Chapter 630 Geosynthetics

630.01 General

Geosynthetics include a variety of manufactured products that are used by the Washington State Department of Transportation (WSDOT) in drainage, earthwork, erosion control, and soil reinforcement applications.

The following geosynthetic applications are addressed in the *Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications)*:

- Low survivability underground drainage
- Moderate survivability underground drainage
- Separation
- Soil stabilization
- Moderate survivability permanent erosion control
- High survivability permanent erosion control
- Ditch lining
- Temporary silt fence

The *Standard Specifications* addresses geosynthetic properties as well as installation requirements and are not site-specific. The geosynthetic properties provided are based on the range of soil conditions likely to be encountered in Washington for the applications defined. Other applications, such as prefabricated edge drains, pond liners, and geotextile retaining walls, are currently handled by special provision.

Design responsibilities are discussed in 630.05 and illustrated in Exhibits 630-4 and 630-5.

This chapter does not address applications where geosynthetics are used to help establish vegetation through temporary prevention of erosion (vegetation mats).

630.02 References

Highway Runoff Manual, M 31-15, WSDOT

Hydraulics Manual, M 23-03, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

Standard Specifications for Road, Bridge, and Municipal Construction (Standard Specifications), M 41-10, WSDOT

Temporary Erosion and Sediment Control Manual, M 3109, WSDOT

WSDOT *Pavement Policy*, available at the Pavements website:
www.wsdot.wa.gov/business/materialslab/pavements/default.htm

- Permeable base beneath highway pavement (see the *WSDOT Pavement Policy* for additional information on permeable bases).
- A parking lot drainage layer.

Note that pipe wrapping (the geotextile is wrapped around the surface of the pipe) is not included as an underground drainage application.

Locate the geotextile such that it will function as intended. For example, if the objective is to keep the drainage aggregate surrounding a drain pipe clean, locate the geotextile so that it completely separates the drainage aggregate from more silty surrounding soils, which may include native soils as well as relatively silty roadway base or fill materials.

Consider the flow path of any groundwater or surface water when locating the geotextile.

The flow path from the geotextile, as part of the groundwater drainage, is typically directed to a surface water conveyance system. Design of surface water conveyance is guided by the *Hydraulics Manual*. The surface water conveyance must be low enough to prevent backflow and charging of the groundwater drainage—typically, by matching inverts of groundwater drainage to crowns of surface water conveyance pipes. A 1-foot allowance is usually applied when connecting to open water or ditches.

(2) Separation

Geotextile used for separation must prevent penetration of relatively fine grained subgrade soil into the ballast or other roadway or parking lot surfacing material to prevent contamination of the surfacing material (the separation function). This application may also apply to situations other than beneath roadway or parking lot surfacing where it is not necessary for water to drain through the geotextile unimpeded (filtration), but where separation of two dissimilar materials is required.

Separation geotextile should only be used in roadway applications where the subgrade is can be prepared and compacted as required in the *Standard Specifications*, but without removal and replacement of the subgrade soil with granular material. Such removal and replacement defeats the purpose of the geotextile separator.

Separation geotextile placed beneath roadway surfacing is feasible if the subgrade resilient modulus is greater than 5,800 psi and if a saturated fine sandy, silty, or clayey subgrade is not likely to be present. Note that the feasibility of separation geotextile may be dependent on the time of year and weather conditions expected when the geotextile is to be installed.

For separation applications, a geotextile is not needed if the subgrade is dense and granular (silty sands and gravels), but is not saturated fine sands. In general, a separation geotextile is not needed if the subgrade resilient modulus is greater than 15,000 psi.

(3) Soil Stabilization

Geotextile used for soil stabilization must function as a separator, a filtration layer, and (to a minor extent) a reinforcement layer. This application is similar to the separation application, except the subgrade is anticipated to be softer and wetter than in the separation application.

Soil stabilization geotextile is used in roadway applications if the subgrade is too soft and wet to be prepared and compacted as required in the *Standard Specifications*. Soil stabilization geotextile is placed directly on the soft subgrade material, even if some overexcavation of the subgrade is performed. Backfill to replace the overexcavated subgrade is not placed below the geotextile soil stabilization layer, as this would defeat the purpose of the geotextile.

Anticipate the need for soil stabilization geotextile if the subgrade resilient modulus is less than or equal to 5,800 psi, or if a saturated fine sandy, silty, or clayey subgrade is likely to be present.

Consider the flow path of any groundwater or surface water when locating the soil stabilization geotextile and when selecting the geotextile to be used. For saturated fine sandy or silty subgrades, water must be able to flow from the subgrade through the geotextile soil stabilization layer during the pumping action caused by traffic loads.

Even if the subgrade is not anticipated to be saturated based on available data, if the subgrade is silty or clayey and it is anticipated that the geotextile will be installed during prolonged wet weather, a soil stabilization geotextile may still be needed.

Soil stabilization geotextile should not be used for roadway fills greater than 5 feet high or when extremely soft and wet silt, clay, or peat is anticipated at the subgrade level (for example, the deposits encountered in wetlands). In such cases, the reinforcement function becomes more dominant, requiring a site-specific design.

(4) Permanent Erosion Control: Moderate and High Survivability

The primary function of geotextile used for permanent erosion control is to protect the soil beneath it from erosion due to water flowing over the protected soil.

The need for a permanent erosion control geotextile depends on the type and magnitude of water flow over the soil being considered for protection, the soil type in terms of its erodability, and the type and amount of vegetative cover present (see the *Highway Runoff Manual*).

The source of flowing water could be streams, constructed channels, wave action, or runoff. Water may also flow from the soil behind the geotextile depending on the groundwater level.

If groundwater cannot escape through the geotextile, an erosion control system failure termed *ballooning* (resulting from water pressure buildup behind the geotextile) or soil piping could occur. Therefore, the geotextile must have good filtration characteristics.

Three classes of permanent erosion control geotextile are available to approximately match geotextile filtration characteristics to the soil. In order to select the drainage geotextile class, determine the gradation of the soil, specifically the percent by weight passing the #200 sieve. Base selection of the appropriate class of geotextile on Exhibit 630-1.

A minimal amount of soil sampling and testing is needed to determine the geotextile class required. Permanent erosion control geotextile generally does not extend along the roadway alignment for significant distances as does underground drainage geotextile. One soil sample per permanent erosion control location is sufficient. If multiple erosion control locations are anticipated along a roadway alignment, soil sampling requirements for underground drainage can be applied.

