STANDARD OPERATING PROCEDURE
FOR

EMERGENCY CLOSURES ASSOCIATED WITH LEVEES

16 November 2023

The purpose of this Standard Operating Procedure (SOP) - instructional material to aid the Contractor's design) is to provide the Contractor with guidance and the minimum design requirements for the creation of an Emergency Closure Plan, so it should not be copied directly onto plan sheets.

An emergency closure fills or shields on opening through the levee and assures the levee will continue to provide the same level of flood damage risk reduction where construction activities have compromised the levee's ability to perform as designed. The complexities of an Emergency Closure Plan can range from simply detailing how a piece of plate steel will be secured over an opening through a floodwall, to scheduling the necessary equipment to move and place stockpiled soil into the excavated area, to detailed assembly instructions for a designed structure. Although a closure may be planned, designed, and constructed for temporary use, it must have no higher probability of failure than a permanent structure since it defends the same consequences. The equipment and materials must be stored on the landside of the excavation, unless otherwise authorized by the Louisville District USACE (District), so they will not be threatened by rising water. The closure must be installable from the landside in case later increases in the water level, prior to its recession, requires subsequent increases in the closure height. Installation of the closure from the waterside may be approved if the installation plan includes a requirement to install the closure the full levee height upon initiation of the plan, regardless of the predicted water level. The District may also approve a hybrid closure in which a portion is placed from the waterside and the remainder is placed from the landside.

Excavations through a levee are often associated with the installation or replacement of pipes, so the most vulnerable phase to flooding is between the completion of the pipe trench excavation, and the point where the CLSM encasement has cured enough to support embankment placement. For this reason, the excavation and restoration of the embankment should be limited to months generally having the lowest risk of flooding (mid-May to mid-November) with the materials and equipment required to construct the closure reasonably located as approved by the District. If the excavation occurs during, or continues into, the flood season of mid-November to mid-May, the District will require that the total volume of material necessary to construct the closure to the levee crest height be stockpiled no more than 100 feet from the excavation, and that all equipment necessary for its installation be on-site (no reliance on unsecured rentals). Using the excavated soil as an emergency closure provides an opportunity for the contractor to close the levee excavation without handling the material twice if the soil is placed according to the "General Earthwork Associated with Levees" SOP; however, for fast-rising waterways with little forewarning, this may not be an option and other closure methods may be required. The footprint of an excavation to install a pipe is typically small, so the District has established a maximum soil placement rate of 150 cubic yards per hour for a single crew, but a higher rate may be considered if the size of the closure footprint is judged large enough to allow more than one crew to work at the same time. An example of the necessary calculations for a soil-replacement closure is provided on the last page.

Closures using traditional sandbags may not exceed 3 feet in height and must be placed according to USACE standards. Closure plans using proprietary systems (e.g., TrapBag, Defencell, Hesco barriers, etc.) must include product information/brochures with enough supporting information that the sufficiency of the proposed placement can be confirmed. For exceptionally wide or tall closures, or ones incorporating atypical geometries, the District may require documented communications with the product designers that demonstrate compliance with the product's intended uses and limitations. A "one-off" closure uniquely designed for an individual situation, not using a proprietary system or in-kind soil replacement, must present evidence, in the form of calculations and drawings stamped by a registered professional engineer, that the proposed closure method will be structurally stable when loaded to the levee crest.

The ability to raise the closure at a rate no less than the maximum rate-of-rise for the associated body of water (provided in Table 1) must be proven to the District's satisfaction; however, a lower placement rate may be approved for a specific flood event based on the USGS hydrograph predictions.

