

APPENDIX A  
**EARTHEN EMBANKMENT**

VERSION 1.0  
March 1, 2011



**SECTION A-1: DESCRIPTION OF PRACTICE**

An earthen embankment is a raised impounding structure made from compacted soil. The embankment is the feature of pond-type practices that causes the impoundment of water.

**SECTION A-2: PERFORMANCE CRITERIA**

Not applicable

### SECTION A-3: PRACTICE APPLICATIONS AND FEASIBILITY

An earthen embankment is appropriate for use with infiltration, detention, extended-detention, retention or constructed wetland facilities.

The design procedures presented in this section **may not** apply to small embankments or to storm drainage outfall structures with less than 3 feet of embankment height. The review and approval of such structures should be based on sound engineering practices and supporting calculations that verify a stable outfall for the 10-year storm, at a minimum.

Similarly, this section **does not** apply to embankments with a height of 25 feet or more and a maximum storage capacity of 50 acre-feet or more, as measured from the top of the embankment. Such structures may be regulated under the Virginia Dam Safety Act (§ 10.1-606.1 et seq., Code of Virginia) and the Virginia Dam Safety Regulations (4 VAC 50-20 et seq.).

The *height of an earthen embankment* is the vertical distance from the natural bed of the stream or watercourse, measured at the downstream toe of the embankment, to the top of the embankment. If the embankment does not span a stream or watercourse, the height is the vertical distance between the lowest elevation, measured at the outside limit of the embankment, and the top of the embankment.

### SECTION A-4: ENVIRONMENTAL AND COMMUNITY CONSIDERATIONS

Not applicable.

### SECTION A-5: DESIGN APPLICATIONS AND VARIATIONS

Not applicable.

### SECTION A-6: SIZING AND TESTING GUIDELINES

Not applicable.

### SECTION A-7: DESIGN CRITERIA

Earthen embankments are complex structures that must be designed and constructed with consideration given to the following: (a) *specific site and foundation conditions*, (b) *construction material characteristics*, (c) *purpose of the impoundment*, and (d) *hazard potential associated with the particular site and/or impoundment*.

The *hazard potential* associated with an impoundment is defined in the Virginia Dam Safety Regulations. It is based on the potential for loss of life and/or economic loss due to facility failure. While stormwater management embankments are typically much smaller than those regulated under the Virginia Dam Safety Program, the potential for significant property damage and loss of life may still be present. The engineer is responsible for analyzing potential downstream impacts and for determining if more stringent analyses are required. **Minimum**

guidelines for those facilities **not covered** under Virginia's Dam Safety Regulations are provided in this handbook.

### Embankment Types

The type of embankment selected will depend on the purpose of the stormwater facility (detention, extended-detention, retention, etc.) and the available soil material for construction. The two general types are listed below:

1. A *homogeneous embankment* is composed of one kind of material (excluding slope protection). The material used must be sufficiently impervious to provide an adequate water barrier, and the slopes must be moderately flat for stability and ease of maintenance (see **Figure A-1a**).
2. A *zoned embankment* contains a central impervious core, flanked by zones of more pervious material called shells. These pervious zones or shells enclose, support, and protect the impervious core. Typically, a zoned embankment requires an internal drain, or filter, between the impervious zone and the downstream shell and between the shell and the foundation (see **Figure A-1b**).

### Soils Investigation

A soils investigation, or geotechnical study, should be completed before designing any earthen embankment covered in this section. The scope of such a study will vary from site to site based upon the size of each project. Recommended minimum guidelines for a geotechnical study are provided below. Refer to U.S. Department of Interior (USDI), *Design of Small Dams*, latest edition, for additional information.

### Geotechnical Guidelines

The following discussion presents minimum recommended criteria for the planning and design of earthen embankments. The designer is responsible for determining which of the guidelines are applicable to the specific project and for determining if any additional investigations are required.

The validity of the design depends on the thoroughness of the site investigation, the adequacy of the testing program, and the soundness of the designer's judgment. Design components based on quantitative soil tests, such as analyses of slope stability, seepage, and settlement, are not discussed herein, but they are necessary to design large dams. Such analyses will logically follow the selection of a preliminary design. Even for small earth dams that have a low hazard potential, the following criteria should be considered in a geotechnical report.

A geotechnical engineering study should evaluate the stability of the proposed embankment and should consist of (1) *a site investigation*, (2) *laboratory testing*, and (3) *an engineering analysis*.

1. A field investigation should include the review of available soils information and a

subsurface exploration. Test borings, test pits, or both, should be used to evaluate the foundations, abutments, borrow materials, reservoir area, embankment design and any other pertinent geological considerations. In areas underlain by Karst limestone, a subsurface profile using seismic or sonar technology should be considered to verify that subsurface anomalies do not exist. This type of subsurface investigation may also be recommended in areas known to have been previously mined for mineral extractions.

2. Laboratory testing should be completed to evaluate the various soils. At a minimum, an *index property test* should be completed to classify the soils following the Unified Soil Classification System. Shear strength, compressibility, and permeability testing may be required depending upon the size and complexity of the embankment and the nature of the site's subsurface conditions.
3. A geotechnical engineer should do an engineering analysis and present his or her findings, recommendations and comments on items such as: foundation materials and preparation; design of interior drainage features and filters; and geotechnical design of conduits/structures through the embankment, including seepage and stability analyses. The engineer should also provide a summary describing the soil types and rock strata encountered and explaining the laboratory tests and their results.