If soil conditions vary widely along the alignment where permanent erosion control geotextile is anticipated, different classes of erosion control geotextile may be required for specific sections of a continuous system.

Examples of the permanent erosion control application are the placement of geotextile beneath riprap or gabions along drainage channels, shorelines, and waterways; around bridge piers; and under slope protection for highway cut or fill slopes.

If a moderate survivability geotextile is to be used, the geotextile must be protected by a 12-inch aggregate cushion and be placed on slopes of 2H:1V or flatter to keep installation stresses to a relatively low level. Large stones can cause significant damage to a moderate survivability geotextile if the geotextile is not protected in this manner. If these conditions are not met, then a high survivability erosion control geotextile must be used.

(5) Ditch Lining

The primary function of the geotextile in a ditch lining application is to protect the soil beneath it from erosion. This ditch lining application is limited to constructed ditches less than 16 feet wide at the top with side slopes of 2H:1V or flatter. If the ditch does not meet these requirements, then permanent erosion control, with moderate or high survivability geotextile, must be used. It is assumed that only quarry spall-sized stones or smaller will be placed on the geotextile, so only a moderate survivability geotextile will be required.

Filtration is not a significant function in this application. Since the ditch is relatively shallow, it is expected that the main water source will be the water carried by the ditch, and little water will pass through the geotextile.

Another application with a similar geotextile function is the placement of geotextile below culvert outlets to prevent erosion at the outlet.

(6) Temporary Silt Fence

The primary function of geotextile used in a temporary silt fence is to prevent eroded material from being transported away from the construction site by runoff water. The silt fence acts primarily as a temporary dam and secondarily as a filter.

In some cases, depending on the topography, the silt fence may also function as a barrier to direct flow to low areas at the bottom of swales where the water can be collected and temporarily ponded. It is desirable to avoid the barrier function as much as possible, as silt fences are best suited to intercepting sheet flow rather than the concentrated flows that would occur in swales or intermittent drainage channels.

To function as intended, the silt fence should have a low enough permeability to allow the water to be temporarily retained behind the fence, allowing suspended soil particles in the water to settle to the ground. If the retention time is too long, or if the flow rate of water is too high, the silt fence could be overtopped, thus allowing silt-laden water to escape. Therefore, a minimal amount of water must be able to flow through the fence at all times.

Temporary water ponding is considered the primary method of silt removal and the filtration capabilities of the fence are the second line of defense. However, removal of silt-sized particles from the water directly by the geotextile creates severe filtration conditions for the geotextile, forcing the geotextile to either blind or allow the fines to

pipe through the geotextile. (*Blinding* is the coating of the geotextile surface with soil particles such that the openings are effectively plugged.) If the geotextile openings (AOS) are designed to be small enough to capture most of the suspended soil particles, the geotextile will likely blind, reducing the permeability enough to allow water to overtop the fence. Therefore, it is best to allow some geotextile openings that are large enough to allow the silt-sized particles to easily pass through. Even if some silt particles pass through the fence, the water flow rate below the fence will be decreased and the volume of silt-laden water passing through the geotextile is likely to be relatively small and the water is partially filtered.

The geotextile apparent opening size (AOS) and permittivity are typically used to specify the filtration performance of geotextiles. The geotextile function in silt fence applications is more complex than this and AOS and permittivity do not relate directly to how well a silt fence will perform. However, nominal values of AOS and permittivity can be specified such that the types of geotextile products known to perform satisfactorily in this application are selected. These values are provided in the *Standard Specifications*.

The source of load on the geotextile is from silt buildup at the fence and water ponding. The amount of strength required to resist this load depends on whether or not the geotextile is supported with a wire or polymer grid mesh between the fence posts. Obviously, unsupported geotextile must have greater strength than supported geotextile. If the strength of the geotextile or its support system is inadequate, the silt fence could fail. Furthermore, unsupported geotextile must have enough stiffness that it does not deform excessively and allow silt-laden water to go over the top of the fence.

(a) **Need for Silt Fence**

The need for a silt fence can be anticipated where construction activities disturb and expose soil that could erode. The ground surface is considered disturbed if vegetative cover is at least partially removed over a significant area by construction activities. Consider whether or not silt-laden runoff water from the disturbed area can reach an environmentally sensitive area or a constructed stormwater system. If the exposed soil is a clean sand or gravel or if a significant zone of heavy vegetative cover separates the exposed soil from the environmentally sensitive area, a silt fence may not even be needed. Contact the Headquarters (HQ) Hydraulics Section for help in determining whether or not a silt fence is needed in such situations.

(b) **Feasibility of Silt Fence**

The feasibility of a geotextile silt fence depends on the magnitude of water flow to the fence, the steepness of the slope behind the fence ,and whether or not flow is concentrated at the fence. If the silt fence is not feasible, alternative erosion control methods may be needed (see the *Temporary Erosion and Sediment Control Manual*).

Consider all feasible erosion control options in terms of potential effectiveness and economy before making the final decision to use a silt fence. Select the best option for the site conditions, including site geometry and contours, soil type, and rainfall potential. Consider silt fences for temporary erosion control in disturbed areas in the following circumstances:

- Fully covering disturbed areas temporarily with polyethylene sheeting or other temporary covering is not feasible or practical.

- Permanent ground cover for disturbed areas is not yet established.
- Runoff water reaches the silt fence primarily as sheet flow rather than as concentrated flows, with the exception of some ditch and swale applications.
- Slopes above the silt fence are not steeper than 1.5H:1V.
- The sheet flow length (length of slope contributing runoff water to the silt fence) is not too long.

(c) Sheet Flow Length

Maximum sheet flow lengths allowed for silt fences are provided in Exhibit 630-2, which is based on the typical 2-year, 24-hour design storm for Washington, resulting in a 24-hour rainfall of 3 inches.

Slope	Sheet Flow Length
1.5H:1V	100 ft
2H:1V	115 ft
4H:1V	150 ft
6H:1V	200 ft

Maximum Sheet Flow Lengths for Silt Fences
Exhibit 630-2

The sheet flow length represents the area contributing runoff water from precipitation. The sheet flow length is defined in Exhibit 630-8. The sheet flow lengths provided in Exhibit 630-2 were determined assuming a bare soil condition, with the soil classified as a silt. These are worst-case assumptions because less runoff would be expected for sand or gravel soils or when some vegetation is present.

