CONSERVATION ENGINEERING
TECHNICAL NOTES

Engineering Technical Note SD-2015-1 **April 2015**

Rehabilitating and Restoring Earth Dams

From time to time our technicians are requested to furnish technical assistance for enlarging, restoring, or rehabilitating existing earth dams. Many times these rebuilding projects are more difficult to construct than new embankments. However, lack of other sites for water facilities may leave no other alternative than to improve the existing dam.

This technical note sets forth general design procedures applicable to most of these projects. The criteria contained in the Field Office Technical Guide should be followed whenever work is performed on existing structures. This will include an evaluation of present needs as well as depth requirements, runoff volumes and other Standards. On all restoration or rehabilitation projects, the reason or causes of the failure must be eliminated if the additional construction work is to be successful.

Generally, our work with existing structures can be divided into the following four categories:

A. The present structure is stable but the existing depth is not sufficient.
B. The present structure may or may not be adequate for depth but the downstream slope indicates a slope failure has occurred so additional repair work is needed. In many cases, the phreatic line has intercepted the downstream slope a considerable distance above the downstream toe. This may be because the original embankment was never compacted to a sufficient density at the proper moisture content.
C. The present dam is still adequate but the auxiliary spillway has eroded and gullied.
D. The principal spillway has failed or has inadequate capacity.

There also may be combinations of the above types of restoration or enlargement projects.

Whenever additional earthfill is placed against existing structures, extreme care must be exercised to obtain a bond between the new and old fill. The plane between the new and old earthfill is not only a potential line for seepage but usually occurs at the approximate location where most sliding planes are located. Consequently, enlargements or restoration projects in many ways are construction projects requiring better construction methods than new structures. Any additional earthfill placed should have a density equal to or greater than the original embankment.

Following are various methods which may be used to enlarge or restore structures in the various categories cited above.

A. The present structure is stable but the existing depth is not sufficient.

   If the dam is to be enlarged several items must be considered. Many times the area at the downstream toe of the existing structure is quite wet indicating inadequate control of seepage. This may be corrected by constructing a core trench. (See Figure 1) Soft surface material or stratified sand-gravel layers at the toe of the dam may be further indication for the need of a core trench. Wet material requiring the use of an excavator should not be the reason for omitting a core trench unless some other means is provided to control seepage. This may be done by the use of foundation drains as shown in Figure 2. However, it should be understood that the use of a foundation drain does nothing to reduce seepage; it only controls the seepage outlet to prevent damage to the embankment.

   If there is a line of seepage extending out from underneath the embankment which appears to be following the ground line between the foundation and the fill, a core trench should be considered a necessity. In such cases, the use of foundation drains may also be indicated.

A core trench as shown by Figure 1 performs two important functions. First, it intercepts possible existing seepage lines in the foundation which now exist or which may be started due to the added head of water in the reservoir. Secondly, it keys or ties in the new fill with the present embankment and foundation.

B. The present structure may or may not be adequate for depth but the downstream slope indicates a slide failure has occurred.

This type of failure is quite common and very difficult to correct. The severity of the slide will determine how to proceed with the corrective action.

Figure 3 shows a slide which is just beginning or is relatively small. If corrected immediately, the slope can be stabilized by constructing a berm as shown by Figure 3a. The width of the berm or the distance “W” should be approximately equal to the distance the foundation has been disturbed downstream from the toe of the dam. The height should be as given by Figure 3a.

If a well-graded sand-gravel mixture is available, (ASTM C33 - Fine Concrete Aggregate) the use of a foundation drain at the downstream toe of the original structure would decrease the width "W” needed for the berm by approximately 50 percent (%). However, width less than 10 feet should never be used.

Figure 4 shows a failure which is much more serious. This failure has been caused by a weak embankment material. Many times the effective height of the embankment is reduced creating a situation where an overtopping failure of the embankment is eminent. Repair of such cases (See Figure 4a) should include removal of the disturbed material. The remaining earthfill should have all banks sloped to 2:1 or flatter before starting to replace the fill. Usually this repair should not be attempted without first pumping or otherwise draining the water from the reservoir.

It is necessary that adequate compaction at proper moisture content be performed when replacing this earthfill. Although it will be difficult for earthmoving equipment to operate, all earthfill must be compacted to a density at least equal to that of the surrounding embankment. Failure to thoroughly compact in hard to-get at corners will create potential seepage lines which may again lead to a future failure. A bond must be obtained with the previous embankment.

Repair of a slide of this type should include placement of a downstream berm. The width of the berm will vary from 10 feet to 20 feet or more depending upon height of dam, borrow material, foundation conditions, etc. A rule of thumb is to use a width of berm equal to 1/2 of the maximum height of the dam. The height of the berm should also be equal to approximately 1/3 to 1/2 the height of the dam. If roller compaction is used, the above dimensions may be reduced by 25%.

Figure 5 shows a failure very similar to Figure 4. However, the cause of failure as shown by Figure 5 is due to a weakness in the foundation rather than a weak embankment. Repair of this type of failure is difficult as the foundation will usually be very soft requiring an excavator to remove the disturbed material.

The repair of this type of failure (See Figure 5a) is similar to that for Figure 4a. In addition to the disturbed material in the embankment to be removed, the disturbed foundation material should also be removed. In addition to backfilling with good material, it is advisable to place a foundation drain at the base of the original embankment as shown by Figure 5a. This drain should be placed as low as possible and still retain a free flowing outlet. The drain is more important on structures 25 feet or more in height.

C. The present structure has a severely eroded auxiliary spillway. Figure 6 shows a cross section

of an eroded auxiliary spillway.

The possible causes for this erosion include: (1) inadequate or no primary spillway, (2) lack of maintenance or failure to maintain proper stand of vegetation, (3) excessive durations of trickle flows, (4) insufficient width which is level to distribute flow over a wide area, and (5) soils not capable of supporting adequate vegetation.

Repair of a severely eroded auxiliary spillway is typically accomplished by relocation of the spillway and placing a berm or extending the embankment to prevent flow from entering the headcut. If there is adequate space the auxiliary spillway may be expanded to the side with the embankment extended along with a wing dike to divert flow away from the existing head cut and the downstream embankment toe.

The redesign of an auxiliary spillway should include a recomputation of the peak flow and a determination of the necessary width required to bypass this flow at a non-erosive velocity.

