Appendix F
Methods of Dam Raising

F-1. Introduction

a. Reasons for embankment raising. It may be necessary to raise an embankment dam to accommodate a revised inflow design flood that exceeds the original design flood, to restore reservoir storage capacity lost due to siltation, or to meet increased irrigation or water supply demands. This appendix considers only that method of providing increased reservoir capacity involving embankment dam raising schemes.

b. Solutions to increase reservoir storage capacity. Reservoir storage capacity may be increased by raising the dam crest elevation, constructing a new auxiliary spillway, raising and widening the existing spillway, or widening the spillway and raising the dam crest elevation.

F-2. General Design Considerations to Raise Embankment Dams

a. Basic requirements.

(1) The dam must be raised in a manner that will preserve the integrity of the structure with respect to stability and seepage control. Increased embankment height, and the corresponding increase in potential reservoir level, will impose greater loads in the embankment and foundation zones and on adjacent structures such as spillway walls and outlet structures, which must be considered in design. Increased reservoir levels may change pore pressures and seepage patterns in the embankment and foundation. Impervious elements of the dam (impervious core, cutoff trench, and cutoff wall) and filter or drainage elements (chimney, blanket, and toe drains, relief wells, etc.) must be evaluated to assure that these features can adequately handle the increased hydraulic loading.

(2) The dam must continue to satisfy functional requirements such as prevention of overtopping during the design inflow event with adequate freeboard, access for human and equipment traffic, access for inspection and emergency operations. The raising sequence must take into consideration provision for emergency closure of the excavation during a flood event and maintenance of essential crest traffic during construction.

b. Design considerations. The dam raising design should consider the required increase in height, the minimum acceptable crest width, maximum embankment slopes, methods of achieving steeper than normal slopes, abutment contact areas, contact areas with appurtenant structures, and seepage control features. The modified dam must be stable under the design seismic event for the site.

F-3. Methods of Raising Embankment Dams

a. General. The principal methods of raising embankment dams include parapet walls, mechanically stabilized earth and mechanically stabilized earth walls, roller-compacted concrete, and earth or earth and rock-fill raisings (Examples 1-3, Figures F-1 to F-3). Following is a brief description and sketch of each potential raising scheme. Sketches are not to scale and do not attempt to address the details associated with specific dam geometry or internal zoning.

b. Parapet walls and cap raising. Generally, the most cost-effective dam raising up to a height of approximately 15 ft will be accomplished using a 3.5-ft-high parapet wall in combination with a 7- to 12-ft embankment crest raising (Figure F-4). Although higher walls may be theoretically possible, this reflects the greatest height that will not interfere with visual observation of the upstream side of the dam from a vehicle

Figure F-1. Example 1: curved parapet wall, maximum protection against wave action

Figure F-2. Example 2: a conventional parapet wall

on the crest. The "effective height" of the wall may be increased by incorporating a hydraulically efficient wave deflection configuration. Figure F-4 illustrates a concept for accomplishing an embankment crest raising while maintaining traffic flow. Figure F-5 illustrates the temporary excavation and internal zoning extension considerations for a typical embankment raising. The extent of the temporary crest reduction should be limited as necessary to assure that closure could be accomplished in response to a flood event.

Figure F-3. Example 3: additional fill to raise the embankment

c. Mechanically stabilized earth. Embankments may be raised by 10 to 15 ft using mechanically stabilized earth fill zones with or without modular wall elements. Greater heights can be achieved for the same crest width if modular block or panel elements are used to provide a vertical or near-vertical wall face as illustrated by Figure F-6. Without facing elements, mechanically stabilized earth slopes as steep as 2V on 1H have been achieved. However, some means of containing fill at the steep slope surface must be provided. Mechanically stabilized earth backfill materials do not generally consist of impervious earth such as would typically be used in the core of a dam. However, granular backfill material with an appropriate percentage of material passing the No. 200 sieve may be satisfactory for moderate height raisings not subject to large seepage gradients or a long duration of exposure to the reservoir pool. In all cases, stability analyses must consider internal stability of reinforcing elements, external stability of the reinforced mass, and global stability of the embankment including the load imposed by the additional raising materials. The design should also consider seepage conditions and provide appropriate filter and drainage elements.