Table 1: Project-Related Maximum Rates-of-Rise

Waterway (Reach)	**Maximum Rate-of-Rise (feet/day)***	**Affected Levee Projects**
Duck Creek	7.0	Duck Creek Phases (II), (IIA), (III), (IVB-1A), (IVB-1B), (IVB-2&IVC)
Embarras Creek	11.1	Saint Marie
Flatrock River	10.3	Rushville
Holes Creek	7.0	Holes Creek
Kentucky River (*Winchester to Ohio River*)	6.9	(Frankfort) (South Frankfort)
Ohio River (*Meldahl to Markland*)	15.8	(Cincinnati) (Covington) (Dayton) (Lawrenceburg) (Newport)
Ohio River (*Markland to Cannelton*)	20.4	(Jeffersonville) (Louisville) (New Albany)
Ohio River (*Cannelton to Evansville*)	10.3	(Cannelton) (Evansville) (Hawesville) (Howell NE) (Howell NW) (Tell City North) (Tell City South)
Ohio River (*Evansville to Smithland*)	7.4	(Golconda) (Harrisburg) (Reevesville) (Rosiclare) (Sturgis) (Uniontown)
Ohio River (*Smithland to Cairo*)	9	(Brookport) (Cache River) (Paducah)
Salt River	25.3	(Bardstown) (Lebanon Junction) (Taylorsville)
Wabash (*Lafayette to Ohio River*)	9.9	(Blockson & Jenckes) (Gill Township) (England Pond) (Honey Creek) (Island) (Levee Unit #5) (Lyford) (Mason J. Niblack) (Mount Carmel) (Rochester-McCleary) (Russell-Allison-Ambraw) (Terre Haute) (Vincennes-Brevoort) (West Terre Haute)
White River	10.7	(Anderson) (Indianapolis) (Indianapolis North) (Levee Unit #8) (McGinnis) (Muncie NE) (Muncie NC) (Muncie NW) (Muncie South)
Whitewater	2.7	Hagerstown