This spillway should be level throughout its entire width. The exit channel should also be approximately level down to a point where the flow re-enters the original channel downstream from the dam. Figure 6a is a cross section of an auxiliary spillway showing how shaping may be accomplished.

Whenever erosion has damaged an auxiliary spillway, consideration should be given to reducing the frequency of the use of the spillway. This can be accomplished by installing a principal spillway (or putting in a larger one if a principal spillway is already present) or by increasing the detention storage provided a principal spillway is to be utilized. If the present structure has more depth and storage than needed, the crest of the principal spillway inlet may be able to be lowered; thereby, increasing the detention storage.

If the dam is to be enlarged, the elevation of the crest of the auxiliary spillway can also be raised to obtain additional detention storage with resulting protection to the auxiliary spillway.

D. The present principal spillway has failed either from corrosion, improper material, or inadequate size.

The possible causes of this type of failure can be:
1. Metal conduit exceeding the life expectance and is corroding to the point of failure or has failed.
2. Original conduit was corrugated HDPE, improper gauge, or wall thickness and has collapsed.
3. Seepage along the conduit has caused the principal spillway to wash out due to dispersive earthfill material or lack of a drainage diaphragm.
4. Conduit is undersized for the drainage area and the available detention storage.

This type of restoration typically involves a thorough site investigation to determine current runoff conditions, adequacy and condition of existing auxiliary spillway, available detention storage, available permanent storage and a soils investigation. The restoration may require draining or pumping the existing pond prior to construction. The redesign of the principal spillway shall meet current NRCS Standards and specifications.

In all cases the existing conduit must be removed from the existing fill using proper trench safety measures.

Prior to placing a new conduit in the same location, the bed shall be undercut a minimum of 2 feet or until suitable bed material has been reached. The sides of the trench shall be 3:1 or flatter. After the new conduit is installed to current standards and specifications, refill the

excavation. Extreme care must be exercised when replacing the earthfill to obtain a bond between the new and old earthfill and to avoid damage or displacement of the conduit.

Figure 7 shows details of foundation and embankment drains suitable for most structures less than 30 feet in height. A drain of this type will lower the phreatic line and collect seepage water and transport the seepage to a stable outlet; thereby, aiding in stabilizing the downstream slope. To be effective, the drain must extend entirely across the flood plain or valley and be composed of a clean, well graded sand gravel mixture. ASTM C33 – Fine Concrete Aggregate will meet the material requirements for foundation drains in most situations. A drainfill envelope to transmit the seepage to a stable outlet at the downstream toe of the embankment will be necessary. The outlet of the drainfill envelope should be protected from erosion by covering with a geotextile filter fabric and larger aggregate or rock riprap. In some situations, a perforated pipe may be necessary to transport the seepage water inside the drain material. A non-perforated pipe should then be used to convey this flow to a point down-stream from the embankment. Drainage systems with piping would normally be used when a drainfill envelope would not have sufficient capacity to transport the expected seepage flow. These drains should be placed as low as possible and still be able to have a free outlet with positive grade. On wide flat valleys where the foundation drain may be several hundred feet long, the perforated pipe should extend for a considerable distance inside the sand-gravel drainfill material.

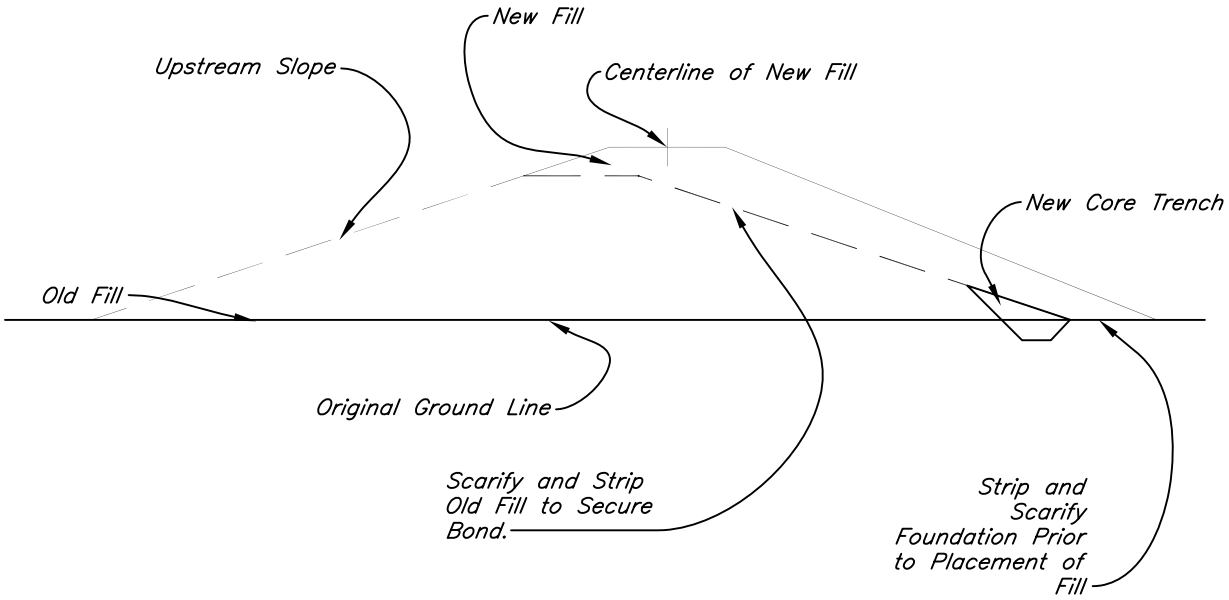

New Fill
Upstream Slope
Centerline of New Fill
New Core Trench
Old Fill
Original Ground Line
Scarify and Strip
Old Fill to Secure
Bond.
Strip and
Scarify
Foundation Prior
to Placement of
Fill