The sheet flow length is usually equal to or greater than the disturbed soil slope length. However, undisturbed sloping ground above the disturbed slope area may also contribute runoff to the silt fence area. The length of undisturbed sloping ground above the disturbed slope to be included in the total contributing slope length depends on the amount and type of vegetation present, the slope steepness, and the degree of development above the slope.

If unsure whether the proposed silt fence meets the requirements in Exhibit 630-2, contact the HQ Hydraulics Section for assistance.

Average or Ditch Swale Grade	Ditch or Swale Storage Length	Allowable Contributing Area per Foot of Ditch or Swale Storage Width
16%	13 ft	200 ft^2
10%	20 ft	250 ft^2
5%	40 ft	300 ft^2
4%	50 ft	400 ft^2
3%	65 ft	500 ft^2
2%	100 ft	600 ft^2
1%	200 ft	1000 ft^2

Maximum Contributing Area for Ditch and Swale Applications
Exhibit 630-3

(d) **Temporary Silt Fence**

Temporary silt fences may also be used in ditch or swale applications. If the area contributing runoff to the fence exceeds the value determined from Exhibit 630-3, hydraulic overload will occur. The ditch or swale storage length and width are defined in Exhibit 630-9. The assumptions used in the development of Exhibit 630-3 are the same as those used for Exhibit 630-2 in terms of the design storm and ground conditions.

As an example, if a site has a 13-foot-wide ditch with an average slope of 2%, the fence can be located such that 7800 ft^2 of area drain to it. If it appears that the area draining to the fence will be larger than the allowable, it may be possible to divide the contributing area into smaller areas and add a silt fence for each smaller area as shown in Exhibit 630-10.

The minimum storage length for the ditch behind each silt fence must be maintained. If this is not possible, it may be necessary to use an alternate erosion control structure, as described in the *Temporary Erosion and Sediment Control Manual*, or develop a special silt fence design.

Exhibit 630-3 was developed with the assumption that water will be able to pond to a depth of at least 2 feet behind the fence. If this is not the case (the ditch or swale depth is less than 2 feet), the table cannot be used. Furthermore, the ditch depth must be greater than the height of the silt fence at its lowest point within the ditch. Otherwise, there will not be enough storage available behind the fence and water will circumvent the fence by flowing around it.

(e) **Locating a Silt Fence**

Locate silt fences on contour as much as possible. At the ends of the fence, turn it up hill such that it captures the runoff water and prevents water from flowing around the end of the fence. This is illustrated in Exhibit 630-11.

Silt fences are designed to capture up to a 2-foot depth of water behind the fence. Therefore, the ground line at the ends of the fence must be at least 2 feet above the ground line at the lowest part of the fence. This 2-foot requirement applies to ditches as well as to general slope erosion control.

If the fence must cross contours (except for the ends of the fence), use gravel check dams placed perpendicular to the back of the fence to minimize concentrated flow and erosion along the back of the fence (see Exhibit 630-12).

- The gravel check dams are approximately 1 foot high at the back of the fence and are continued perpendicular to the fence at the same elevation until the top of the dam intercepts the ground surface behind the fence.
- Locate the gravel check dams every 10 feet along the fence.
- In general, the slope of the fence line is not to be steeper than 3H:1V.
- For the gravel check dams, use Crushed Surfacing Base Course, Gravel Backfill for Walls, or Permeable Ballast (see the *Standard Specifications*).

If the silt fence application is considered critical (such as when the fence is placed immediately adjacent to environmentally sensitive areas like streams, lakes, or wetlands), place a second silt fence below the first silt fence to capture any silt that passes through the first fence and/or place straw bales behind the silt fence. Locate silt fences at least 7 feet from an environmentally sensitive area.

Where this is impossible, and a silt fence must be used, a special design may be necessary.

Temporary silt fences are sometimes used to completely encircle underground drainage inlets or other similar features to prevent silt from entering the drainage system. This is acceptable, but the silt fence functions primarily as a barrier, and not as a ponding or filtering mechanism, unless the drainage inlet is in a depression that is large enough to allow water to pond behind the silt fence.

- If the drainage inlet and silt fence are not in a large enough depression, silt-laden water will simply be directed around the fence and must be captured by another fence or sedimentation pond downslope.
- If the depression is deep, locate the silt fence no more than 2 feet below the top of the depression to prevent overtopping. A site-specific design may be needed if the silt fence is located deeper than 2 feet within the depression.

It may be necessary to relocate silt fences during the course of a construction project as cuts and fills are built or as disturbed areas change. An erosion control/silt fence plan that accounts for the anticipated construction stages (and eventual removal) should be developed. Do not assume that one silt fence location can routinely be used for the entire life of the contract. Periodically check the locations in the field during the construction project, and field-adjust the silt fence locations as necessary to ensure the silt fences function as intended.

(7) Standard Specification Geotextile Application Identification in the Contract Plans

Identify the geotextile in the contract plan detail in a way that ties it to the appropriate application in the *Standard Specifications*. For example:

- If a geotextile is to be used to line an underground trench drain 3 feet deep and the native soil has less than 15% passing the #200 sieve, identify the geotextile on the plan sheet as "Construction Geotextile for Underground Drainage, Low Survivability, Class A."
- If the geotextile is to be placed beneath riprap on a slope without a cushion layer between the geotextile and the riprap, and the native soil contains 35% passing the #200 sieve, identify the geotextile on the plan sheet as "Construction Geotextile for Permanent Erosion Control, High Survivability, Class B."
- If the geotextile is to be placed between the roadway base course and a moist silt subgrade with a resilient modulus of 6,500 psi, and the roadway is planned to be constructed during the dry summer and early fall months, identify the geotextile on the plan sheet as "Construction Geotextile for Separation."

(8) Site-Specific Designs (All Applications)

A site-specific design is required:

- For all reinforcement applications.
- For applications not covered by the *Standard Specifications*.

Consider a site-specific design for:

- High-risk applications.
- Exceptionally large geotextile projects: if the geotextile quantity in a single application is over 35,000 yd^2 or over 85,000 yd^2 for the separation application.
- Severe or unusual soil or groundwater conditions.