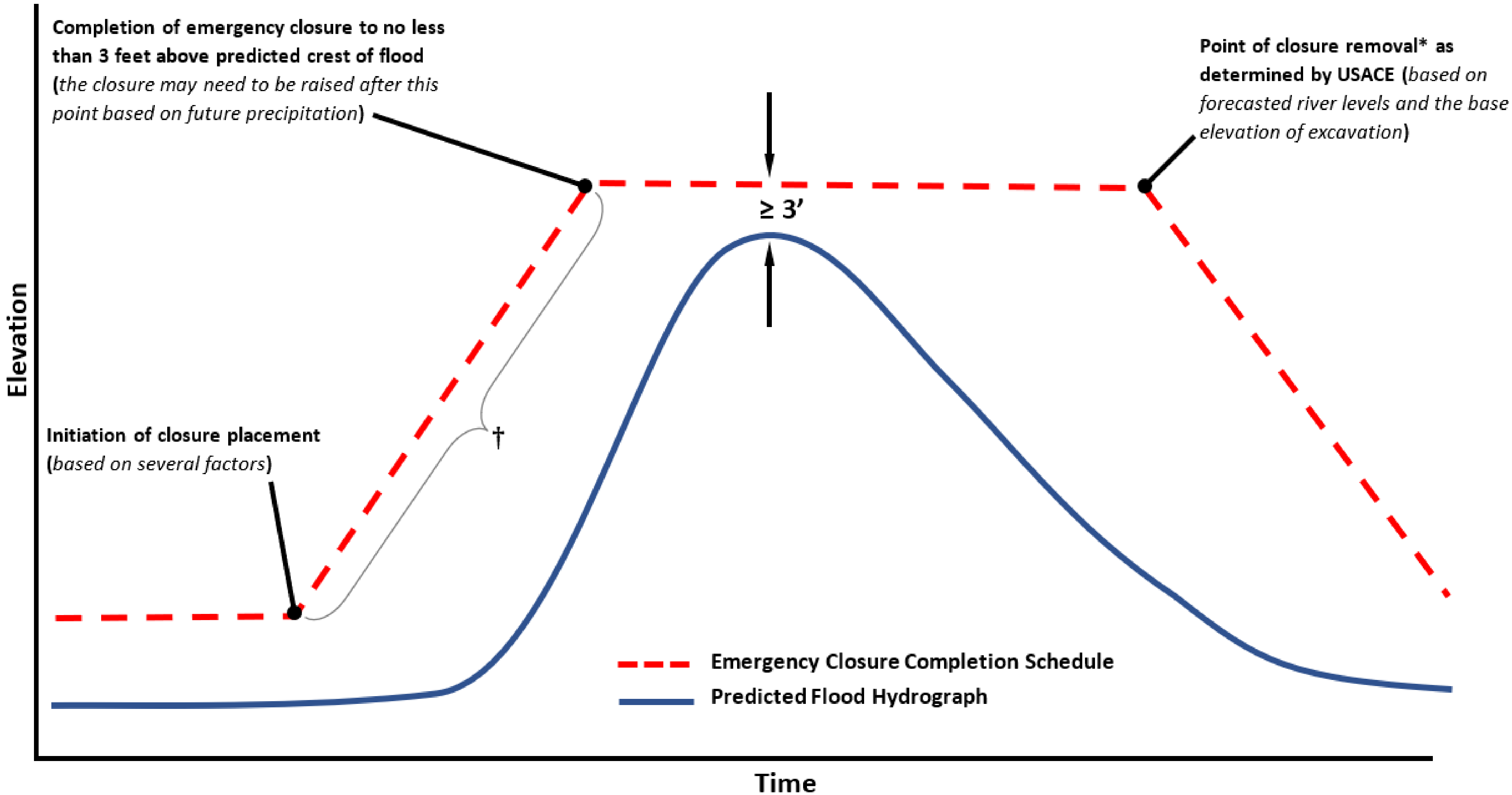
*, Based on data from 1997 to 2022

It is the Contractor's responsibility to provide the means and methods necessary to install the closure to the necessary height. An inflatable bladder or other approved method of sealing the pipe will be required until the designed means of closure, such as a flap gate or sluice gate, is installed. "Sealing" pipes with sandbags will not be approved. Once installed, a temporary emergency closure may not be removed or lowered without written authorization from the District.

At a minimum, the Emergency Closure Plan must include:

- The USGS gage identification number to be used for determining when to start installing the emergency closure. If the project-associated USGS gage does not provide water level predictions, the District will establish the point of initiation and to what height the closure must be installed for each event during construction.
- Calculations showing that installation using the chosen method of closure can outpace the rate-of-rise based on the value in Table 1, the total time required to install the closure to the levee crest height, and the proposed trigger elevation/gage reading at which installation would begin.
- The equipment anticipated to be used to install the closure.
- A plan view showing the location of the materials to be used to install the closure in relation to the excavation.
- A plan view showing the dimension of the excavation into or through the levee and the proposed stockpile location. (Greater detail will be required if an argument will be made that more than one placement crew can operate in the area at the same time.)
- Any necessary information from the supplier of a proprietary system to make the case for suitability and timely completion.
- An agreement with the local ready-mix supplier that sufficient CLSM will be deliver on-site within 24 hours of notification in case flooding threatens the project.
- A short narrative explaining the installation sequencing.

Fundamental Closure Placement-to-Hydrograph Relationship

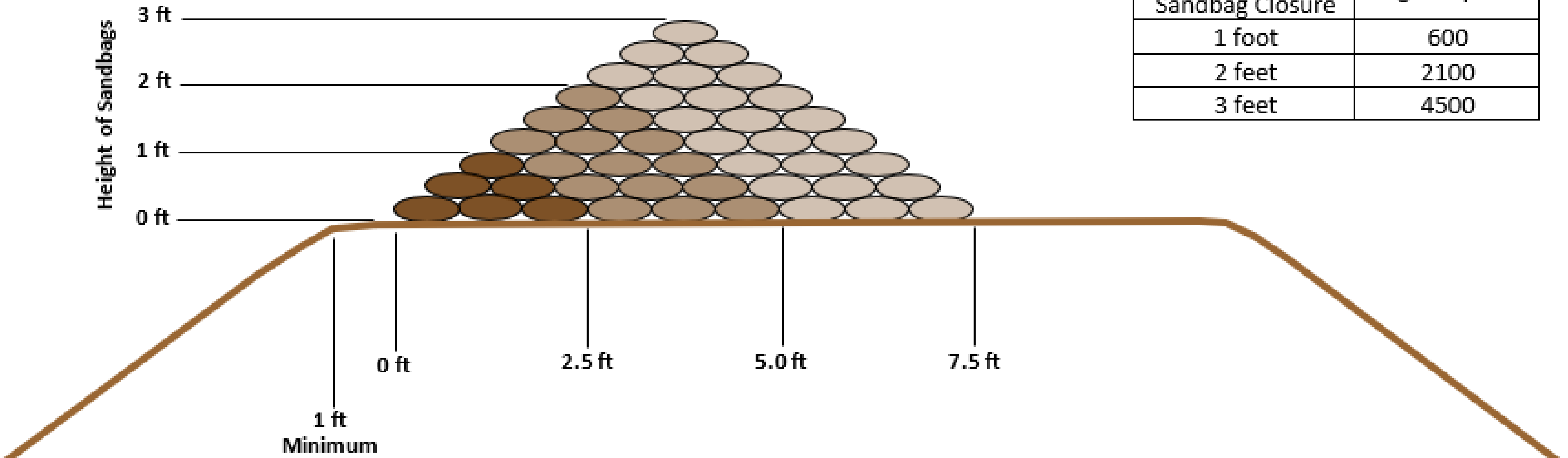


†, The rate of rise for the soil placed from the base of the levee to the midpoint height of the levee would theoretically be slower than the placement from the midpoint to the top of the levee, due to the increasing and then decreasing footprint of the closure, but the placement rate was assumed linear since progress above the midpoint would likely be slowed due to the difficulties of delivering soil to a higher level, offsetting the smaller footprint.