Figure 1
NTS

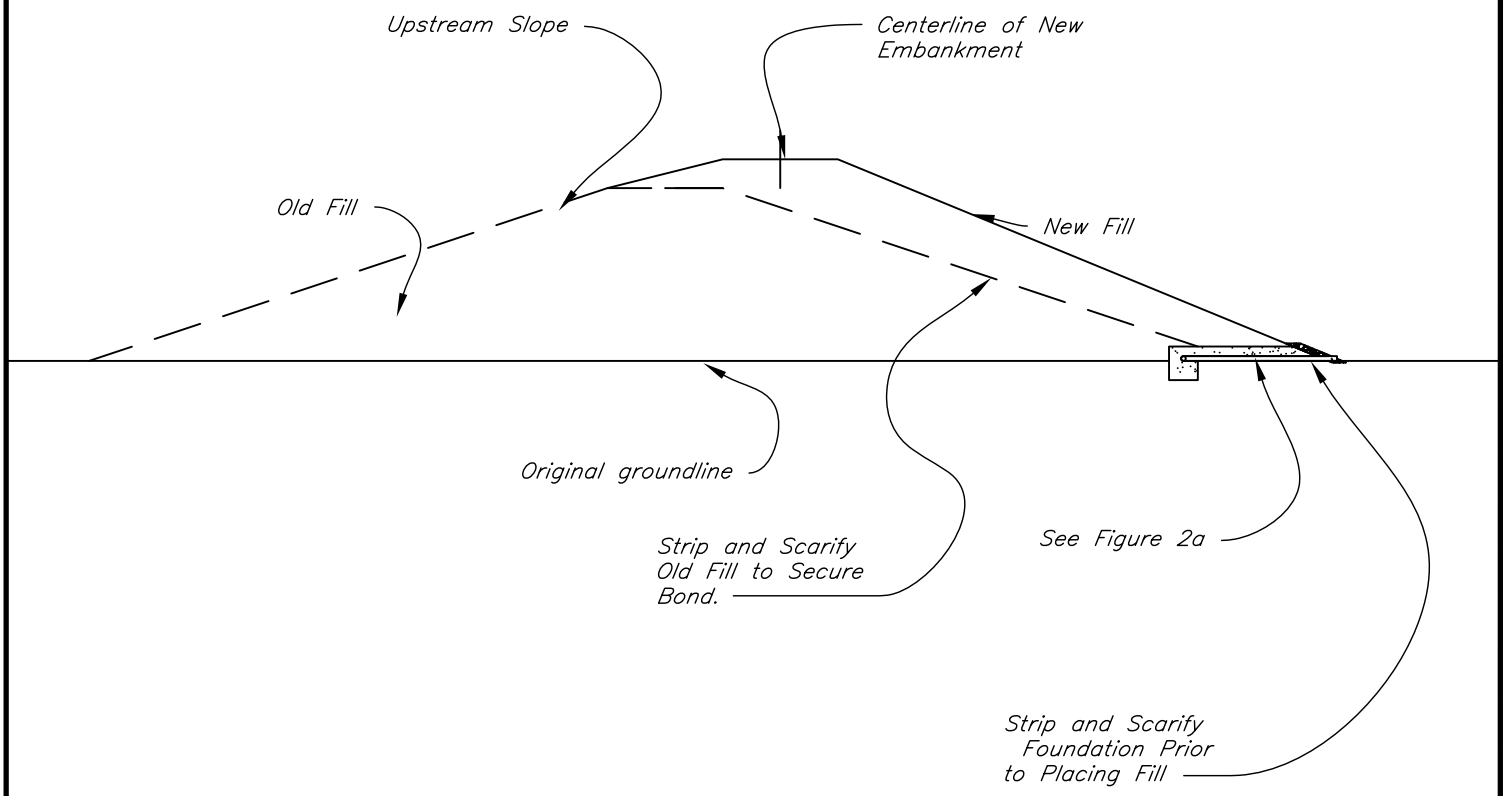


Figure 2
NTS

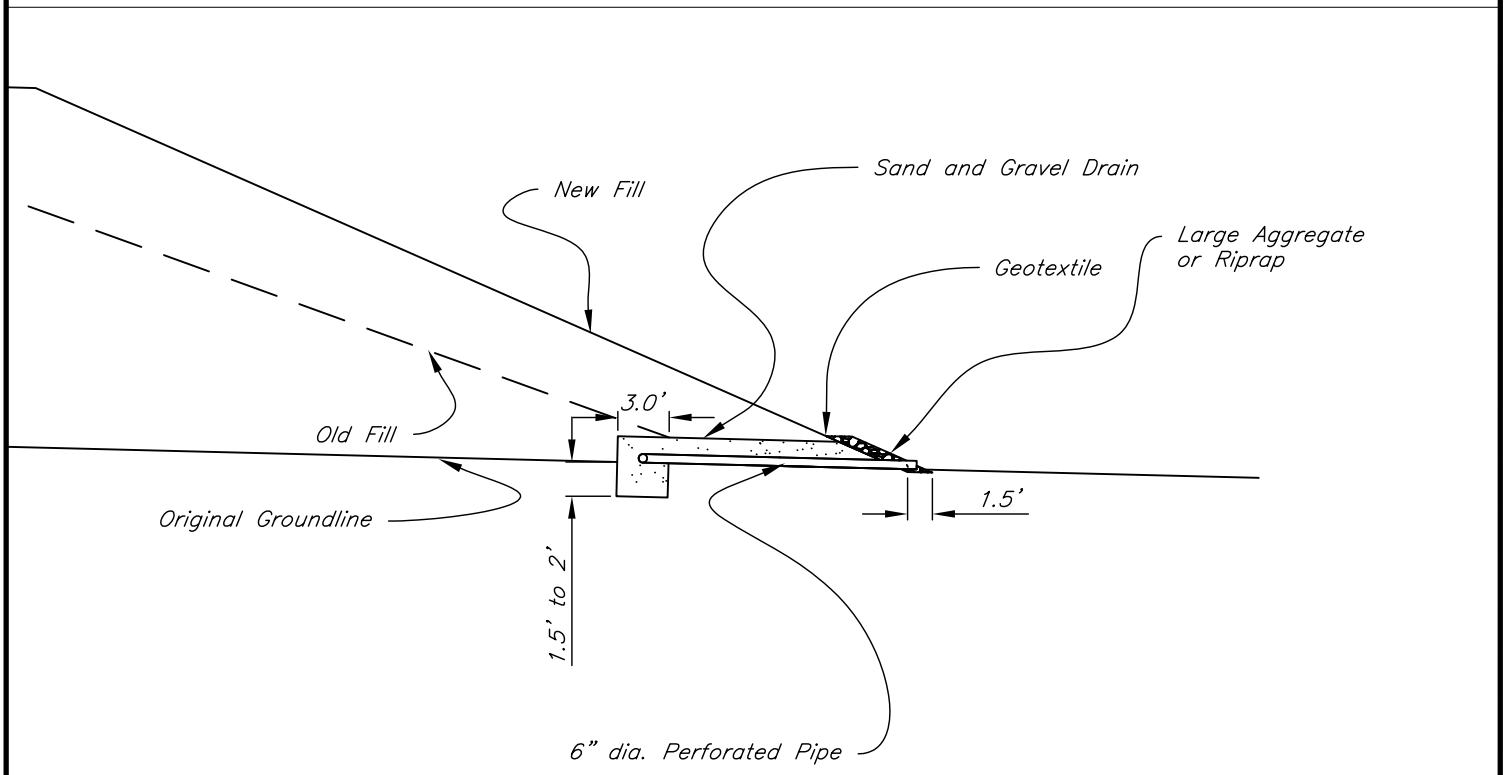


Figure 2a
NTS

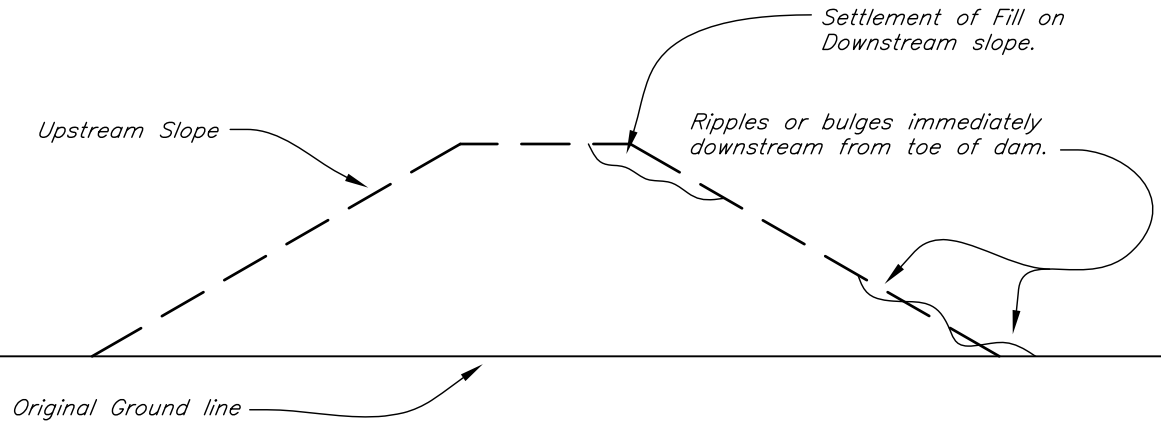


Figure 3
NTS

Use h = ½ H if not roller compacted.
Reduce height and width of berm 25%
if roller compaction is used.

