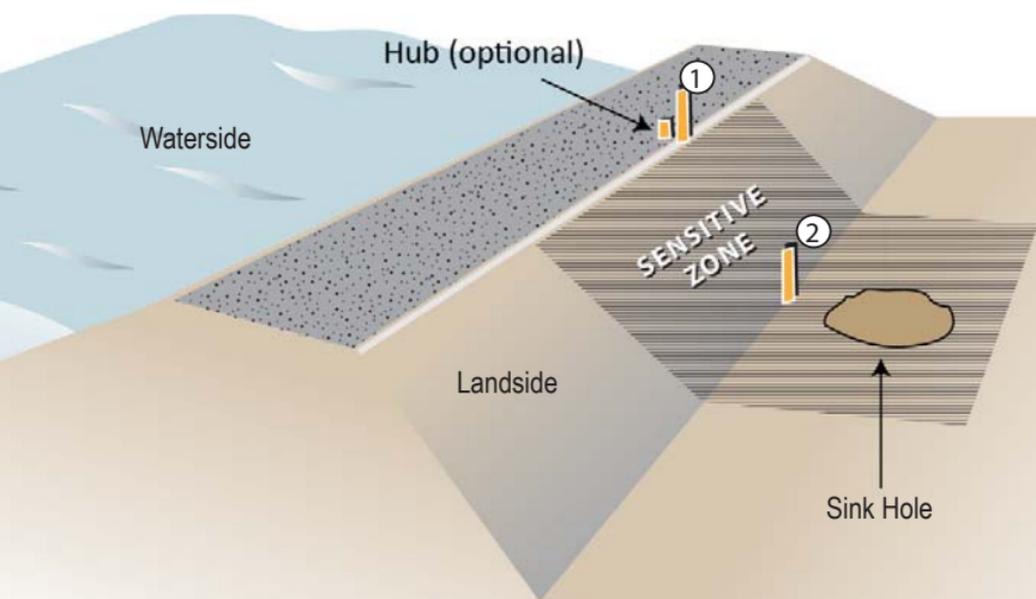
What to Measure and Record in Log Book:

Monitor changes in width and depth.

- Date, Time, Person's Name
- Location along levee (GPS coordinates, levee mile, or approximate description) – use lath ① for reference
- Threat and description of the threat:
 - » Diameter of sink hole
 - » Distance from levee toe
 - » Is it filled with water?
 - » Approximate water surface elevation
 - » Note if pipes, risers, valves or other appurtenances are present.
- Take photos for records



How to Mark Sink Hole



- ① Mark what the diameter is of the sink hole. Stake an (optional) "Hub" at the base of the lath for extra location identification protection from lath being lost or stolen.



- ② Mark what the distance is from the levee toe to the edge of the sink hole.



****Replace lath if lost or stolen****

CRACKING

Considerations Around Cracking

1. Do not park directly on the cracks.
2. Place lath 1' offset from cracks (typical).

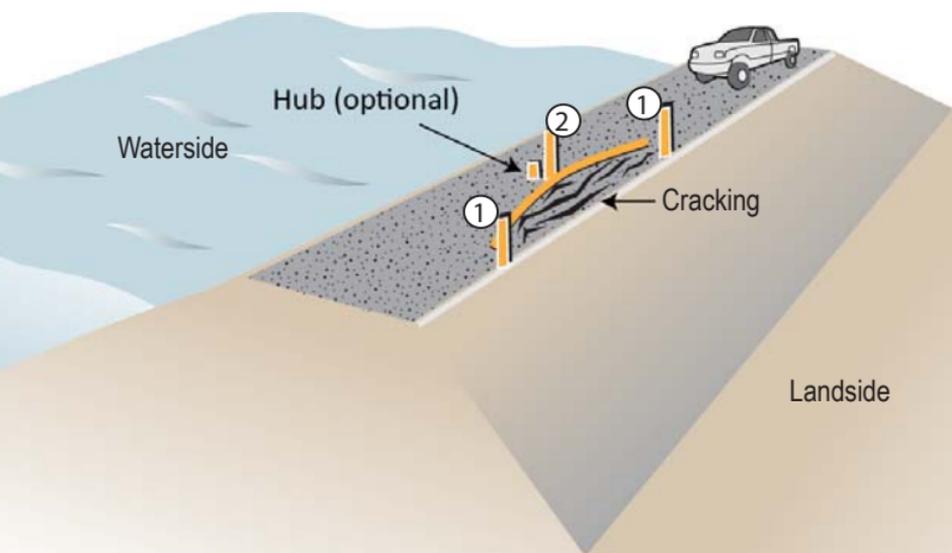
What to Measure and Record in Log Book:

Monitor change in length, width, depth and extent into crown.