### Stream Diversions

The design of some earthen embankments will require provisions for stream diversions around or through the embankment site during construction. A stream diversion can be accomplished by a variety of acceptable means, including open channels, conduits, coffer dams, and pumping. Occasionally, stream diversions may be required to meet additional requirements and/or to be permitted by agencies such as the U.S. Army Corps of Engineers, the Virginia Department of Environmental Quality, and/or the Virginia Marine Resources Commission. Refer to the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition, for additional guidance on stream diversions.

To establish *design water surface elevations* and *spillway capacity* for earthen embankments, various hydrologic design methods and spillway storm frequencies may be used. Factors that affect their selection include: (a) *the purpose of the stormwater facility: flood control, water quality enhancement, and/or channel erosion control*, (b) *the contributing watershed size*, and (c) *local regulations*. Despite the design method selected or the frequency storm is used, **the embankment should always be analyzed to ensure safe passage of the maximum spillway design storm while maintaining its structural integrity and stability**. Furthermore, the embankment height should be set such that runoff from the spillway design storm can safely pass through one of the following spillways without overtopping the embankment:

- a natural or constructed spillway;
- a principal spillway; or
- a combination of a principal spillway and an emergency spillway.

Hydrologic and hydraulic methods are described in **Chapter 12** of the Virginia Stormwater Management Handbook (2009).

Local ordinances or watershed conditions may require a more stringent analysis of the embankment concerning overtopping or spillway capacity. The USDA-Natural Resource Conservation Service's (NRCS) *National Engineering Handbook* and the Virginia Dam Safety Regulations provide a classification of dams based on the *potential hazard* from failure. A dam failure analysis, or *breach analysis*, may be required to learn the extent of the potential hazard. Any dam breach analysis should use a method similar to the Army Corps of Engineers, NRCS (*TR-60*), National Weather Service, or that specified by the local authority.

### Embankment Stability

An earthen embankment must be designed to be stable against any *force condition* or combination of *force conditions* that may develop during the life of the structure. Other than overtopping caused by inadequate spillway capacity, the three most critical conditions that may cause failure of the embankment are:

1. *Differential settlement* within the embankment or its foundation due to a variation in materials, a variation in embankment height, or compression of the foundation strata. Differential settlement may, subsequently, cause the formation of cracks through the embankment that are roughly parallel to the abutments. These cracks may concentrate seepage through the dam and lead to failure by internal erosion.
2. *Seepage* through the embankment and foundation. This condition may cause piping within the embankment or the foundation, or both.
3. *Shearing stresses* within the embankment and foundation due to the weight of the fill. If the shearing stress force exceeds the strength of the materials, sliding of the embankment or its foundation may occur, resulting in the displacement of large portions of the embankment.

The stability of an embankment and its side slopes is dependent on the following: (1) *construction materials*, (2) *foundation conditions*, (3) *embankment height and cross-section geometry*, (4) *normal and maximum pool levels*, and (5) *purpose of BMP: retention, detention, or extended-detention*. The embankment cross-section should be designed to provide an adequate factor of safety to protect against sliding, sloughing, or rotation in the embankment or foundation. USDA-NRCS's *TR-60* publication provides guidelines for slope stability analysis when required. The most important factors in determining the stability of an embankment are:

1. **Physical characteristics of the fill materials:** Soil classification for engineering uses can be found in the USDA-NRCS *Engineering Field Manual*, Chapter 4, and other references listed at the end of this section.
2. **Configuration of the site:** The height of the embankment may vary considerably throughout its length, so the total settlement of any given section of the embankment may differ from that of adjacent sections. The length of the embankment and slope of the abutments

profoundly influence the degree of differential settlement between adjacent sections of the embankment. As the length shortens and the abutments become steeper, differential settlement becomes more likely. (**Appendix B, Principal Spillway** discusses the use of a concrete cradle to protect the spillway barrel sections from separating due to the forces of differential settlement.)

- 3. Foundation materials:** The character and distribution of the foundation material must be considered for its *shear strength*, *compressibility*, and *permeability*. Occasionally, the shear strength of the foundation may govern the choice of embankment slopes. Permeability and stratification of the foundation may dictate the need for a *zoned embankment*. Quite often, foundations contain compressible soils that settle under the weight of the embankment, although the shear strength of these soils is satisfactory. When such settlement occurs in the foundation, the embankment settles. This settlement is rarely uniform over the basal area of the embankment. Therefore, fill materials used on such sites must be sufficiently plastic to deform without cracking. (**Appendix B, Principal Spillway** discusses the use of a concrete cradle to protect the spillway barrel sections from separating due to the forces of differential settlement.)

A foundation composed of homogeneous soil is simple to evaluate; however, this condition rarely occurs in natural soil deposits. Most often, a stratified deposit composed of layers of several soil types is encountered. To determine the suitability of such a foundation, the following information becomes very important: (1) *the geologic history of the site*, (2) *the degree of stratification*, and (3) *the order in which materials occur within the stratification*. A complex, stratified foundation containing plastic or compressible soil should be investigated by an experienced engineer or geologist.

**Foundation cutoff:** A foundation cutoff trench of moderately impervious material should be provided under the embankment. The cutoff trench should be installed at or upstream of the dam's centerline, and should extend up the abutments to the 10-year water surface elevation.

The bottom of the cutoff trench should be wide enough to accommodate excavation, backfill and compaction equipment. The trench's minimum width and depth should be 4 feet and the side slopes should be no steeper than 1H:1V (refer to **Figures A-1a, A-1b** and **A-2**).

**Rock foundations:** The presence of rock in the embankment foundation area requires specific design and construction recommendations (provided in the geotechnical engineering analysis) to insure a proper bond between the foundation and the embankment.