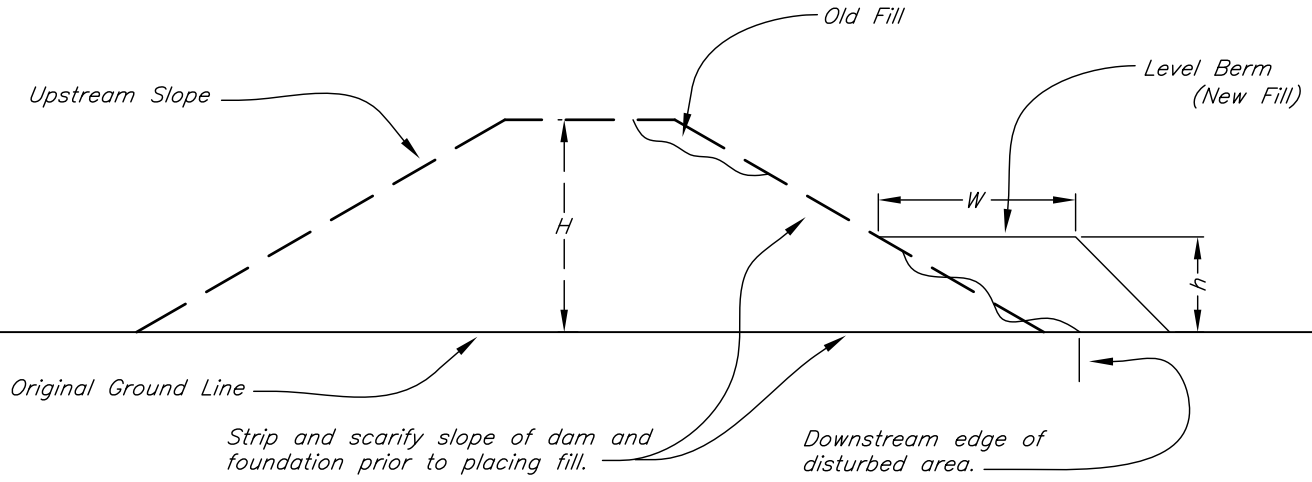


Figure 3a
NTS

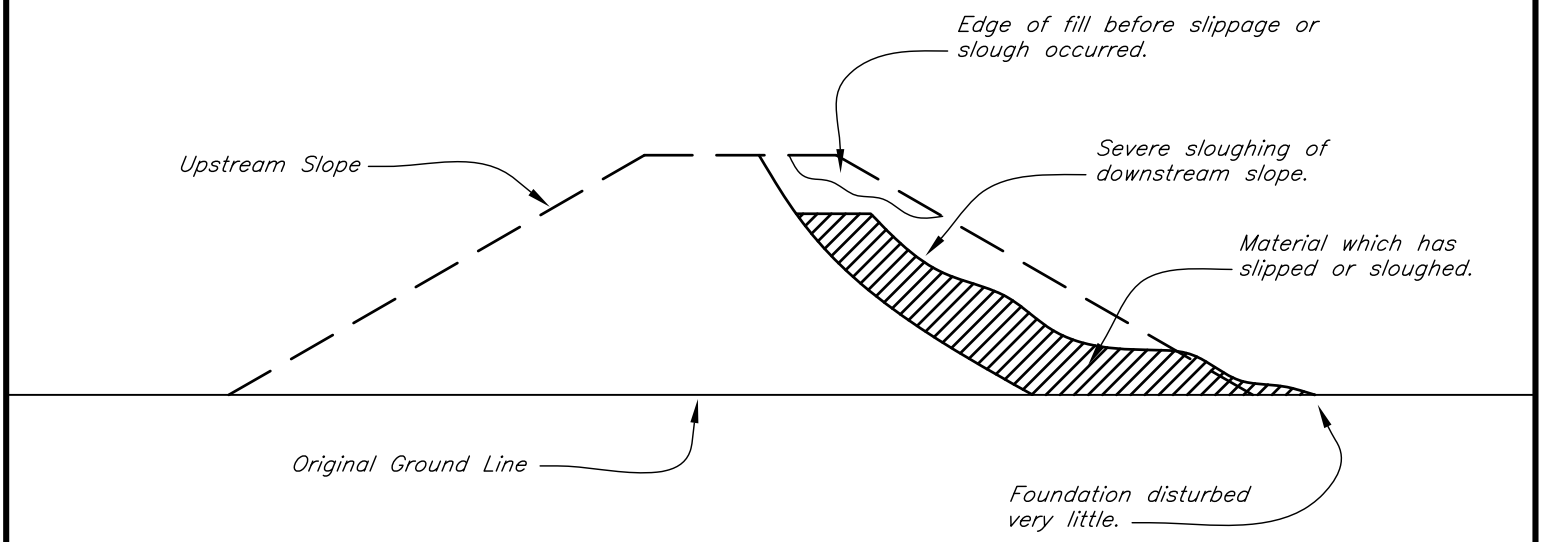


Figure 4
NTS