d. Roller-compacted concrete. Roller-compacted concrete (RCC) or soil cement may be used to achieve a raising of a similar size as mechanically stabilized earth schemes (Figure F-7). These materials allow for construction of very steep slopes that also provide a measure of slope protection and are not subject to rapid deterioration that may be a problem for a mechanically stabilized earth slope. Treatment may be necessary at lift interfaces to preclude excessive seepage. An example of an RCC raising scheme is presented in Figure F-7.

e. Major embankment raising. A major embankment raising, exceeding approximately 15 ft in height, may be accomplished by adding a new downstream section to support the crest raising as illustrated in Figure F-8. The downstream section may consist of earth or rock-fill materials depending on those materials generated by associated excavations for spillway or outlet structure modifications. The critical internal embankment impervious and filter zones must be extended as necessary to provide seepage control and satisfy stability requirements.

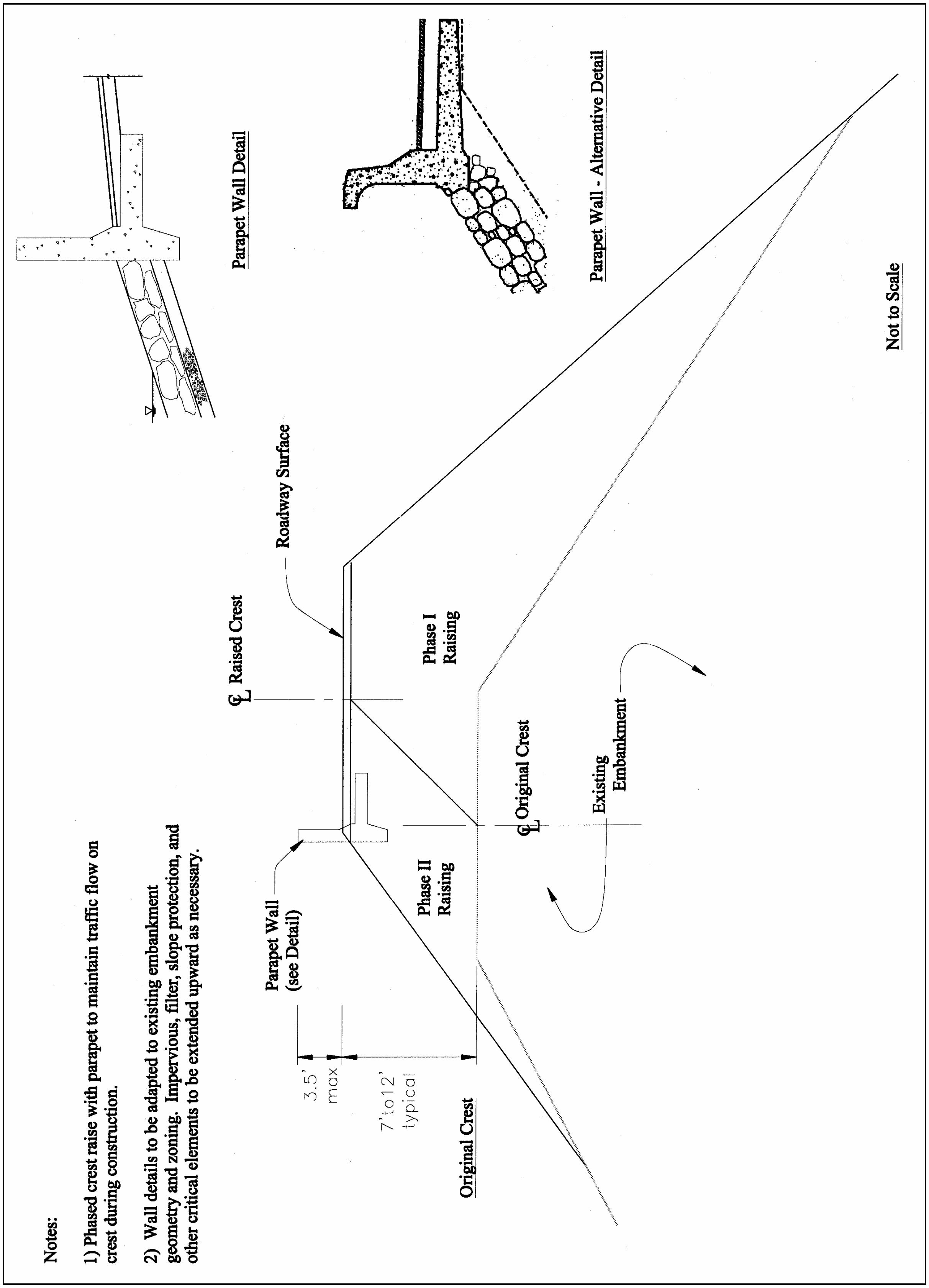

Figure F-4. Embankment raising with parapet wall

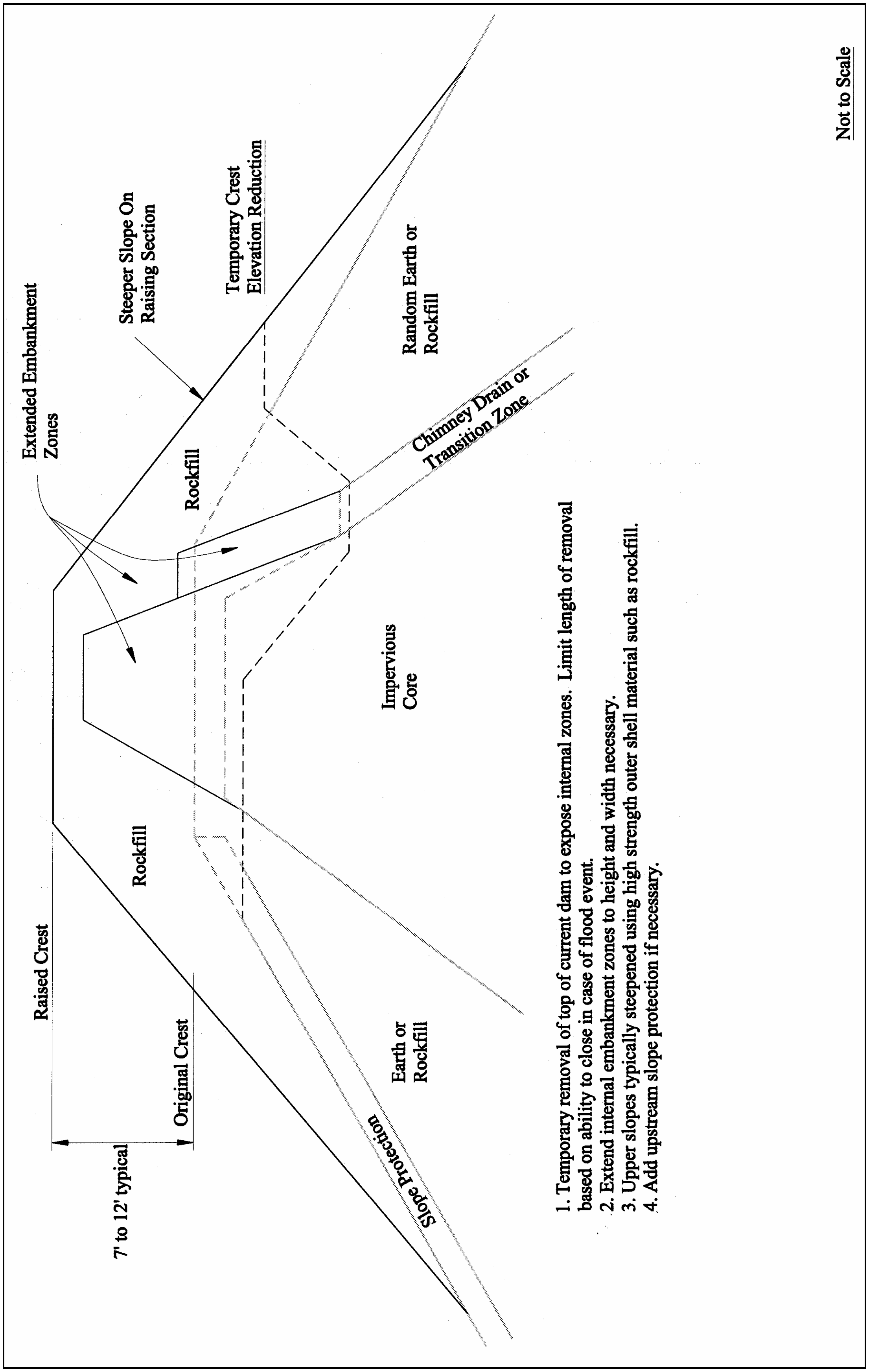

Figure F-5. Embankment crest raising