- Soil in the vicinity of the proposed geotextile location that consists of alternate thin layers of silt or clay with potentially water-bearing sand layers on the order of 1 to 3 inches thick or less.
- Soil known through past experience to be problematic for geosynthetic drains.
- Drains in native soil behind structures except drains contained within granular backfill.
- Drains designed to stabilize unstable slopes.
- Drains designed to mitigate frost heave.

In such cases, obtain assistance from the HQ Materials Laboratory, Geotechnical Office. To initiate the special design, provide a plan and cross section showing:

- The geosynthetic structure to be designed.
- The structure's relative location to other adjacent structures that it could potentially affect.
- The structure's intended purpose.
- Any soil data in the vicinity.

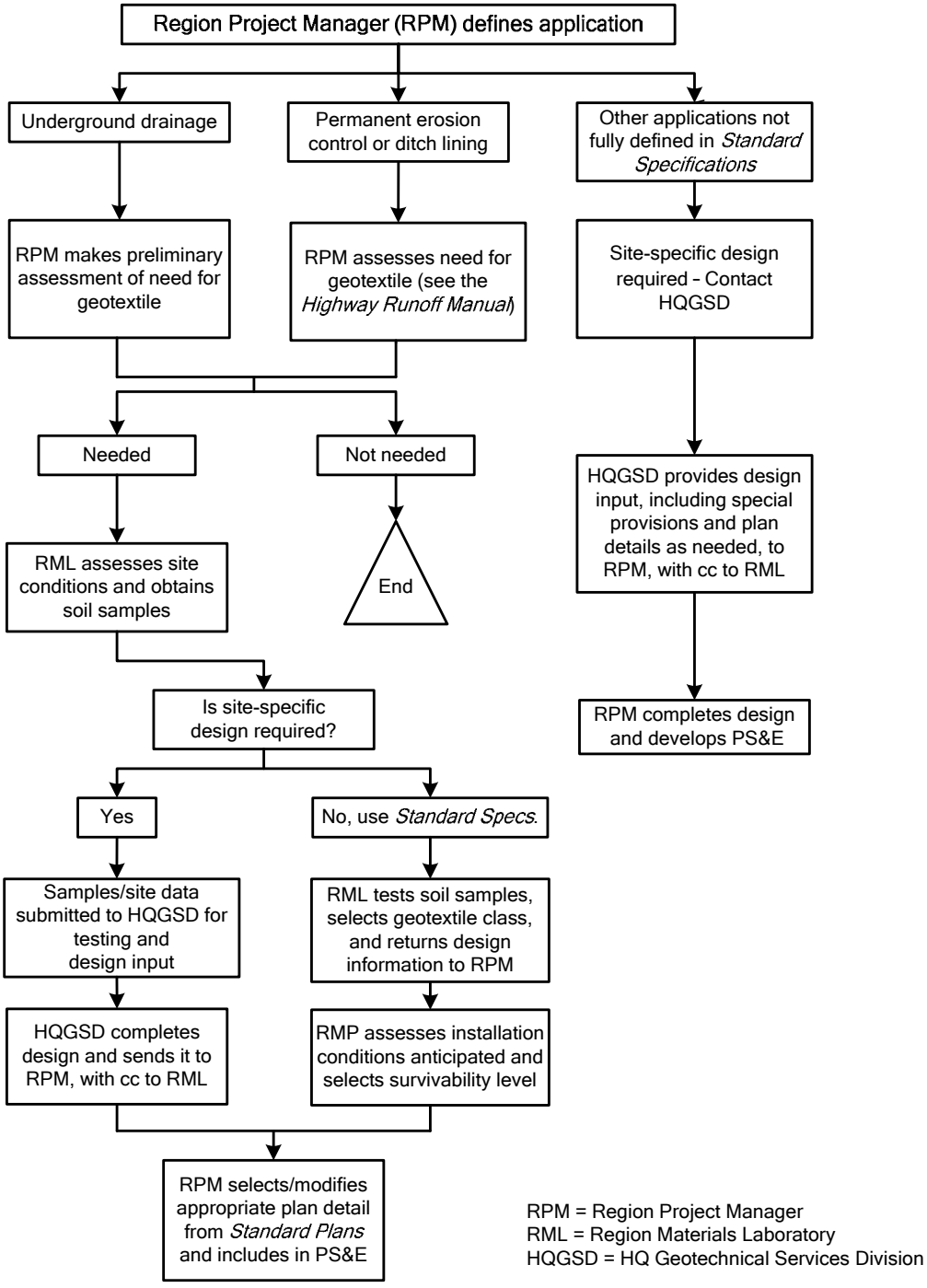
Consider a site-specific design for temporary silt fences:

- If silt fence must be used in intermittent streams or where a significant portion of the silt fence functions as a barrier that directs flow to the lower portions of the silt fence.
- If the fence must be located on steep slopes.
- In situations not meeting the requirements in Exhibits 630-2 and 630-3.
- If the 2-year, 24-hour design storm for the site is greater than the 3 inches assumed for the development of Exhibits 630-2 and 630-3.
- Where concentrated flow is anticipated.
- If closer than 7 feet from an environmentally sensitive area.
- If more than 2 feet of storage depth is needed.