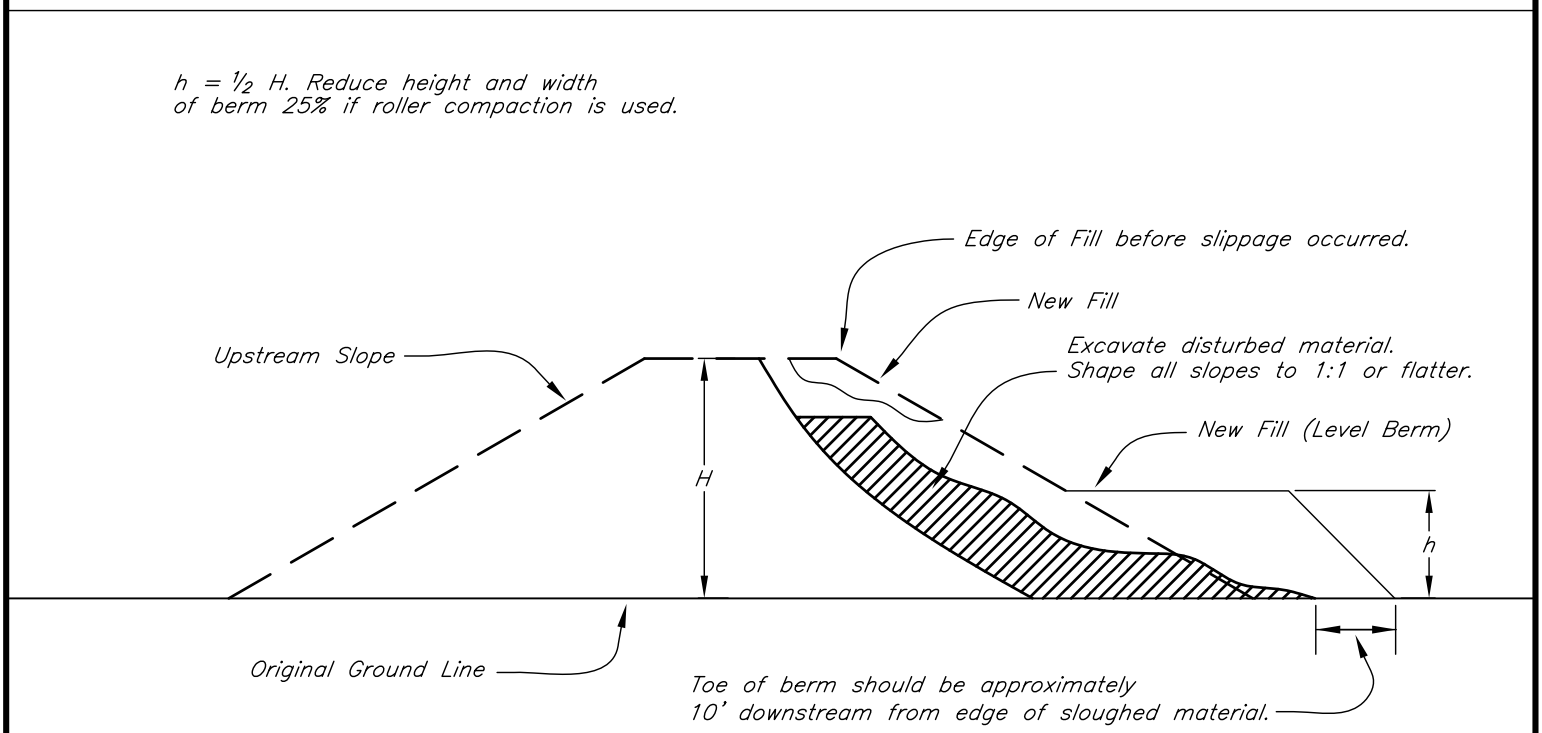


Figure 4a
NTS

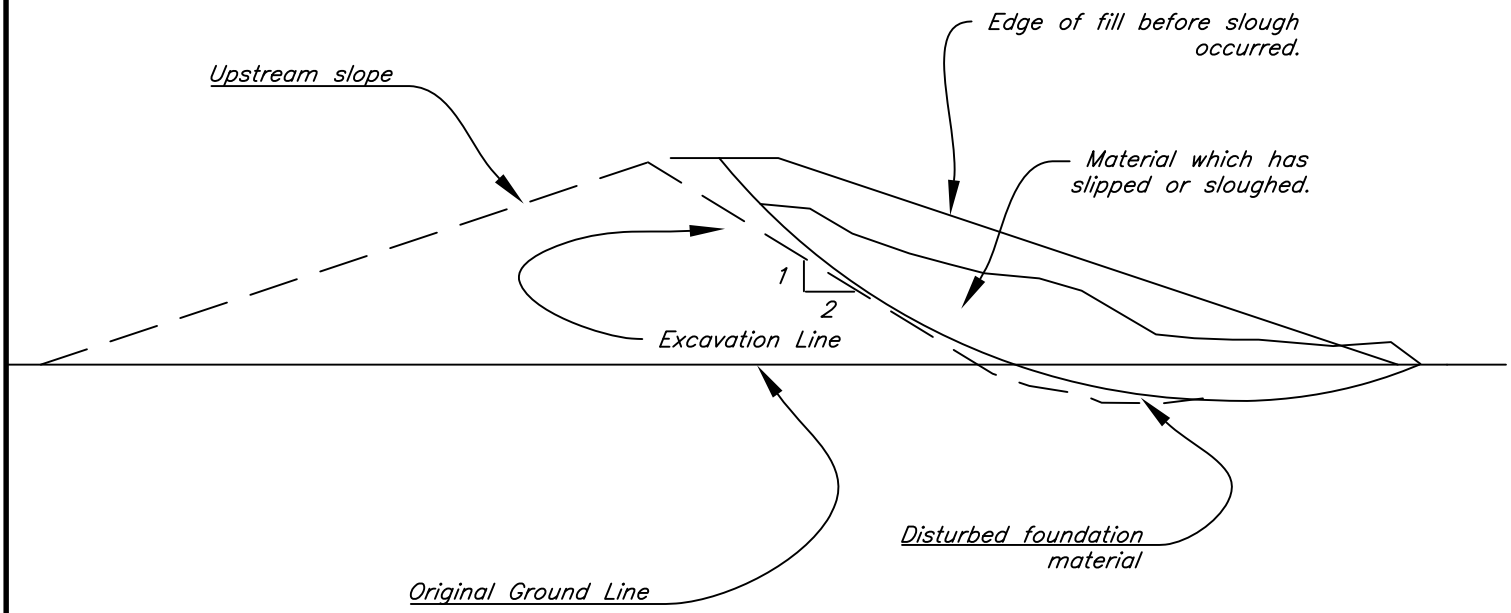


Figure 5.
NTS