- Date, Time, Person's Name
- Location along levee (GPS coordinates or levee mile or approximate description)
- Threat and description of the threat:
 - » Length of cracking
 - » Widest width within crack
 - » Deepest depth within crack
 - » Approximate water surface elevation relative to crown
 - » Look for bulging or instability on levee slope
- Draw schematic for records
- Take photos for records



How to Mark Cracking



- ① Place one lath at the beginning of the cracking location and one lath at the end with arrows pointing inwards toward the cracking. Mark the max width of cracking, and if possible also mark the max depth.
- ② Place one lath at the center of the cracking location. Mark the total aggregate length of the cracking. If the cracking is occurring on the crown, mark the width of cracking into the crown. Stake an (optional) "Hub" at the base of the lath for extra location identification protection from lath being lost or stolen.
- ③ Paint alternative: Draw a line using fluorescent orange spray paint at the edge of the cracking. This will aid in visually displaying the area of cracking. Use in addition to the placing and marking of lath described above.



****Replace lath if lost or stolen****

SEEPAGE

Considerations Around Seepage

1. Do not park directly above the area of seepage.
2. Do not tread unnecessarily near the area of seepage.
3. The sensitive zone may be saturated—do not walk directly from the road straight down to the area of seepage.
4. Confirm the seepage is NOT due to an irrigation pipe.

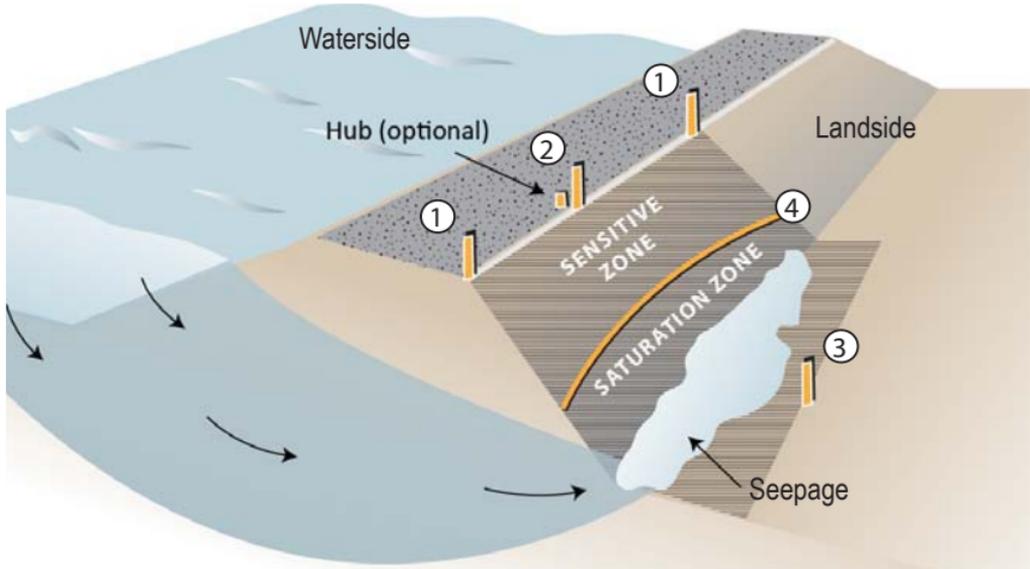
What to Measure and Record in Log Book:

Monitor changes in water flow, material flow, and extent of seepage.

- Date, Time, Person's Name
- Location along levee (GPS coordinates, Levee Mile, or approximate description) – use Lath 2 for reference
- Threat and description of threat:
 - » Approximate length and width of seepage
 - » Does the water appear to be clear?
 - » Approximate water surface elevation relative to crown
 - » Extent of soil saturation relative to levee toe
 - » Note if raining heavily or if there are signs of poor drainage
 - » Note signs of slope instability
- Take photos for records



How to Mark Seepage



- ① Mark whether the water is ponded or if it appears to be running, and whether the water appears to be clear or carrying material.
- ② Mark the longitudinal distance of the Seepage extents, as well as the width of the Seepage extents. Stake an (optional) "Hub" at the base of the lath for extra location identification protection from lath being lost or stolen.
- ③ Lath Alternative: Place an additional lath in the field at the extents of ponding – shows depth of Seepage.
- ④ Saturation Zone: Draw a line up the levee slope using fluorescent orange spray paint to display the edge of the saturation zone.