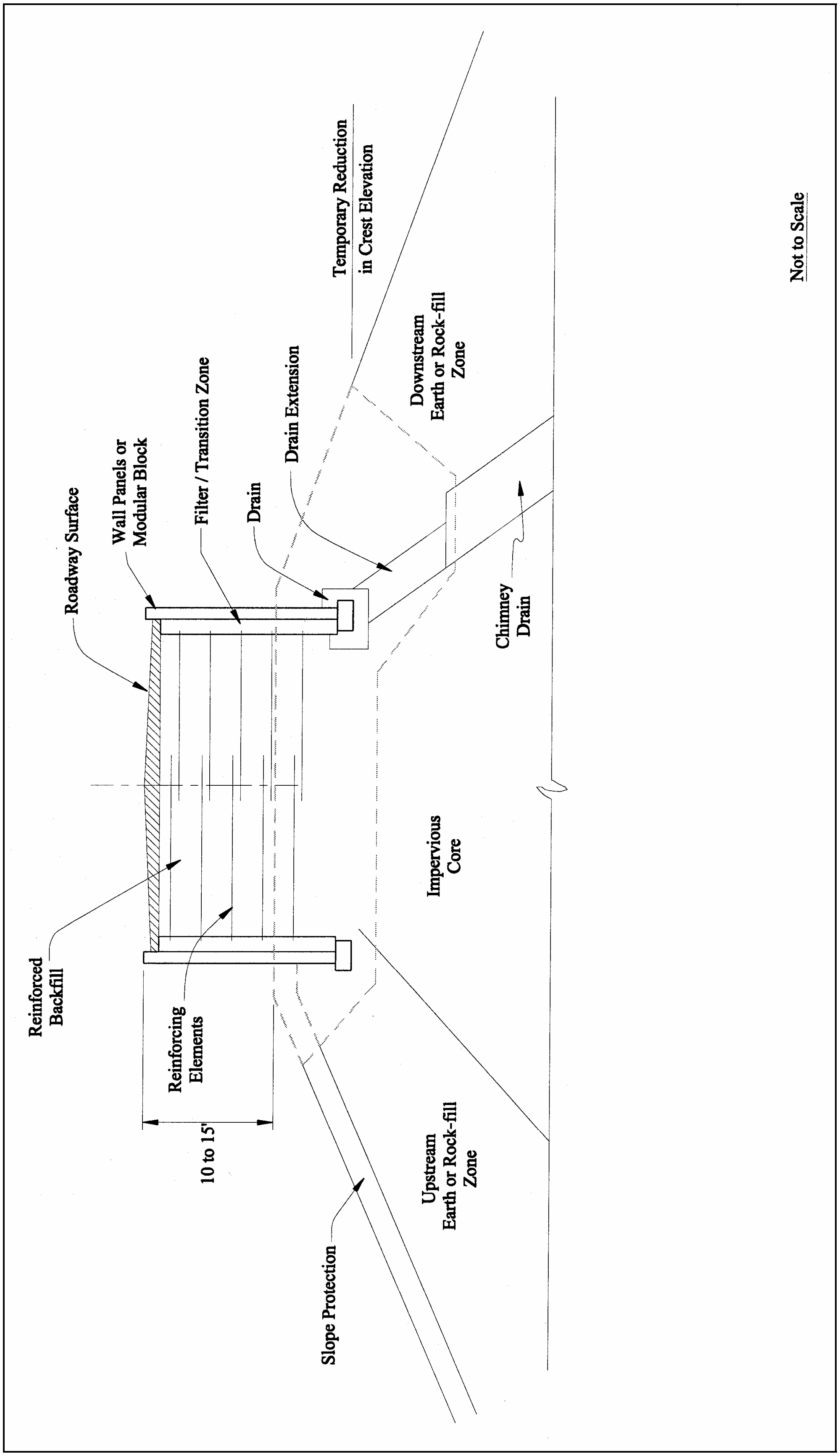

Figure F-6. Embankment raising with mechanically stabilized earth raising

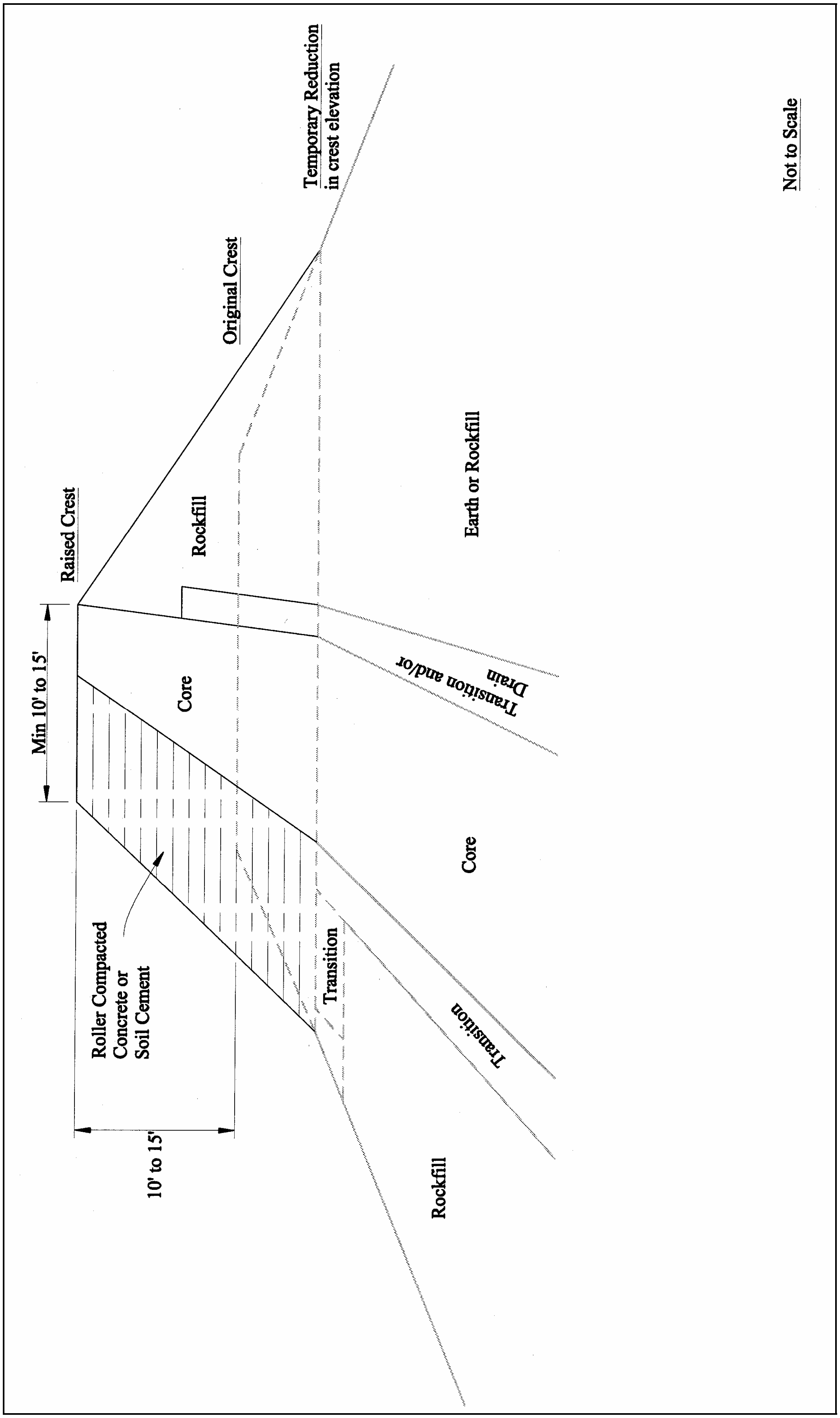

Figure F-7. Embankment raising with modified fills

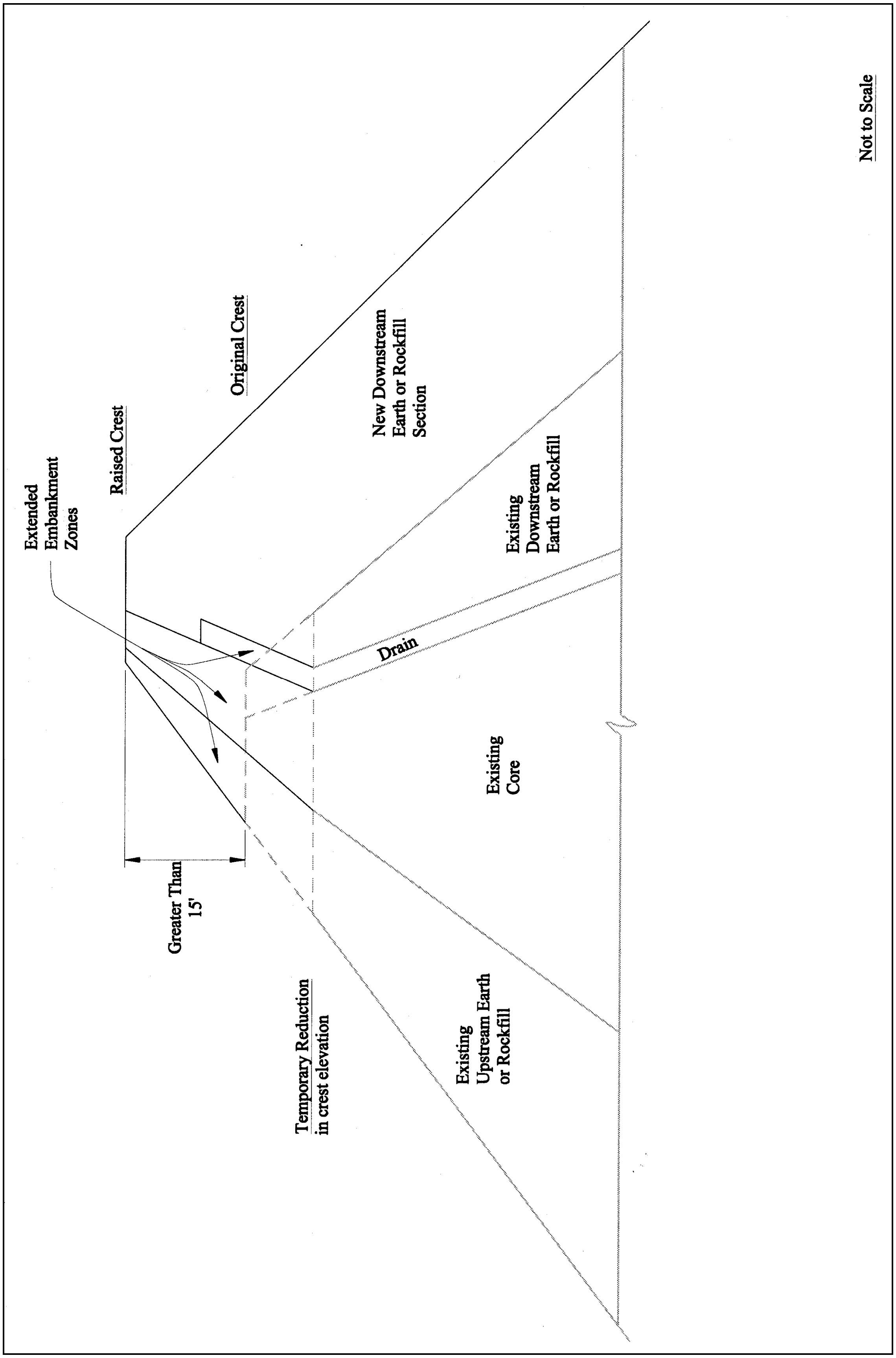

Figure F-8. Downstream raising of embankment dam