Generally, no blasting should be permitted within 100 feet of the foundation and abutment area. If blasting is essential, it should be carried out under controlled conditions to reduce adverse effects on the rock foundation, such as over-blasting and opening fractures. This is especially critical in areas of Karst topography.

**Embankment zoning and seepage:** The stability of an embankment slope and the seepage pattern through it are greatly influenced by the *zoning of the embankment*. (Refer to **Embankment Types** above.) The position of the saturation line within a homogeneous

embankment is theoretically independent of the type of soil used in it. Although soils vary greatly in regard to permeability, even the tightest clays are porous and cannot prevent water from seeping through them. **The rate of seepage through an embankment is dependent on the consistency of the reservoir level and the permeability of the embankment or core material.**

The upper surface of seepage is called the *phreatic surface* (zero pressure). In a cross-section, it is called the *phreatic line*. The position of the phreatic line in a retention basin embankment can be assumed to begin at the normal pool elevation on the upstream slope and extend at a 4H:1V slope downward through the embankment. **This assumption is based on the presence of a permanent pool.** For detention and extended-detention facilities with no permanent pool, many designers assume that the embankment will not impound water long enough for a phreatic surface to occur. This assumption, however, is based on a properly designed, constructed, and maintained embankment. Many jurisdictions, therefore, have chosen a conservative design approach by requiring that the phreatic line start at the 10-year design storm water surface elevation, regardless of the presence of a permanent pool.

For most stormwater management facilities, determining the location of the phreatic surface will often suggest the need to install seepage collars on the barrel. (Refer to **Appendix A-2, Principal Spillway**, for a discussion on seepage control along conduits.) For larger stormwater facilities, especially those with a permanent pool, the location of the phreatic surface may require additional design considerations such as an internal drain.

If the saturation line intersects the downstream slope of the embankment at a point above the toe, then seepage will exit the embankment along the downstream face and toe. Typically, the quantity of seepage is so slight that it does not affect the slope's stability. However, sometimes the saturation of the toe will cause sloughing or serious reduction of the shear strength in the downstream section of the embankment. Seepage control should be included in the design if the following conditions exist:

- Pervious layers in the foundation are not intercepted by the cutoff,
- Possible seepage from the abutments may create a wet embankment,
- The phreatic line intersects the downstream slope, or
- Special conditions exist which require drainage to insure a stable embankment.

For *seepage collar design*, it is recommended that the phreatic line start at the 10-year design storm water surface elevation and extend through the embankment at a 4H:1V slope. **If the phreatic line intersects the downstream slope, a qualified soil scientist should be consulted to decide if additional controls are needed.** The location of the phreatic surface, therefore, may have a significant impact on the design of the embankment.

Seepage may be controlled by:

- Foundation, abutment or embankment drains,
- A downstream drainage blanket,
- A downstream toe drain, or
- A combination of these measures (see **Figure A-1b**).

Foundation drains may control seepage encountered in the cutoff trench during construction. These drains must be downstream of the embankment centerline and outside the limits of the proposed cutoff trench.

Including a toe drain in the design of most homogeneous embankments may be desirable. Embankments built on pervious foundations or constructed of materials that exhibit susceptibility to piping and cracking should always be protected by adequate toe drainage. Toe drains may be constructed of sand, gravel, or rock, depending on the nature of the embankment fill material. Whenever a rock toe drain is installed, a graded filter should be placed between the fill and the drain. Often, a 12-inch layer of well-graded, stream-run, sandy gravel will satisfy this requirement. Filter and drainage diaphragm design criteria are presented in the references listed as USDA-NRCS Soil Mechanics Notes No. 1 and No. 3 at the end of this section, and provided in **Chapter 13 Appendix 13-B**.

### Piping

The contact areas between the embankment soils, foundation material, abutments, and conduits are the most susceptible locations for *piping failures*. Piping occurs due to the variation in materials at contact points and the difficulty in compacting the soil in these areas. Compaction is especially difficult next to and under conduits and seepage collars. Therefore, it is highly recommended that all utility conduits, except the principal spillway, be installed away from the embankment. When utility conduits through the embankment cannot be avoided, they should meet the requirements for spillways, i.e., watertight joints, no gravel bedding, restrained to prevent joint separation due to settlement, etc.

Seepage along pipe conduits that extend through an embankment should be controlled by use of the following:

- Anti-seep collars, or
- Filter and drainage diaphragms.

Refer to **Appendix A-2, Principal Spillway** for additional information on the use of anti-seep collars. Filter and drainage diaphragms are presented in USDA-SCS Soil Mechanics Notes No. 1 and No. 3, available upon request from DEQ or USDA-SCS. When filter and drainage diaphragms are used, their design and construction should be supervised by a registered professional engineer.

### Embankment Geometry

1. **Height:** The height of an earthen embankment is based upon the freeboard requirements relative to the maximum water surface elevation during the 100-year frequency storm event. **An embankment with an emergency spillway must provide at least 1 foot of freeboard from the maximum 100-year storm water surface elevation (WSE) to the lowest point on the top of the embankment (excluding the emergency spillway).** (Note that the *spillway design storm W.S.E*, if specified, may be used instead of the 100-year elevation.)



**An embankment without an emergency spillway must provide at least 2 feet of freeboard from the maximum 100-year storm WSE to the lowest point on the top of the embankment.** (Note that the *spillway design storm WSE*, if specified, may be used instead of the 100-year elevation.)