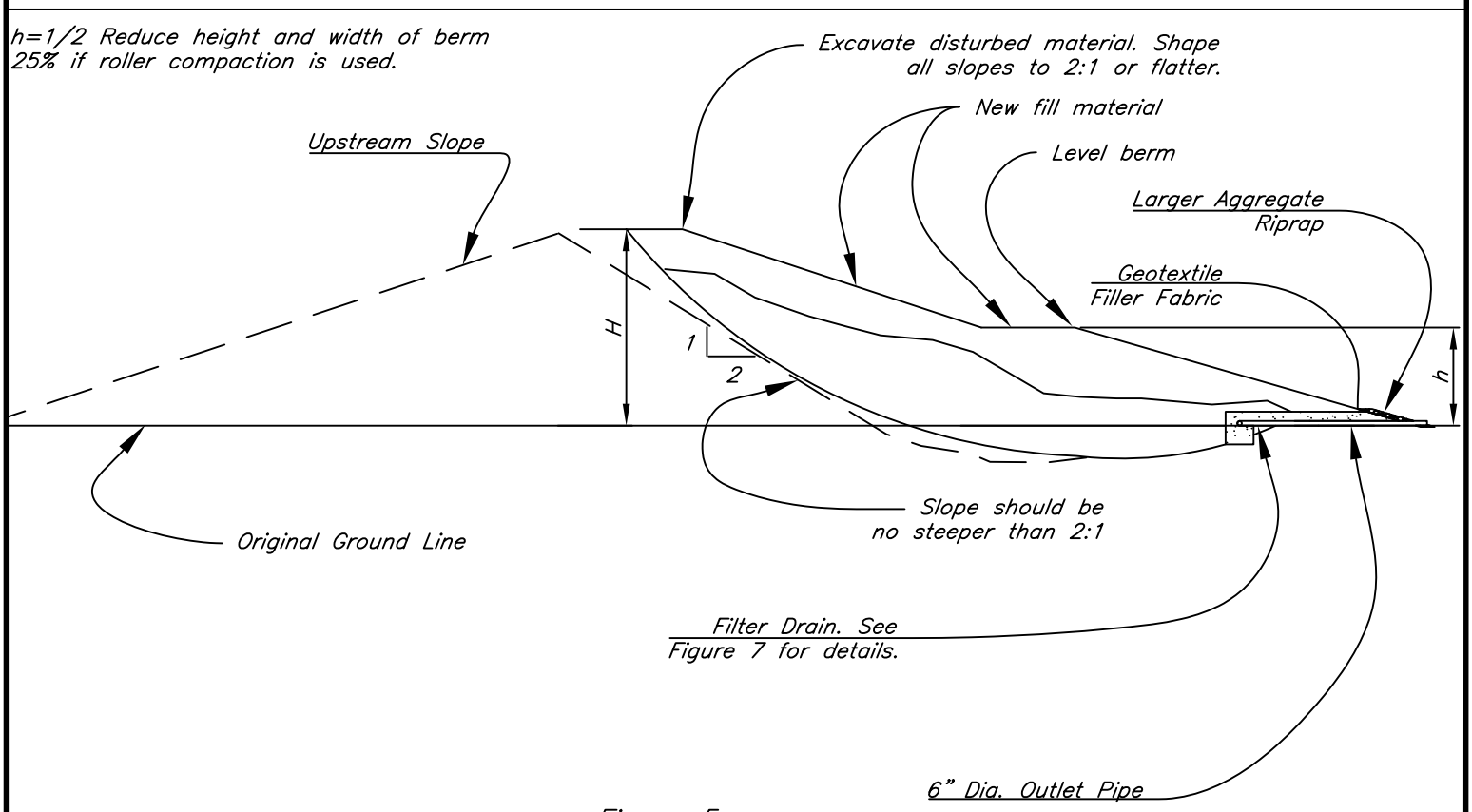


Figure 5a.
NTS

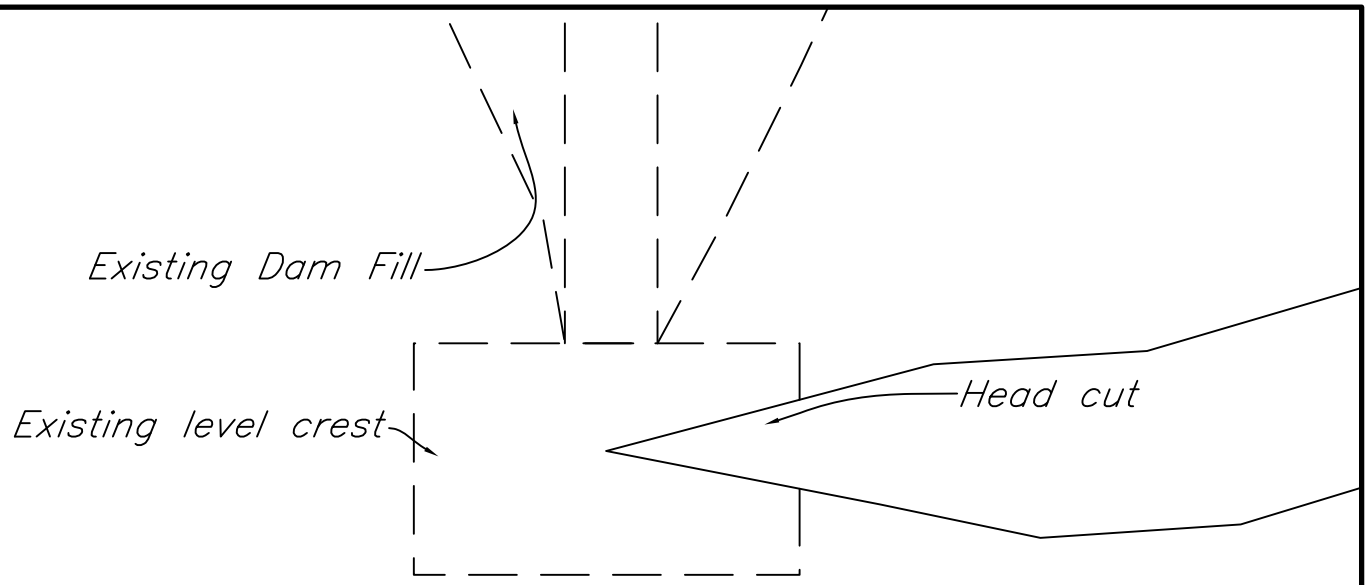


Figure 6
NTS