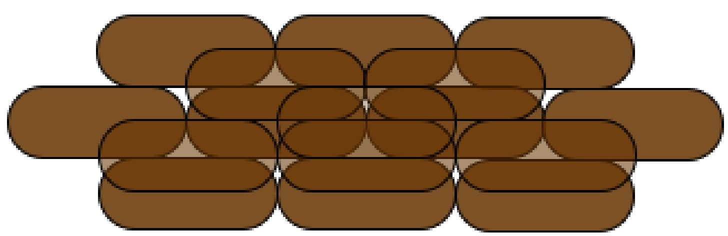
*****, *Removal of the soil closure would not be necessary if adequate field density and moisture tests were conducted during placement.*

USACE-Approved Pyramid Sandbag Placement

Bags Required per 100 Linear Feet	
Height of Sandbag Closure	Bags Required
1 foot	600
2 feet	2100
3 feet	4500

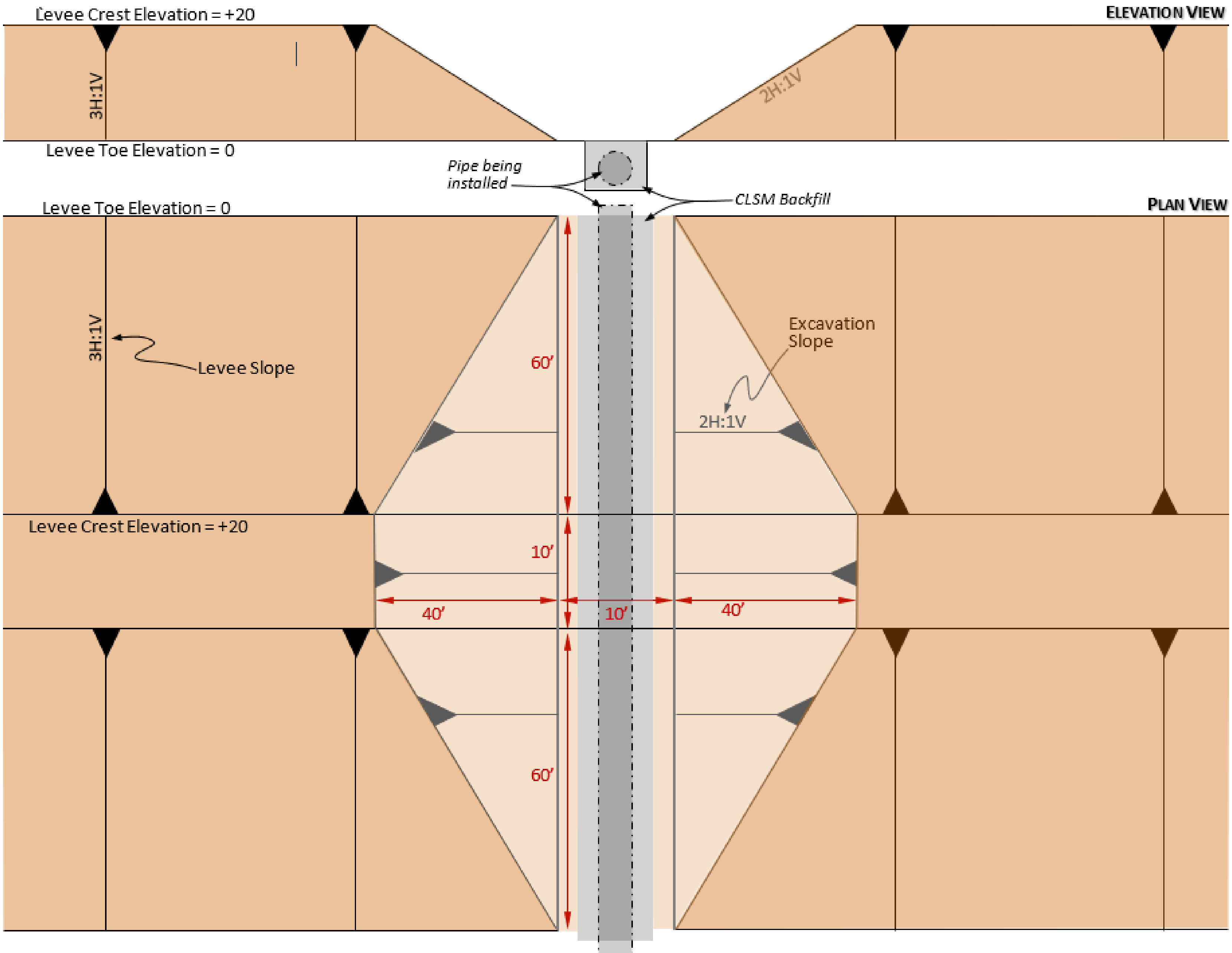