2. **Top Width:** The top of an earthen embankment should be shaped to provide positive drainage. The top width is based on the following table:

<b>Table A-1: Embankment Top Widths</b>	
<b>Total Height of Embankment (ft.)</b>	<b>Minimum Top Width (ft.)</b>
14 or less	8
15-19	10
20-24	12
25 or more	15

### Compacted Fill

Using the Unified Soil Classification System, as covered in the geotechnical analysis, should specify the soil types.

The compaction requirements should include the percent of maximum dry density for the specified density standard, allowable range of moisture content, and maximum loose lift thickness. Refer to **Construction Specifications for Earthen Embankments** later in this standard. In general, the design of an embankment should account for approximately 10% settlement unless otherwise specified by a geotechnical report based on the embankment foundation and fill material. The top of the embankment must be level in order to avoid possible overtopping in one location in cases of extreme storms or spillway failure.

Compaction tests should be performed regularly throughout the embankment construction; typically, one test per 5,000 square feet on each layer of fill or as directed by the geotechnical engineer. Generally, one of two compaction tests will be specified for embankment construction: the *Standard Proctor Test* (ASTM D698) or the *Modified Proctor Test* (ASTM D1557). For the construction of earth dams, the Modified Proctor Test is likely to be more appropriate (Terzaghi, Peck, 1948). This is due in part to the unconfined nature of the earth fill for dam construction. A new Proctor test is required if the material changes from that previously tested.

### Embankment Construction

A geotechnical or construction inspector should be on site during embankment construction. Inspectors should be required to do more than just test fill compaction, i.e., observe foundation

preparation, pipe installation, riser construction, filter installation, etc. (Refer to inspection checklist for impoundment structures, **Appendix F**).

A vertical trench through the embankment material should not be allowed under any circumstances in order to place the spillway pipe. Trench side slopes should be laid back in steps at a 2:1 slope, minimum.

#### Maintenance and Safety

Embankment slopes should be no steeper than 3H:1V if possible, with a maximum combined upstream and downstream slope of 5:1 (3:1 downstream face and 2:1 upstream face). For embankments exceeding 15 feet in height, a 6 to 10 foot wide bench should be provided at intervals of 10 to 15 feet of height, particularly if slopes are steeper than 3H:1V.

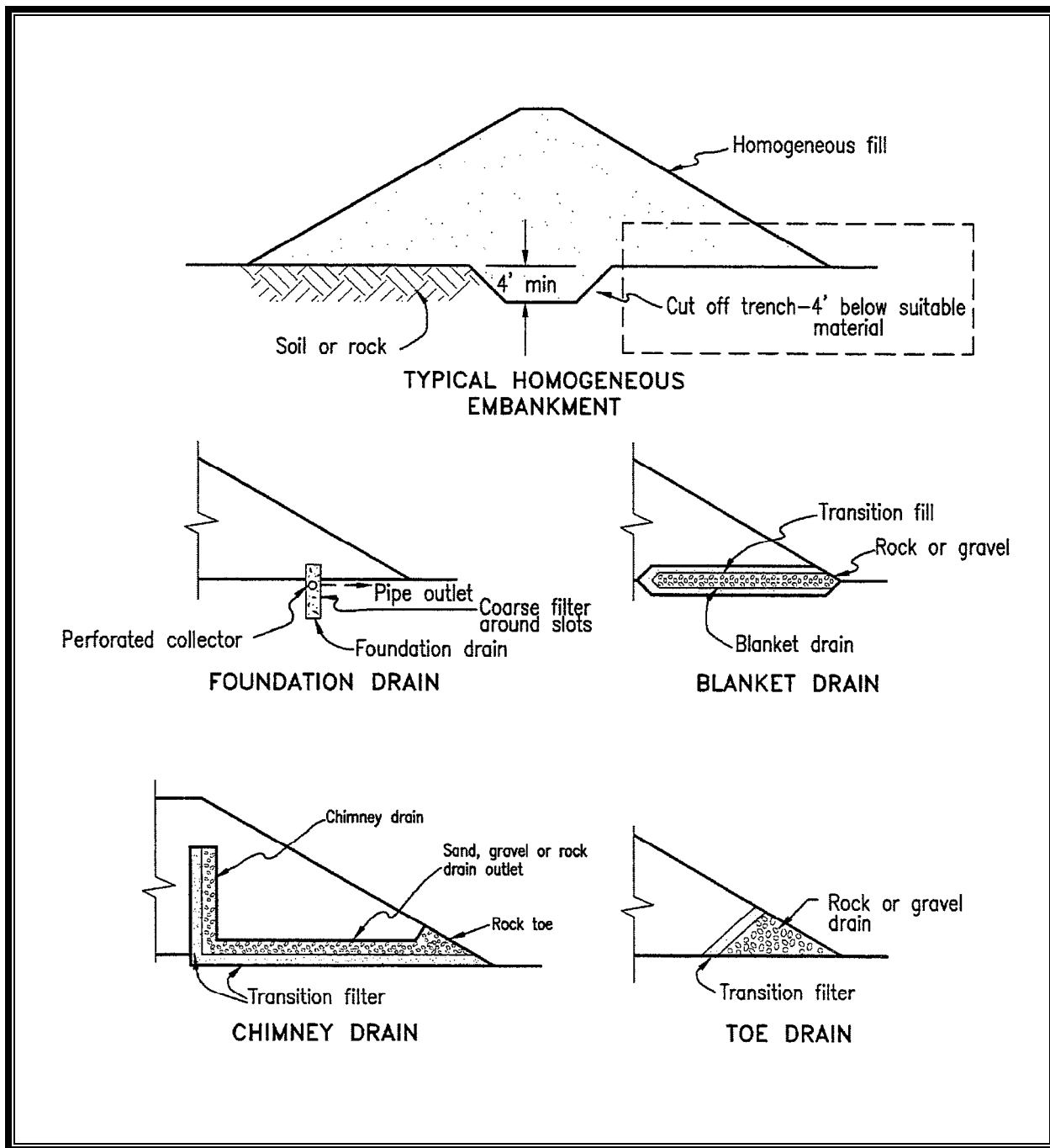
The following design considerations are provided to help reduce the long-term maintenance burden on the owner(s):