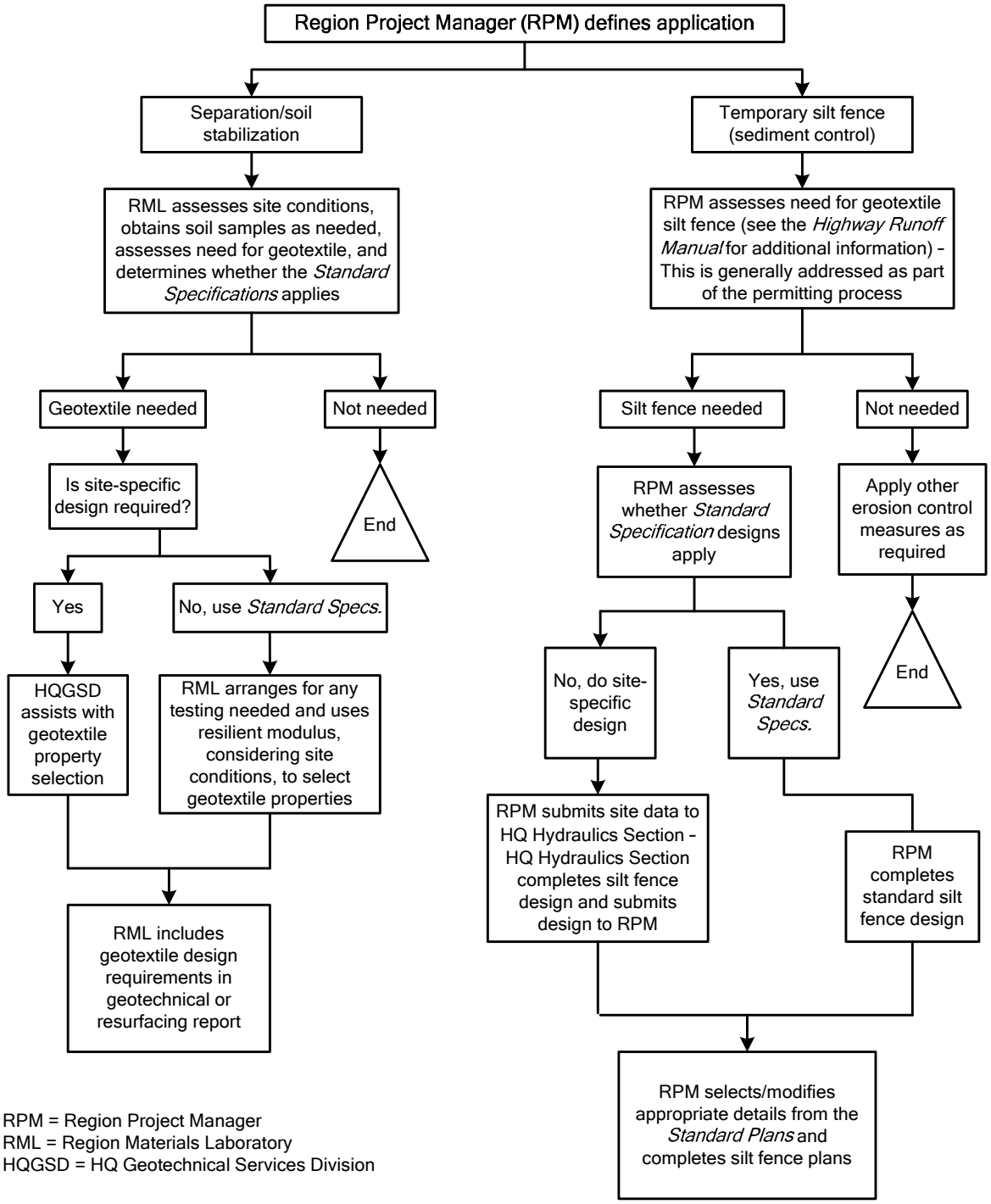
For a site-specific temporary silt fence design, obtain assistance from the HQ Hydraulics Section. To initiate the design, send the following information to the HQ Hydraulics Section and a copy to the HQ Materials Laboratory, Geotechnical Office:

- Plan sheets showing proposed silt fence locations and grading contours.
- Estimate of the area contributing runoff to each silt fence, including percentage and general type of vegetative cover within the contributing area.
- Any available site soil information.

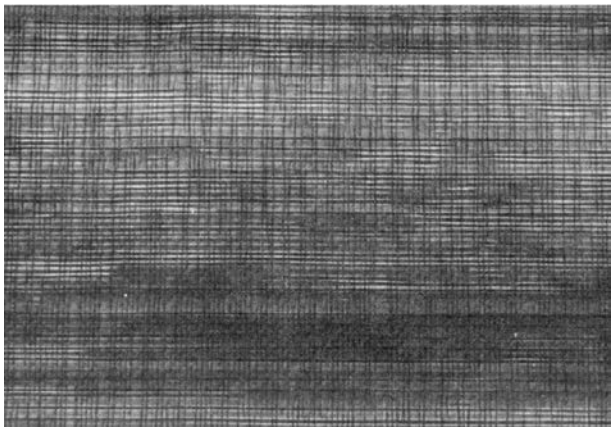
For all site-specific designs of applications not covered by the *Standard Specifications*, complete plans and special provisions are needed. In general, for site-specific designs of *Standard Specifications* applications, only a minor modification of the appropriate geotextile property table will be needed.



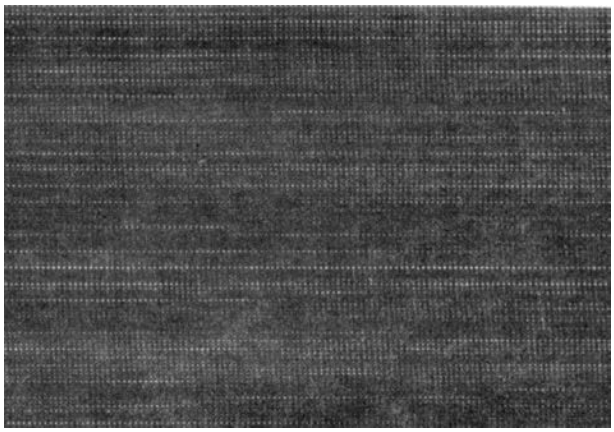
Design Process for Drainage and Erosion Control: Geotextiles and Nonstandard Applications
Exhibit 630-4



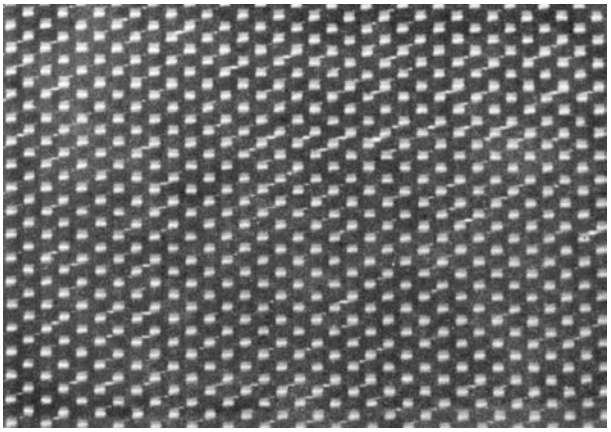
Design Process for Separation, Soil Stabilization, and Silt Fence
Exhibit 630-5