****Replace lath if lost or stolen****

SLOPE INSTABILITY

Considerations Around Slope Instability

1. Do not park directly above unstable slope.
2. Barricade area if more than $\frac{1}{4}$ crown width or more than 2' vertical displacement (severe case).
3. Tread lightly in sensitive zone to prevent furthering threat and/or risking harm to individual.

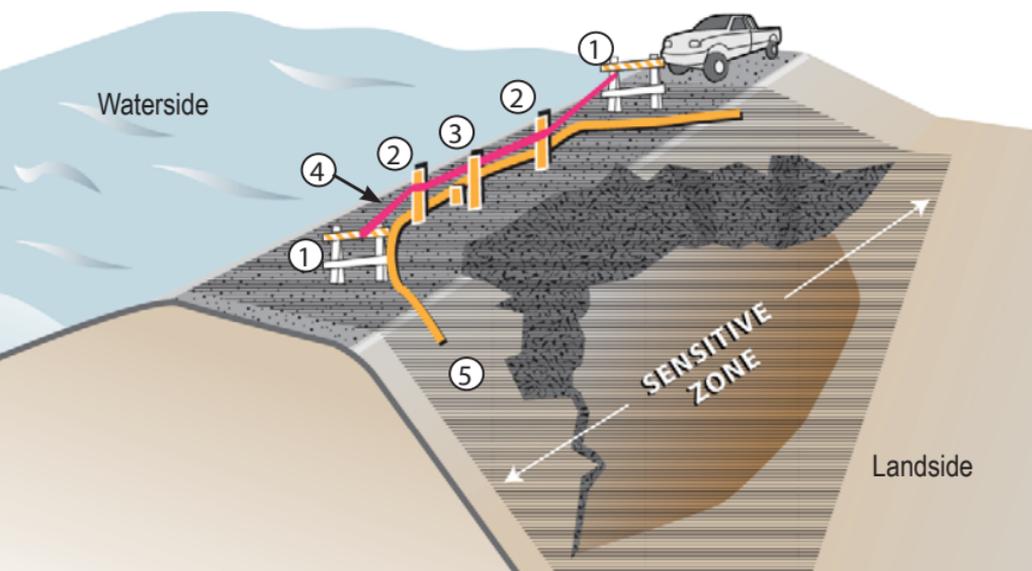
What to Measure and Record in Log Book:

Monitor movement of levee slope and record changes in horizontal & vertical displacement and extent of slope instability.

- Date, Time, Person's Name
- Location along levee (GPS coordinates, Levee Mile, or approximate description) – use Lath ③ for reference
- Threat and description of threat:
 - » Longitudinal Length (feet)
 - » Width (feet)
 - » Depth (inches)
 - » Location of threat (landside crown, slope, toe, etc.)
 - » Is the toe of the slope bulging?
 - » Approximate water surface elevation relative to crown
- Draw schematic for records
- Take photos for records



How to Mark Slope Instability



- ① Place barricade 8' offset (minimum) from lath 2. Barricades prevent vehicles from entering "danger zone" (use in severe cases).
- ② This lath shows extents of slope instability (e.g. typical 2' offset with lath from edge of vertical displacement).
- ③ Center of slope instability (typical 2' offset from edge of vertical displacement). Stake an (optional) "Hub" at the base of the lath for extra location identification protection from lath being lost or stolen.
- ④ Ribbon connects the barricades to lath and encloses the "danger zone" from one side of the slope instability site to the other. Using ribbon comprised of bright colors also helps make the site more visible.
- ⑤ Paint alternative: Spray paint a line offset from the edge of the vertical displacement in 4' increments away from the unstable slope towards the levee. This will aid in visually displaying the rate of the slope instability site. Use in addition to the placing and marking of lath described above.