1. *Internal drainage systems in embankments (e.g., drainage blankets, toe drains)* should be designed such that the collection conduits discharge downstream of the embankment at a location where access for observation is possible by maintenance personnel.
2. *Adequate erosion protection* is recommended along the contact point between the face of the embankment and the abutments. Runoff from rainfall concentrates in these areas and may reach erosive velocities depending on the gutter slope and embankment height. Although a sod gutter will be satisfactory for most small embankments, an evaluation should be made to decide if another type of gutter protection is required. For most embankments, a riprap gutter is preferred to a paved concrete gutter.
3. *Trees, shrubs, or any other woody plants should not be planted on the embankment or adjacent areas extending at least 25 feet beyond the embankment toe and abutment contacts.*
4. *Access should be provided to all areas of an impoundment that require observation or regular maintenance.* These areas include the embankment, emergency spillway, basin shoreline, principal spillway outlet, stilling basin, toe drains, riser structure, extended-drawdown device, and likely sediment accumulation areas.

#### **SECTION A-8: REGIONAL AND CLIMATE DESIGN VARIATIONS**

Not applicable.

SECTION A-9: TYPICAL GRAPHICAL DETAILS



Source: SCS Engineering Field Manual

Figure A-1a. Homogeneous Embankments w/ Seepage Controls

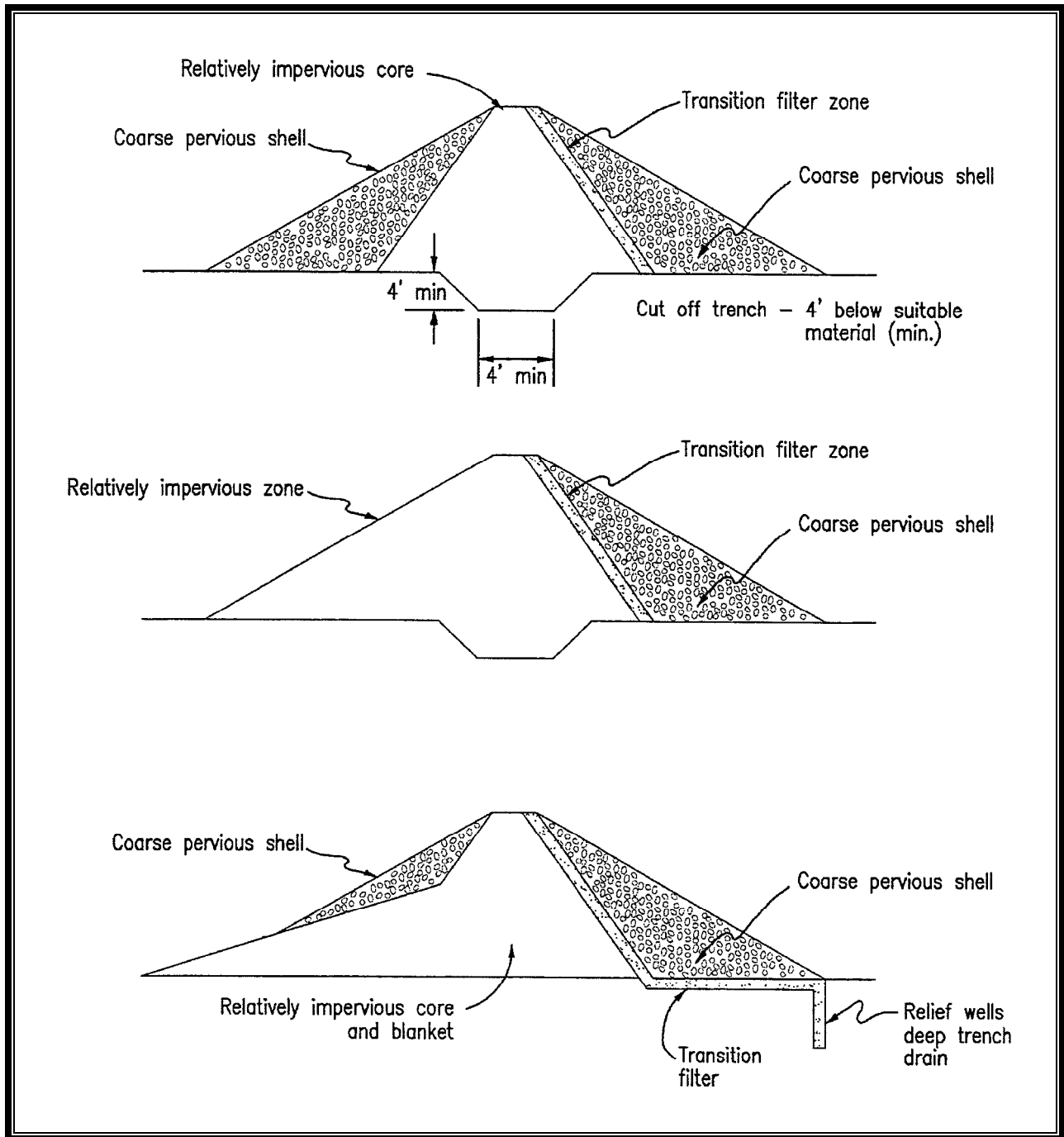


Figure A-1b. Zoned Embankment

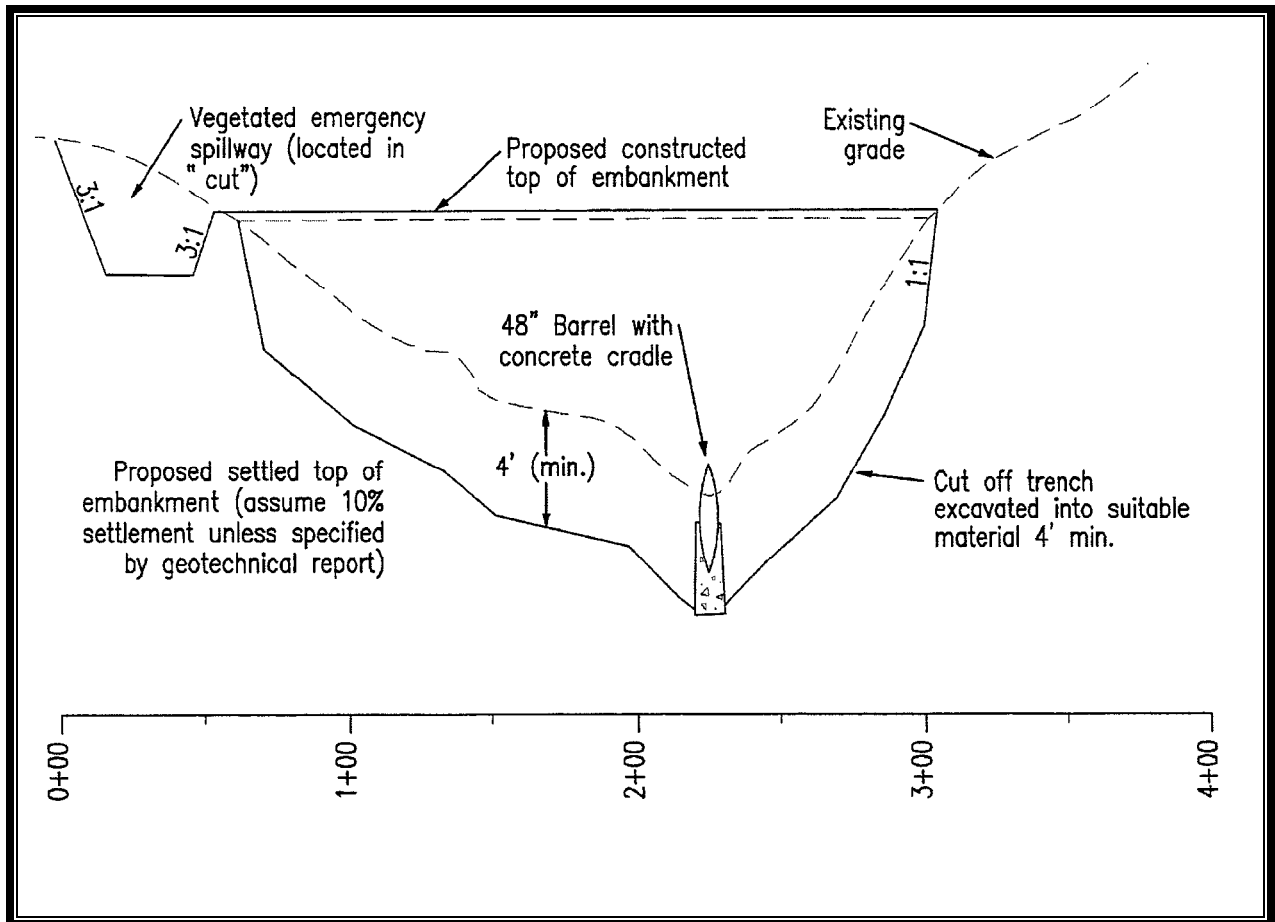
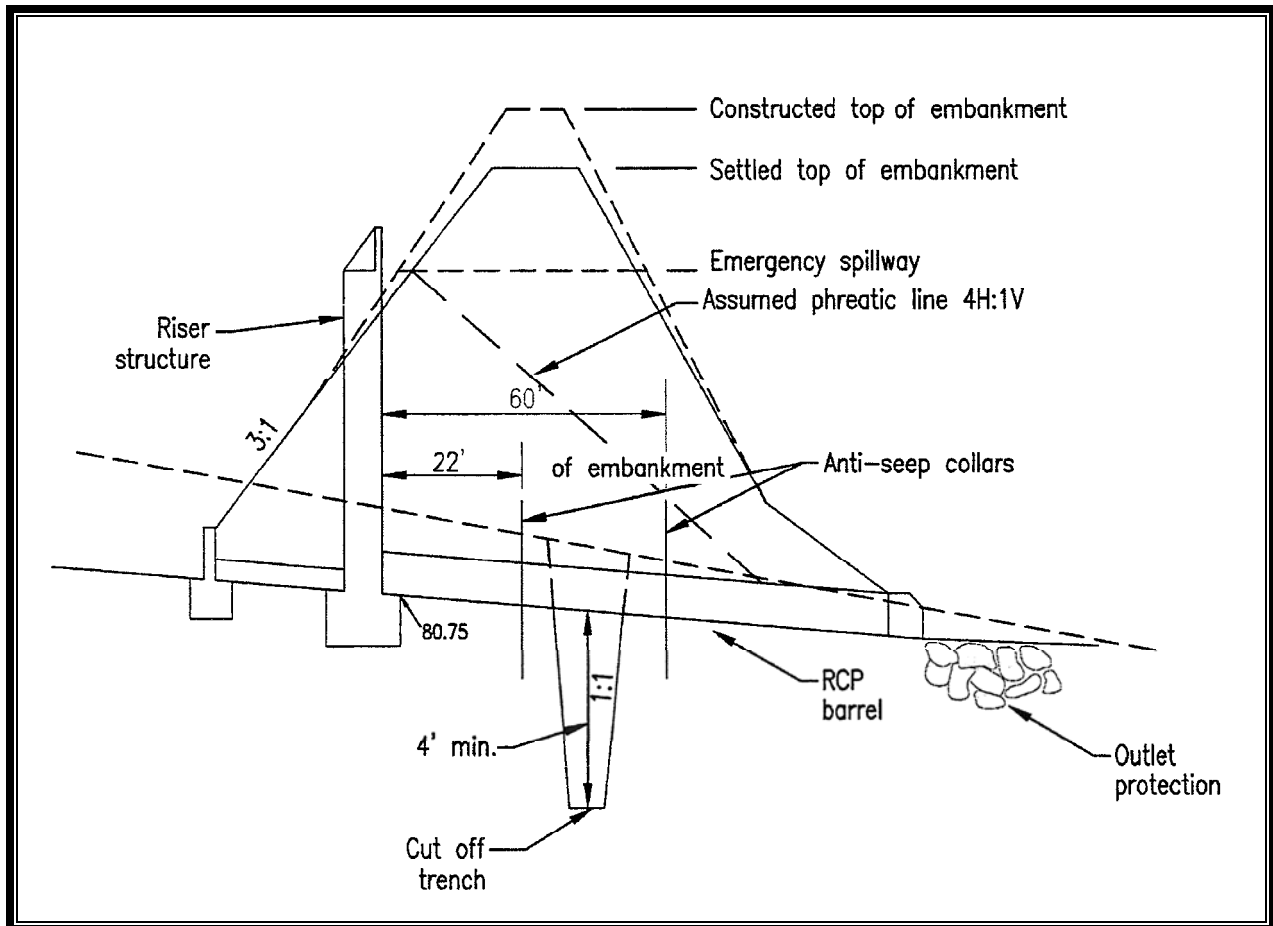