Plan View of Idealized Sandbag Stagger

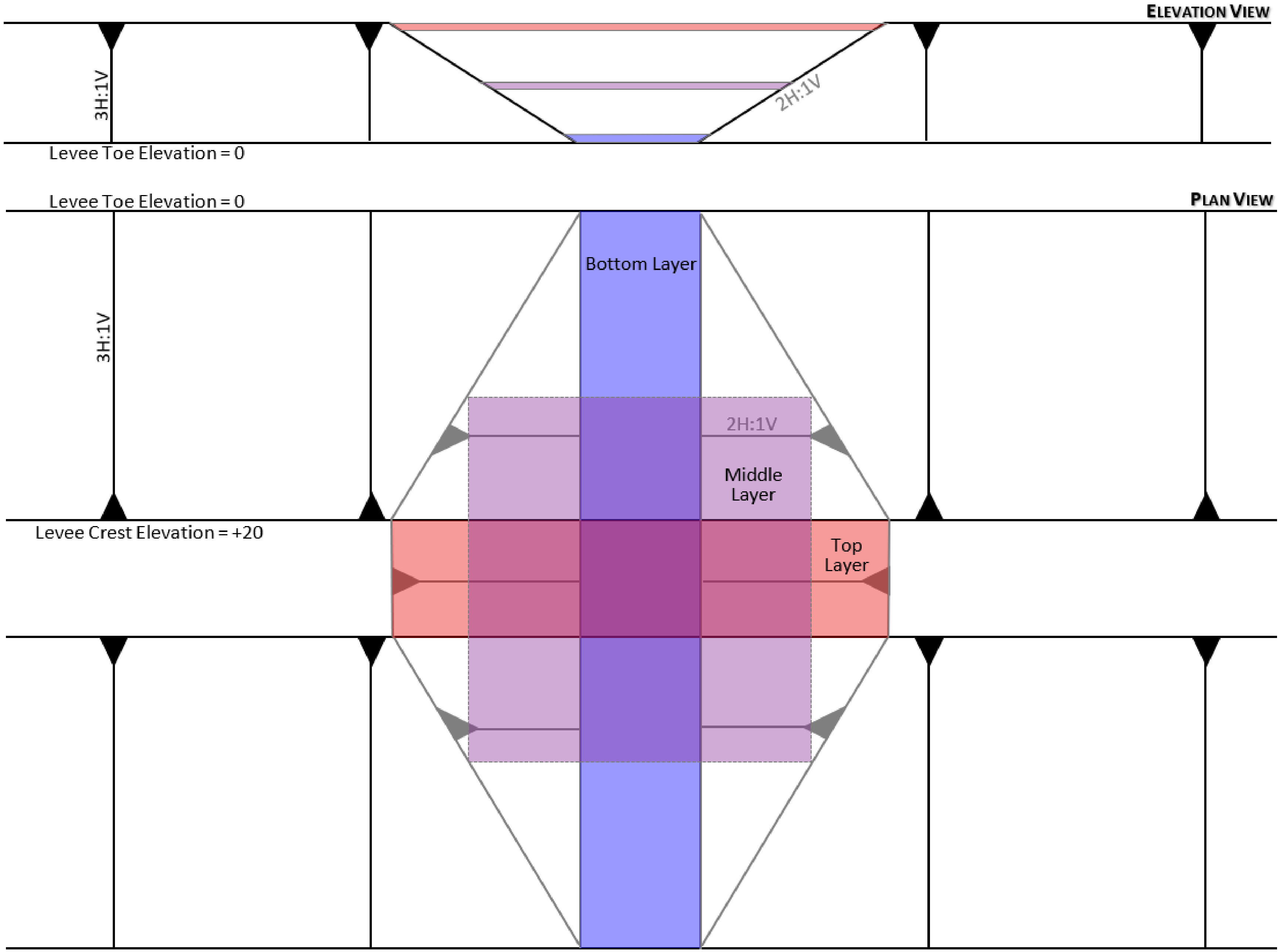


- Fill bags between ½ and ⅔ full.
- Stagger sandbag joints (where the ends butt against each other) so that there are no continuous lines from waterside to landside.
- Fold loose end flaps under bag (if present).
- Compact and shape each bag by walking on it.