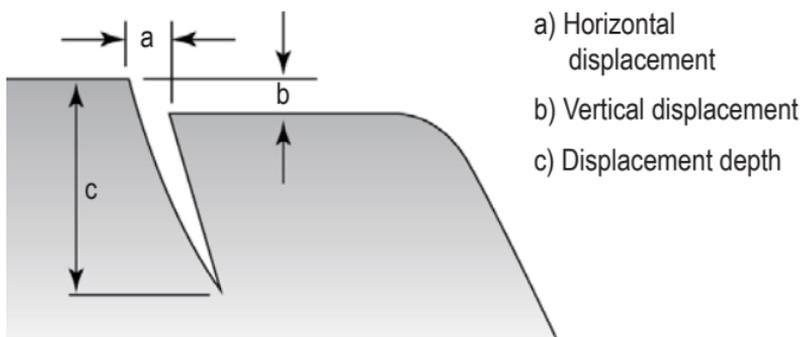
****Replace lath if lost or stolen****

SLOPE INSTABILITY

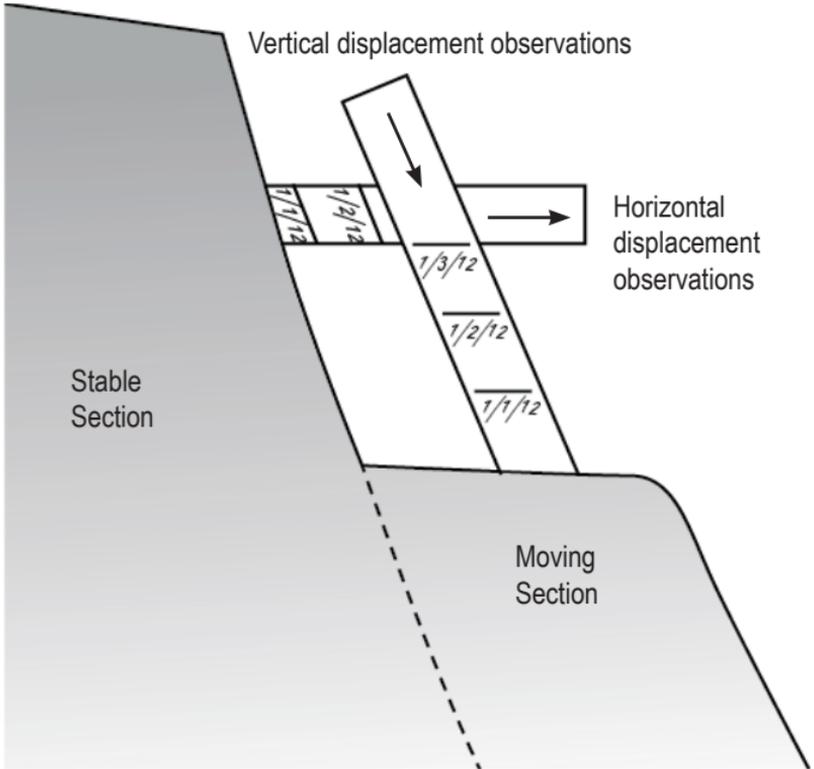
How to Mark Horizontal & Vertical Displacement

1. Prepare two laths as displayed per “Lath Labeling Example” on page 7.
2. Pound a lath (vertical) into moving section.
3. Pound a lath (horizontal) into stable section.
4. Draw a line on the vertical lath at the bottom of where it intersects with the horizontal lath. [This identifies the “baseline” for where to begin measuring vertical displacement]. Mark the date below this line.
5. Draw a line on the horizontal lath at the bottom of where it intersects with the vertical lath. [This identifies the “baseline” for where to begin measuring horizontal displacement]. Mark the date below this line.
6. Come back (some time later) and mark on the horizontal lath where it intersects with the vertical lath, and mark on the vertical lath where it intersects with the horizontal lath. Repeat this step over time as slope continues to displace.
7. Rate of horizontal & vertical displacement is calculated by subtracting the distance measured between the two days lines and divide that number by how many days the two days lines represent.

Early Stage Horizontal and Vertical Displacement



Late Stage Horizontal and Vertical Displacement



EROSION

Considerations Around Erosion

1. Walk and drive carefully around erosion site—loose soil could collapse and cause injury to person and/or vehicle.
2. If erosion encroaches into levee prism (see diagram) it could lead to rapid levee failure.
3. Be cautious that eddy may have undermined bank integrity and may cave in.