Slit Film Woven Geotextile



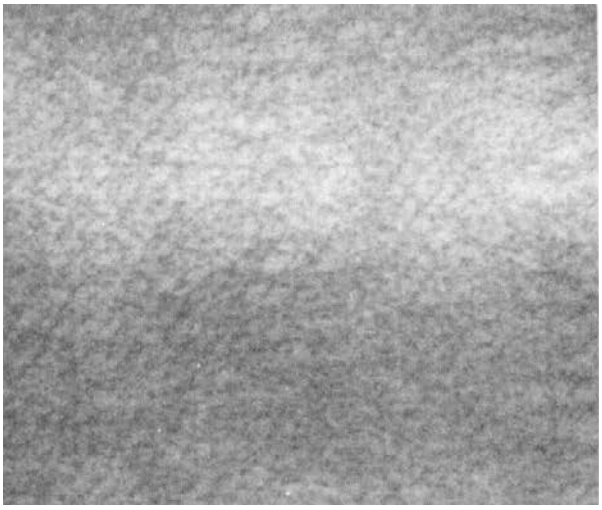
Monofilament Woven Geotextile



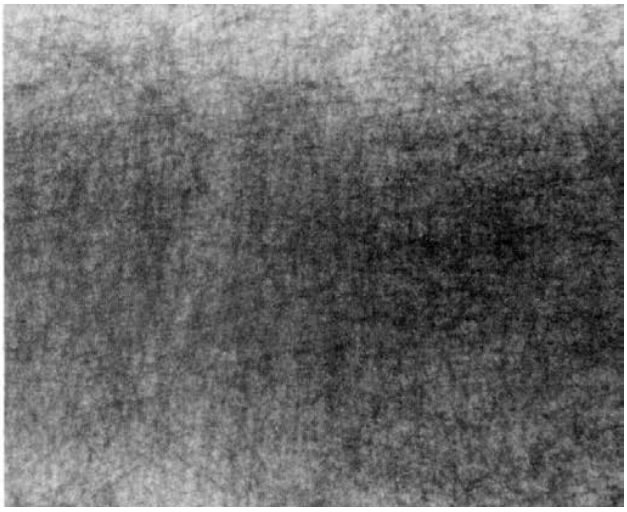
Multifilament Woven Geotextile

Examples of Various Geosynthetics

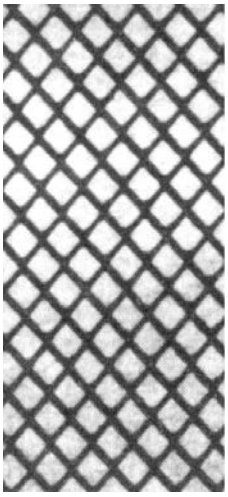
Exhibit 630-6

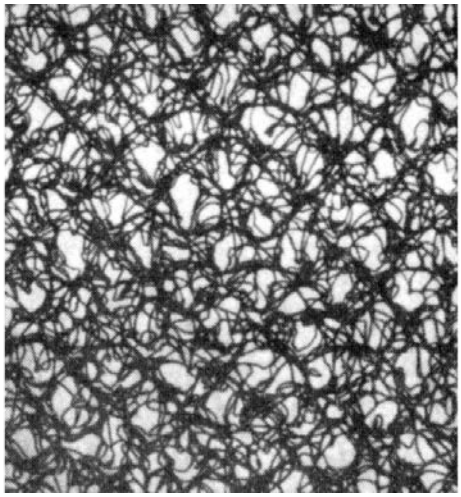


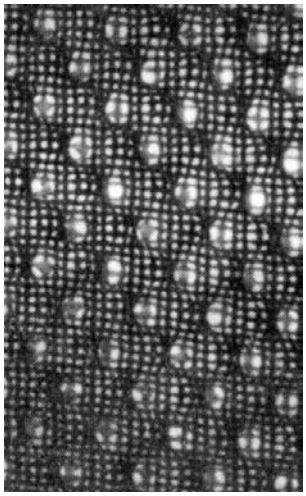
Needle-Punched Nonwoven Geotextile



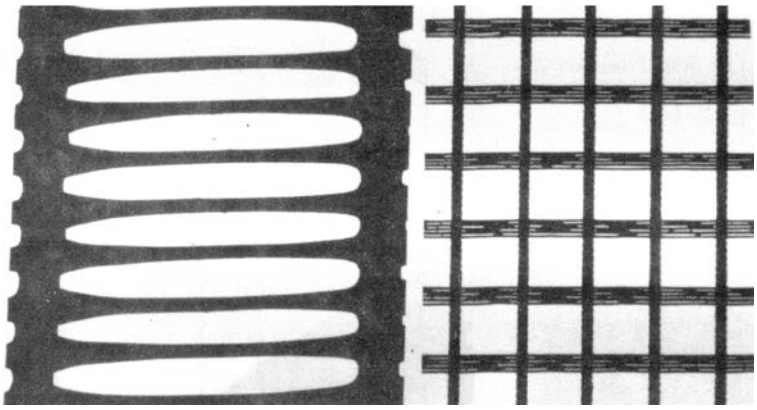
Heat-Bonded Nonwoven Geotextile







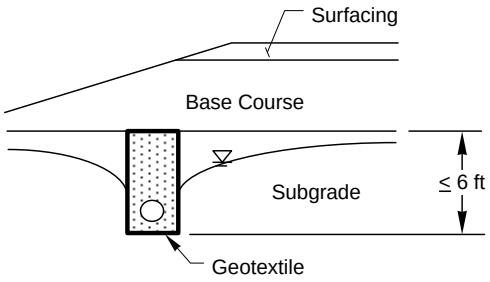
Geocomposite Drains (Geotextile With Core)



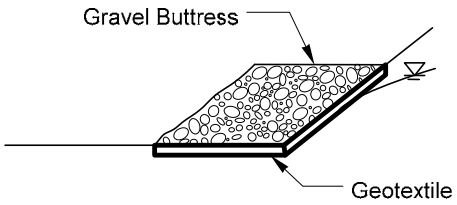
Extruded and Woven Geogrids

Examples of Various Geosynthetics

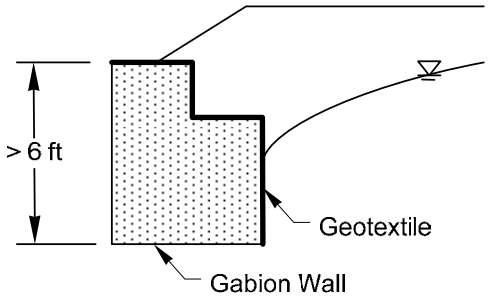
Exhibit 630-6 (continued)