Figure A-2. Profile Along Centerline of Embankment



**Figure A-3. Profile Along Centerline of Principal Spillway**

### SECTION A-10: MATERIAL SPECIFICATIONS

Not applicable.

### SECTION A-11: CONSTRUCTION SEQUENCE AND INSPECTION

The construction specifications for earthen embankments outlined below should be considered as minimum guidelines, with the understanding that more stringent specifications may be required depending upon individual site conditions, as evaluated by the geotechnical engineer. Final construction specifications should be included on the construction plans. In general, widely accepted construction standards and specifications for embankments, such as those developed by the USDA Soil Conservation Service or the U. S. Army Corps of Engineers, should be followed.

Further guidance can be found in the USDA-NRCS *Engineering Field Manual* and *National Engineering Handbook*. Specifications for the embankment work should conform to the methods and procedures indicated for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy all requirements of the local government.

### Site Preparation

Areas designated for borrow sites, embankment construction, and structural work should be cleared, grubbed and stripped of topsoil. All trees, vegetation, roots and other objectional material should be removed.

All cleared and grubbed material should be disposed of outside and below the limits of the embankment and reservoir, as directed by the owner or his representative. When specified, a sufficient quantity of topsoil should be stockpiled in a suitable location for use on the embankment and other designated areas.

### Earth Fill

1. **Material** - Fill material should be taken from an approved, designated borrow area. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, and frozen or other objectionable materials. Fill material for the center of the embankment and the cutoff trench should conform to Unified Soil Classification GC, SC, or CL. Consideration may be given to the use of other materials in the embankment based on the recommendations of a geotechnical engineer supervises the design and construction.
2. **Placement** - Areas on which fill is to be placed should be scarified before its placement. Fill material should be placed in layers a maximum of 8 inches thick (before compaction), which should be continuous over the entire length of the fill. The most permeable borrow material should be placed in the downstream portions of the embankment. The principal spillway must be installed concurrently with fill placement and **not excavated** into the embankment.
3. **Compaction** - Fill material should be compacted with appropriate compaction equipment such as a sheepsfoot, rubber-tired or vibratory roller. The number of required passes by the compaction equipment over the fill material may vary with soil conditions. Fill material should contain sufficient moisture such that the required degree of compaction will be obtained with the equipment used.

The minimum required density is 95% of maximum dry density with a moisture content within  $\nabla$  2% of the optimum, unless otherwise specified by the engineer. Each layer of the fill should be compacted as necessary to obtain minimum density and the engineer should certify, at the time of construction, that each fill layer meets the minimum density requirement. All compaction is to be determined by either Standard Proctor Test (ASTM D698) or the Modified Proctor Test (ASTM D1557) as directed by the geotechnical engineer based on site and soil conditions and the size and type of structure being built.

4. **Cutoff Trench** - The cutoff trench should be excavated into impervious material along or parallel to the centerline of the embankment as shown on the plans. The equipment used for excavation should govern the bottom width of the trench, with the minimum width being 4 feet. The depth should be at least 4 feet below existing grade or as shown on the plans. The side slopes of the trench should be 1H:1V or flatter. The backfill should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum

permeability.