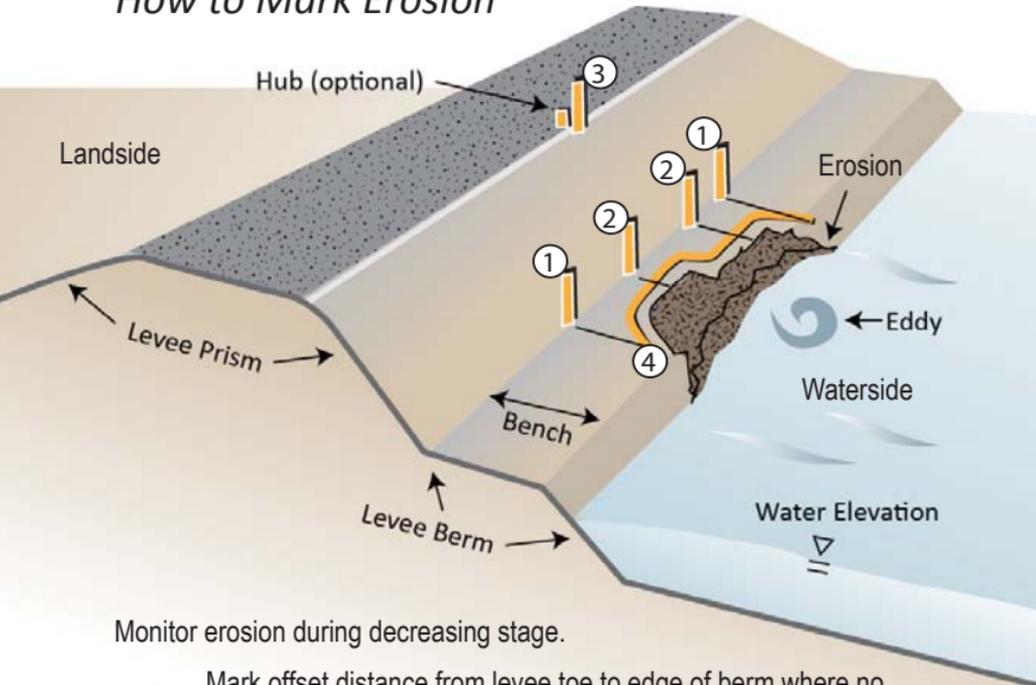
What to Measure and Record in Log Book:

Monitor changes to erosion site (is length expanding, is erosion moving toward crown, etc.)

- Date, Time, Person's Name
- Location along levee (GPS coordinates, Levee Mile, or approximate description) – use Lath ③ for reference
- Threat and description of threat:
 - » Length and depth(s) of erosion
 - » Site relative to bend (straight, inside/outside)
 - » Height and depth of scarp
 - » Approximate water surface elevation relative to crown
 - » Note if eddy has formed
- Draw schematic for records
- Take photos for records

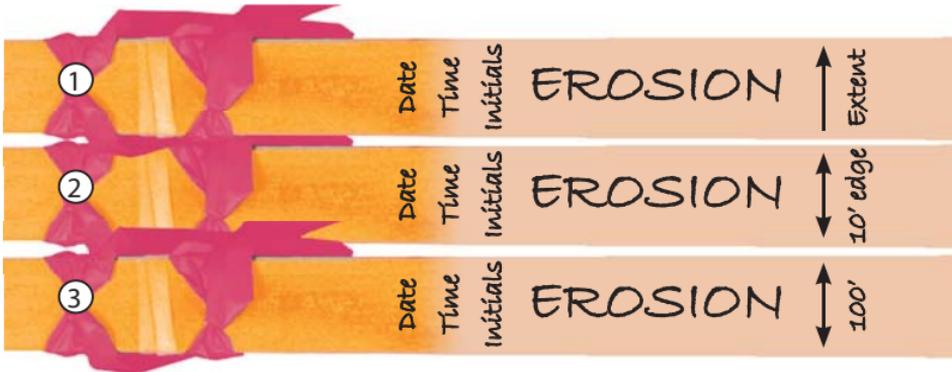


How to Mark Erosion



Monitor erosion during decreasing stage.