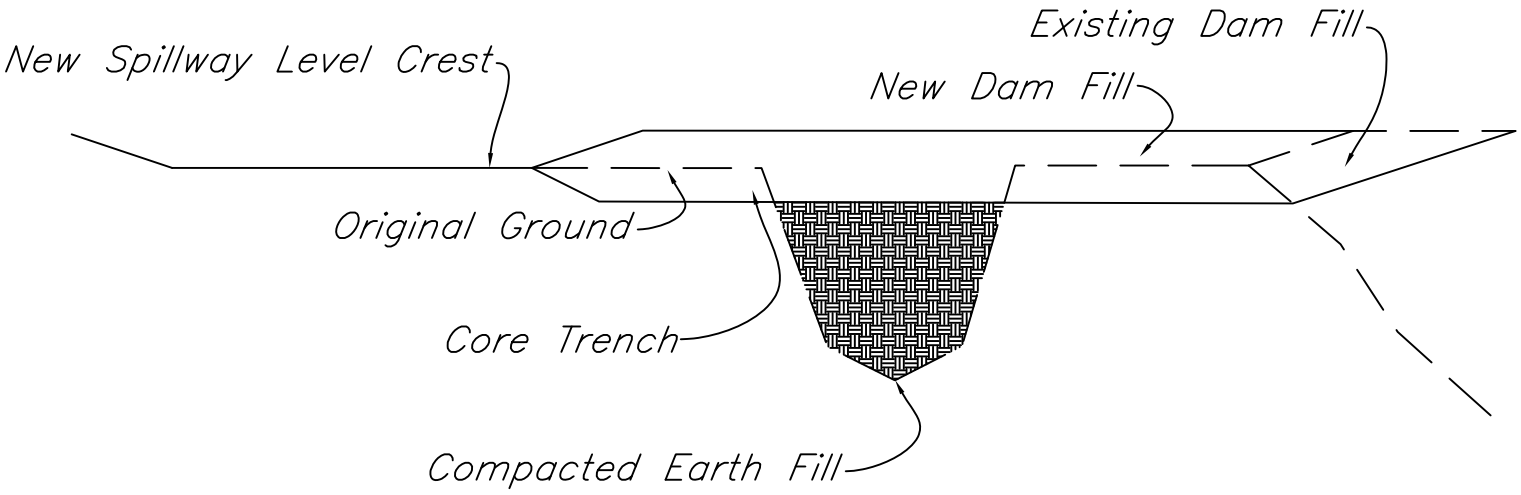


Figure 6a
NTS

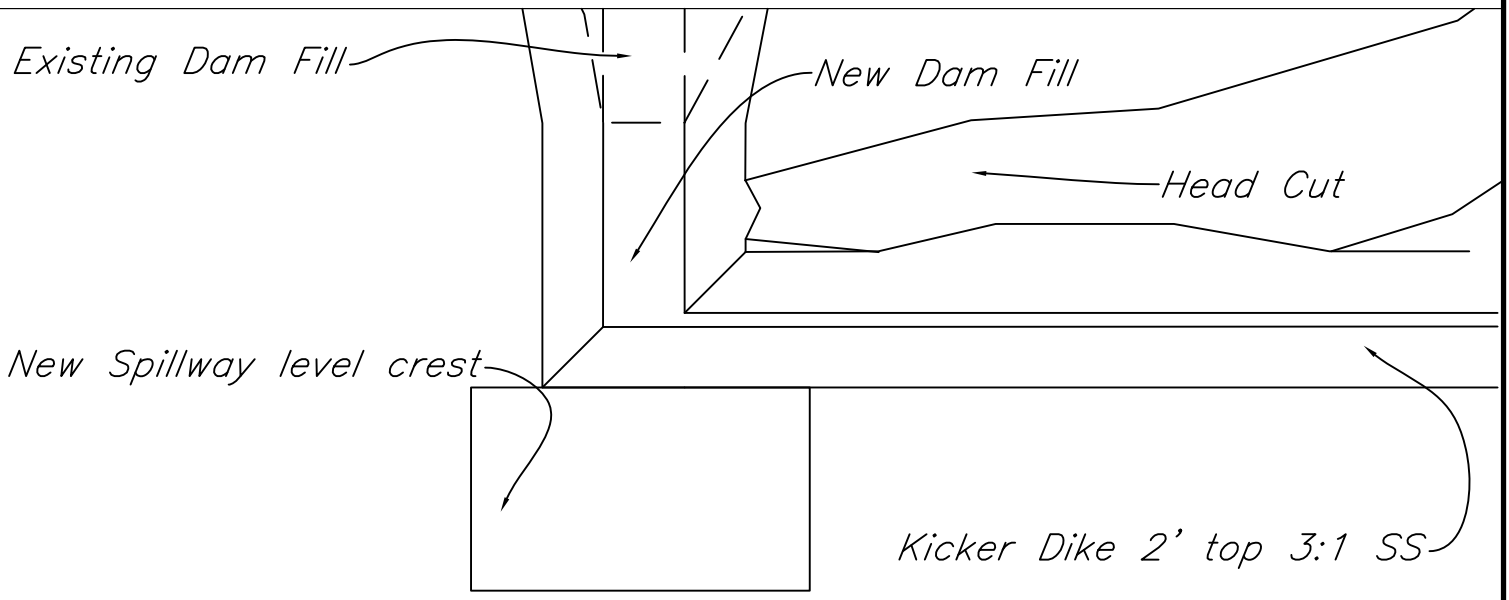
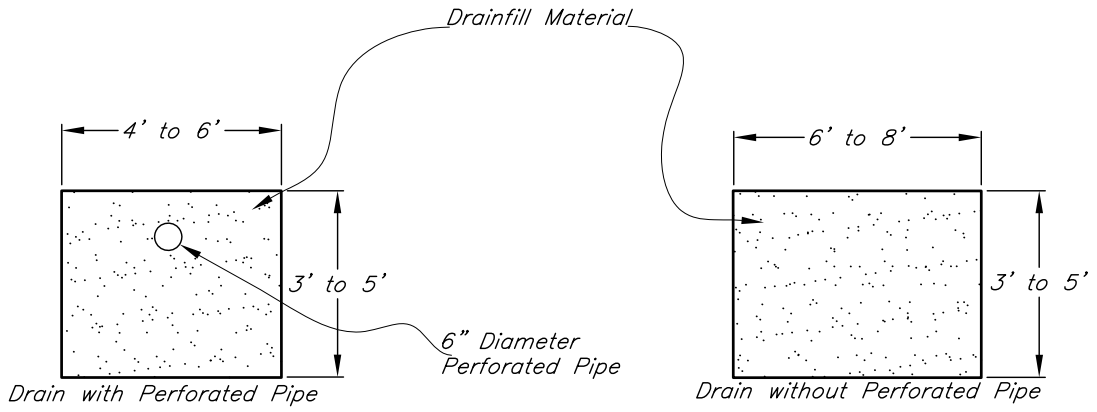