5. **Top Soil** - The surface layer of compacted fill should be scarified prior to placement of at least 6 inches of topsoil. The topsoil shall be stabilized with in accordance with the Virginia Erosion and Sediment Control Handbook, latest edition.



*Figure A-4. Stabilization of a Newly Constructed Earthen Embankment*

#### Structure and Conduit Backfill

Backfill that is beside pipes or structures should be of the same type and quality as specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should completely fill all spaces under and beside the pipe. During the backfilling operation, equipment should not be driven closer than 4 feet, as measured horizontally, to any part of a structure. Also, equipment should **NEVER** be driven over any part of a structure or pipe, unless compacted fill has been placed to a depth specified by the structural live load capacity of the structure or pipe in order to adequately distribute the load.

#### Filters and Drainage Layers



In order to achieve maximum density of clean sands, filter layers should be flooded with clean water and vibrated just after the water drops below the sand surface. The filter material should be placed in lifts of no more than 12 inches.

Up to four feet of embankment material may be placed over a filter material layer before excavating back down to expose the previous layer. After removing any unsuitable materials, the trench may be filled with additional 12 inch lifts of filter material, flooded, and vibrated as described above, until the top of adjacent fill is reached.

**Filter fabrics should not be used in lieu of sands and gravel layers within the embankment.**

## SECTION A-12: OPERATION AND MAINTENANCE

A thick, healthy grass cover, free of trees and brush, should be maintained on the embankment. Such a cover will help stabilize the surfaces of the embankment and will simplify inspections.

The maintenance and inspection guidelines presented below are **NOT** all-inclusive. Specific facilities may require other measures not discussed here. It is the designer's responsibility to decide if additional measures are necessary.

1. The embankment should be mowed periodically during the growing season, ensuring that the last cutting occurs at the end of the season. The grass should not be cut less than 6 to 8 inches in height.
2. If necessary, the embankment should be limed, fertilized and seeded in the fall, after the growing season. Lime and fertilizer application rates should be based on soil test results. The type of seed should be consistent with that originally specified on the construction plans.
3. All erosion gullies noted during the growing season should be backfilled with topsoil, reseeded and protected (mulched) until vegetation is established.
4. All bare areas and pathways on the embankment should be properly seeded and protected (mulched) or otherwise stabilized to eliminate the potential for erosion.
5. All animal burrows should be backfilled and compacted and burrowing animals should be removed from the area.
6. All trees, woody vegetation and other deep-rooted growth, including stumps and associated root systems, should be removed from the embankment and adjacent areas extending to at least 25 feet beyond the embankment toe and abutment contacts. The root systems should be extracted and the excavated volume replaced and compacted with material similar to the surrounding area. All seedlings should be removed at the first opportunity. Similarly, any vine cover and brush should be removed from the embankment to allow for inspections.
7. Any repairs made to the principal spillway (riser or barrel) should be reviewed by a professional engineer. Vertical trenching to expose the barrel should not be allowed under

any circumstances. The trench side slopes should be stepped back at a 2:1 slope, minimum.

### SECTION 13: REFERENCES

ASTM D-2487. *Classification of Soils for Engineering Purposes.*

ASTM D-2488. *Description and Identification of Soils* (visual-manual procedure).

Maryland Department of the Environment-Dam Safety Division. *Dos and Don'ts for Pond Construction.* May 1997.

Sowers, George F. *Introductory Soil Mechanics and Foundations: Geotechnical Engineering.*

Terzaghi and Peck. *Soil Mechanics in Engineering Practice.*

USDA Natural Resource Conservation Service. *Engineering Field Manual.*

USDA Natural Resource Conservation Service. *National Engineering Handbooks.*

#### **USDA Natural Resource Conservation Service, Soil Mechanics Notes:**

- SM Note No. 1, Guide for Determining the Gradation of Sand and Gravel Filters.
- SM Note No. 2, Light Weight Piston Sampler for Soft Soils and Loose Sands.
- SM Note No. 3, Soil Mechanics Considerations for Embankment Drains.
- SM Note No. 4, Preparation and Shipment of Undisturbed Core Samples.
- SM Note No. 5, Flow Net Construction and Use.
- SM Note No. 6, Glossary, Symbols, Abbreviations, and Conservation Factors.
- SM Note No. 7, The Mechanics of Seepage Analysis.
- SM Note No. 8, Soil Mechanics Testing Standards.
- SM Note No. 9, Permeability of Selected Clean Sands and Gravels.
- SM Note No. 10, The Static Cone Penetrometer: The Equipment and Using the Data.

#### **USDA Natural Resource Conservation Service, Technical Releases:**

- TR 709. *Dimensioning of Filter-Drainage Diaphragms for Conduits According to TR-60.*
- TR 026. *The Use of Soils Containing More Than 5% Rock Larger Than the No.4 Sieve.*
- TR 027. *Laboratory and Field Test Procedures for Control of Density and Moisture of Compacted Earth Embankments.*
- TR 028. *Clay Minerals.*
- TR 071. *Rock Materials Field Classification Procedure.*
- TR 60. *Earth Dams and Reservoirs*

U.S. Department of the Interior. *Design of Small Dams.* 1987.

U.S. Department of the Interior, Bureau of Reclamation. *Guidelines for Controlling Seepage Conduits through Embankments.*

*Virginia Erosion and Sediment Control Handbook*. Richmond, Virginia: 1992.