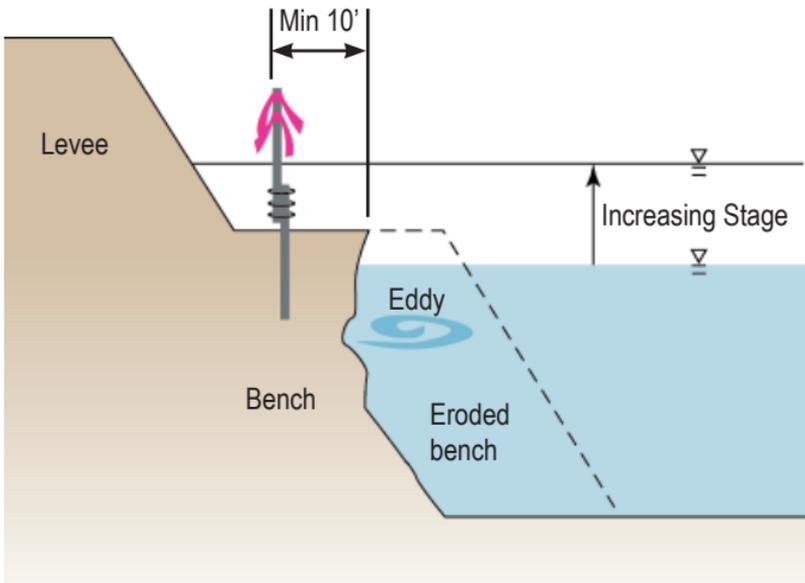
- ① Mark offset distance from levee toe to edge of berm where no erosion has occurred – shows “normal” berm width and the extents of erosion. Place lath at levee toe.
- ② Mark offset distance from levee toe to edge of erosion – shows depth of erosion into berm. Place lath at levee toe.
- ③ Mark total (longitudinal) distance of length of erosion site. Place lath at levee crown shoulder and center it longitudinally across erosion site. Stake an (optional) “Hub” at the base of the lath for extra location identification protection from lath being lost or stolen.
- ④ Paint alternative: Spray paint a line offset from the edge of the erosion, in 4 foot increments away from the erosion towards the levee. This will aid in visually displaying the rate of the erosion site. Use in addition to the placing and marking of lath described above.



EROSION

Monitor Erosion During Increasing Stage

1. Drive No 2 rebar into ground no closer than 10-feet from current erosion edge.
 - » Be aware of potential of undercutting by eddys.
 - » Note location of rebar to levee toe and erosion edge.
2. Attach second No 2 rebar with bailing wire to extend at least 6-feet above bench surface.
3. Attach 2 survey ribbons to rebar.
4. Document in notebook.
5. Take photos for records.



A Special Thank You To:

name

name

name

name

Reference Guide:

DWR Division of Flood Management:

www.water.ca.gov/floodmgmt

California Data Exchange Center (CDEC)

www.cdec.water.ca.gov

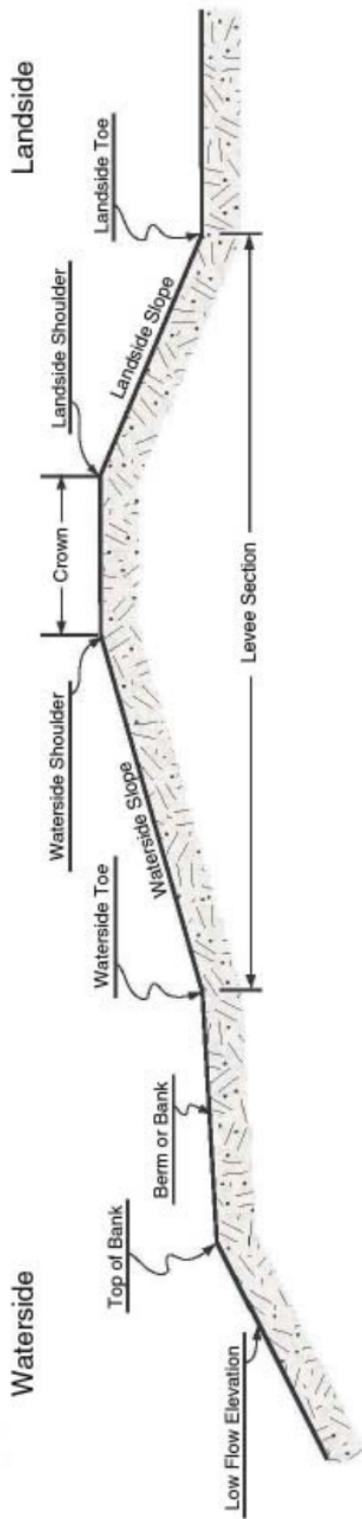
California Emergency Management Agency (CalEMA)

www.calema.ca.gov

National Weather Service

www.weather.gov

To request a copy of the Directory of Flood Officials or Flood Emergency Phone Card, contact the DWR Flood Operations Center at (916) 574-2619



Levee Cross Section

State of California
 Department of Water Resources
 Division of Flood Management
 Flood Operations Branch

FLOOD

EMERGENCY RESPONSE



For all flood emergencies, questions, or
for additional information, please contact:

State-Federal Flood Operations Center

(916) 574-2619

flood_center@water.ca.gov



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