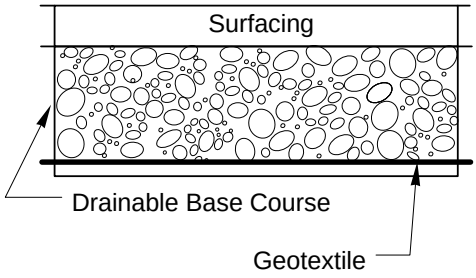
A. Underground Drainage:
Low Survivability
(Roadway Trench Drain)



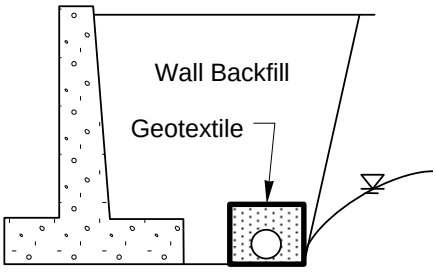
B. Underground Drainage:
Moderate Survivability
(Area Drain Beneath Buttress)



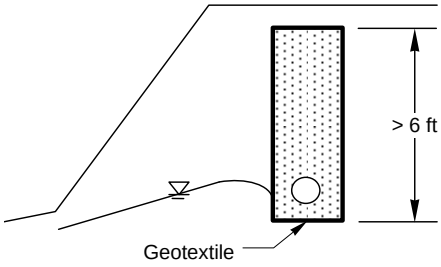
C. Underground Drainage:
Moderate Survivability
(Geotextile Sheet Drain)



D. Underground Drainage:
Moderate Survivability
(Area Drain Under Parking Lot or Roadway)

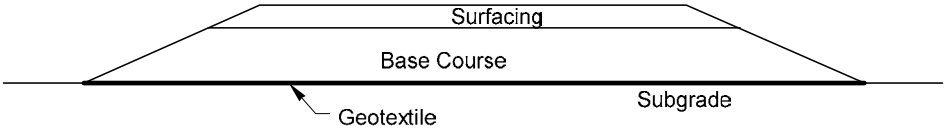


E. Underground Drainage:
Low Survivability
(Wrapped Drain Behind Foundation)

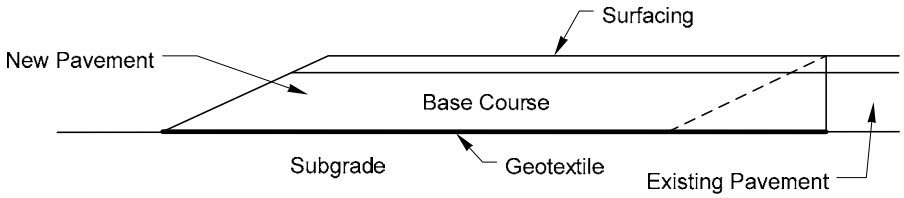


F. Underground Drainage:
Moderate Survivability
(Deep Trench Drain for Slope Stabilization)

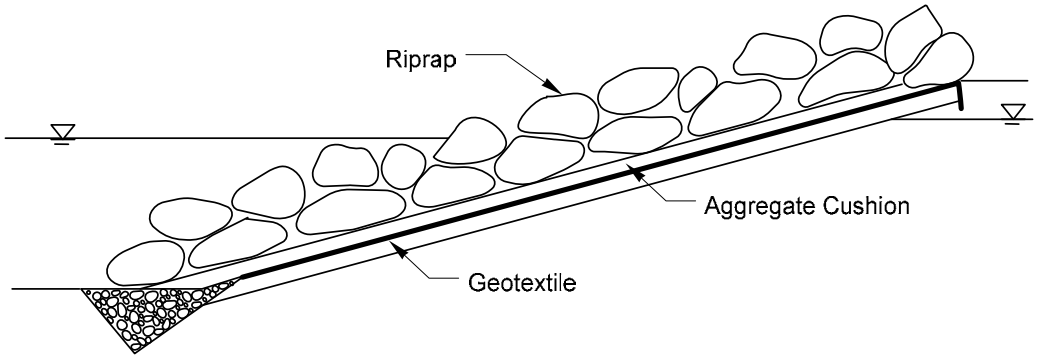
Geotextile Application Examples
Exhibit 630-7



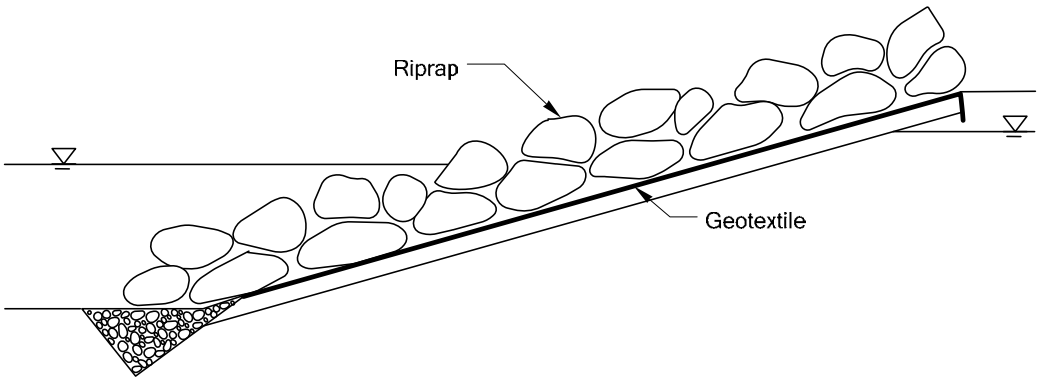
G. Separation or Soil Stabilization for New Roadway
(Depends on Subgrade Condition)