Figure 6b
NTS

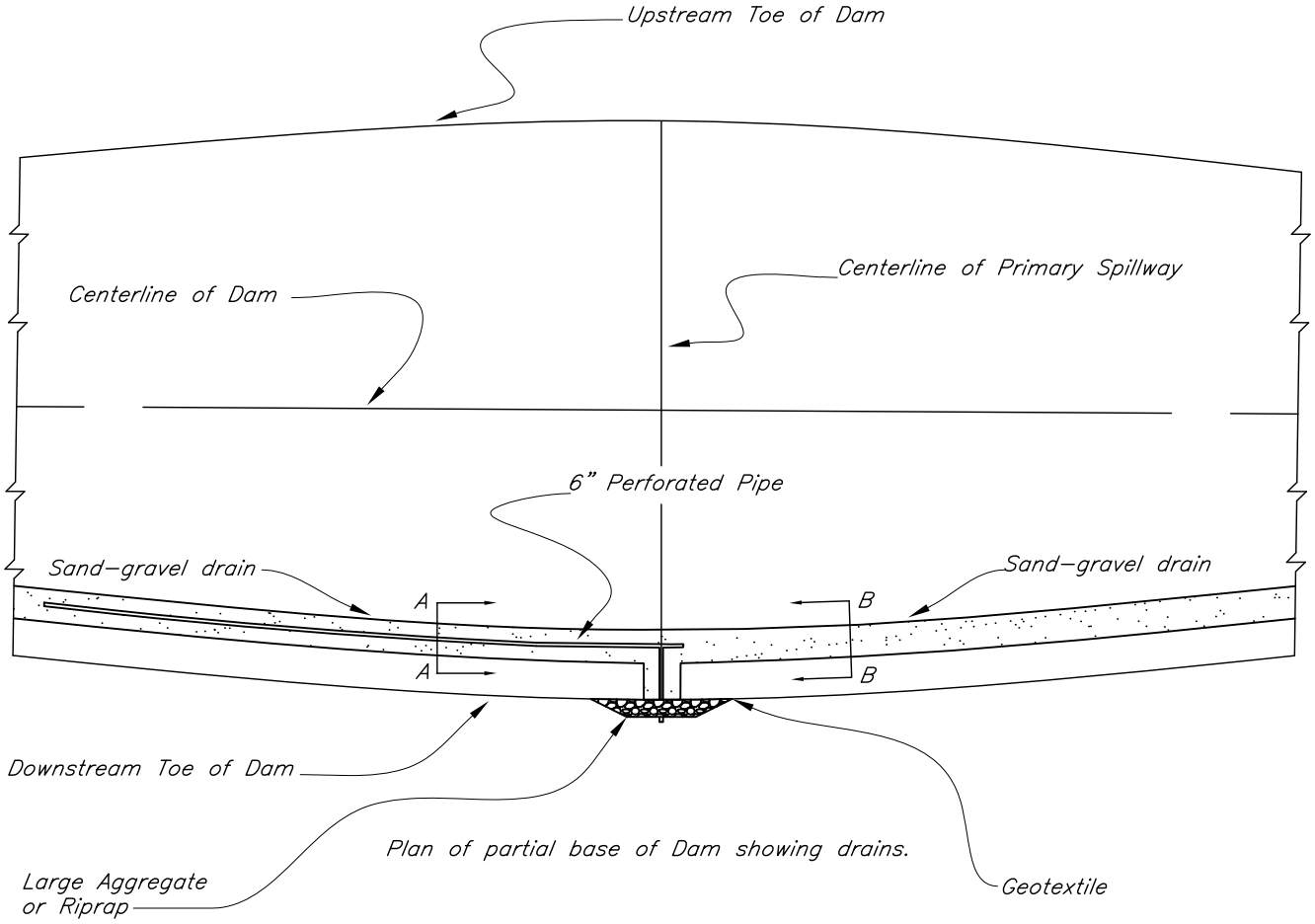


Drainfill Material must be a well graded with not more than 5% by weight which will pass the No. 200 sieve.(ASTM C33) Fine Concrete Aggregate.

Section A–A

Section B–B

NTS



Plan of partial base of Dam showing drains.

Figure 7
NTS