Dimensions for Example Excavation



Anchor Points for Example Volume Calculations



Example Volume Calculations

Layer Volume = (Lift Height) x (Width) x (Length)

Bottom Layer = (1') x (10') x ((10' + (20'x3) + (20'x3)) = 1,300 ft^3 = **$48yd^3$**

Middle Layer = (1') x [(10' + (10'x2) + (10'x2)] x [(10' + (10'x3) + (10'x3)] = 3,500ft^3 = **$130yd^3$**

Top Layer = (1') x ((10' + (20'x2) + (20'x2)) x (10') = 900 ft^3 = **$33yd^3$**

After determining the cubic yardage for the Bottom, Middle, and Top 1-foot layers, linear interpolation for each 1-foot interval between these anchor points can be used to determine the total cubic yards needed to reach any intermediate height. From the 20-foot embankment height example:

Interpolations between the bottom and middle of the levee would use: Bottom layer = 48 yd^3 and Middle layer = 130 yd^3

Volume of 2nd layer = 130+((1-10)/(0-10))x(48-130) = 56.2 yd^3
Volume of 3rd layer = 130+((2-10)/(0-10))x(48-130) = 64.4 yd^3
etc…

Interpolations between the middle and top of the levee would use: Middle layer = 130 yd^3; Top layer = 33 yd^3

Volume of 12th layer = 33+((11-20)/(10-20))x(130-33) = 120.3 yd^3
Volume of 13th layer = 33+((12-20)/(10-20))x(130-33) = 110.6 yd^3
etc…

Completed Volume Calculations

Layer	Stage of Closure Height	Layer Volume (CY)	Total Volume Needed by Height (CY)	Time Required to Reach Height ** (Hrs.)
1	0' - 1'	48	48	0.3
2	1' - 2'	56.2	104.2	0.7
3	2' - 3'	64.4	168.6	1.1
4	3' - 4'	72.6	241.2	1.6
5	4' - 5'	80.8	322.0	2.1
6	5' - 6'	89.0	411.0	2.7
7	6' - 7'	97.2	508.2	3.4
8	7' - 8'	105.4	613.6	4.1
9	8' - 9'	113.6	727.2	4.8
10	9' - 10'	121.8	849.0	5.7
11	10' - 11'	130.0	979.0	6.5
12	11' - 12'	120.3	1099.3	7.3
13	12' - 13'	110.6	1209.9	8.1
14	13' - 14'	100.9	1310.8	8.7
15	14' - 15'	91.2	1402.0	9.3
16	15' - 16'	81.5	1483.5	9.9
17	16' - 17'	71.8	1555.3	10.4
18	17' - 18'	62.1	1617.4	10.8
19	18' - 19'	52.4	1669.8	11.1
20	19' - 20'	33.0*	1702.8	11.4

**, Following the pattern of using the lower dimensions of each layer would have resulted in a volume of 42.7 CY, but the upper dimension of 20' was used for simplicity and consistency with the example calculation.*

***, Times are only for placement under optimum conditions which do not account for initial mobilization, setup, or problematic issues encountered during installation, and are therefore optimistic.*

Based on the typical limited dimensions of the work area and the resulting limitation on the crew and equipment size, the District has restricted the anticipated maximum placement rate at 150 CY/Hr. Once the accumulated totals are calculated for the various heights of placement, the number of hours to place the soil for a particular flood crest can be calculated by dividing the total by 150. For example, if a flood will crest at an elevation equal to a height of 12 feet on the example levee so that a 15-foot-high closure is needed, the total of approximately 1,400 CY would require a minimum of about (1,400/150) 9½ hours. For the purposes of estimating the latest start time, add to the calculated time, the time required to mobilize the necessary personnel and equipment and the need for the closure to stay at least 3 feet above the rising water (using the maximum rate-of-rise for the project area), and a sensible buffer for unplanned delays. Due to the naturally fluctuating ground level that most levees were placed on, each chart will likely be unique to that location and should not be used elsewhere. Relevant elevations for the closure plan must be converted to equivalent gage readings from the gage used for the overall project actions so that no conversion is necessary during an emergency.