H. Separation or Soil Stabilization for Widened Roadway
(Depends on Subgrade Condition)



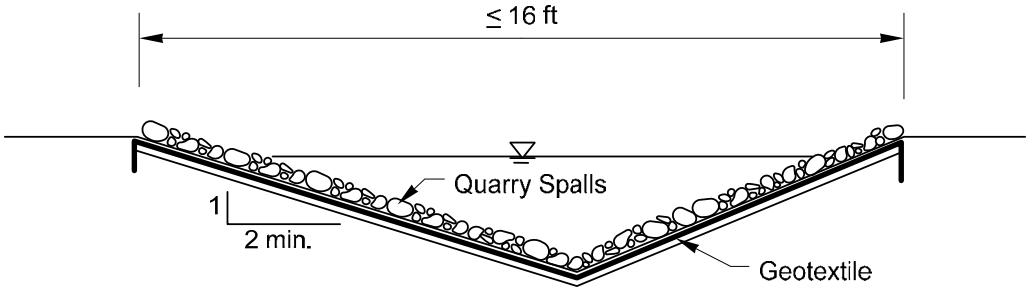
I. Permanent Erosion Control:
Moderate Survivability



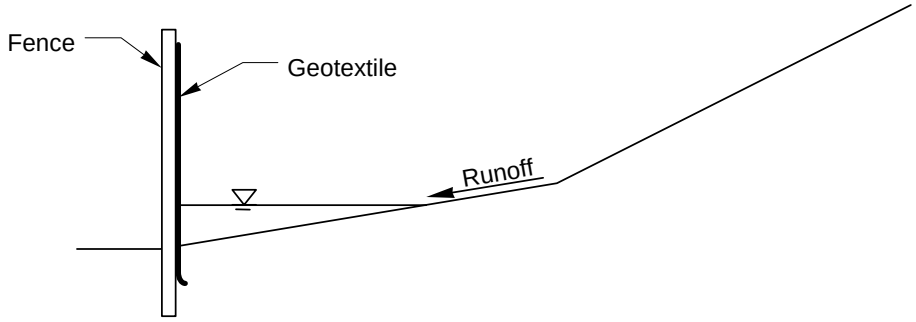
J. Permanent Erosion Control:
High Survivability

Geotextile Application Examples

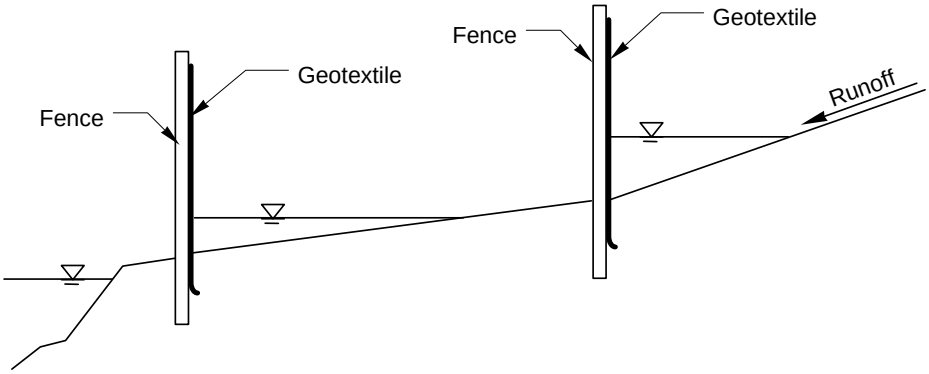
Exhibit 630-7 (continued)



K. Ditch Lining



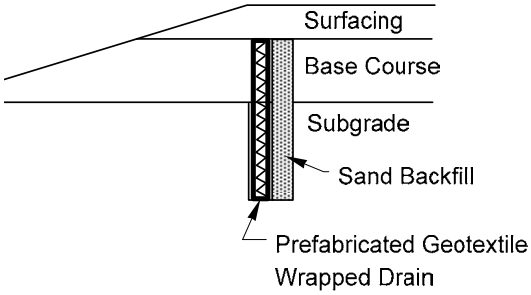
L. Silt Fence Not Immediately Adjacent to Environmentally Sensitive Area



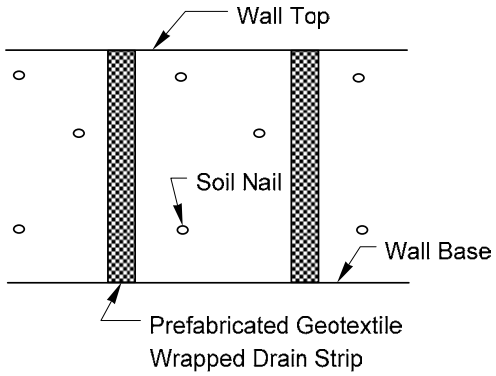
M. Silt Fence Immediately Adjacent to Environmentally Sensitive Area

Geotextile Application Examples

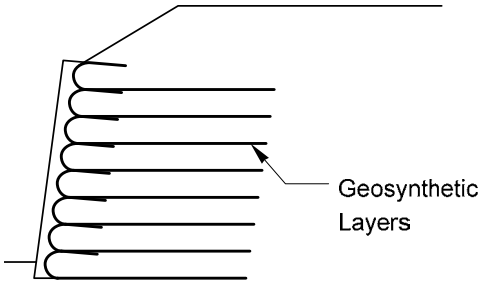
Exhibit 630-7 (continued)



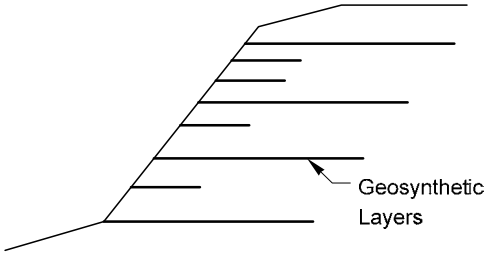
N. Prefabricated Edge Drain for Roadway



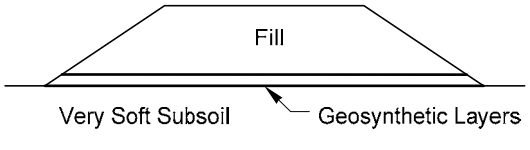
O. Prefabricated Drain Strip Behind Wall Face



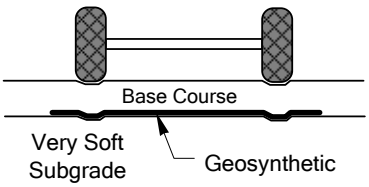
P. Geosynthetic Wall



Q. Geosynthetic Reinforced Slope



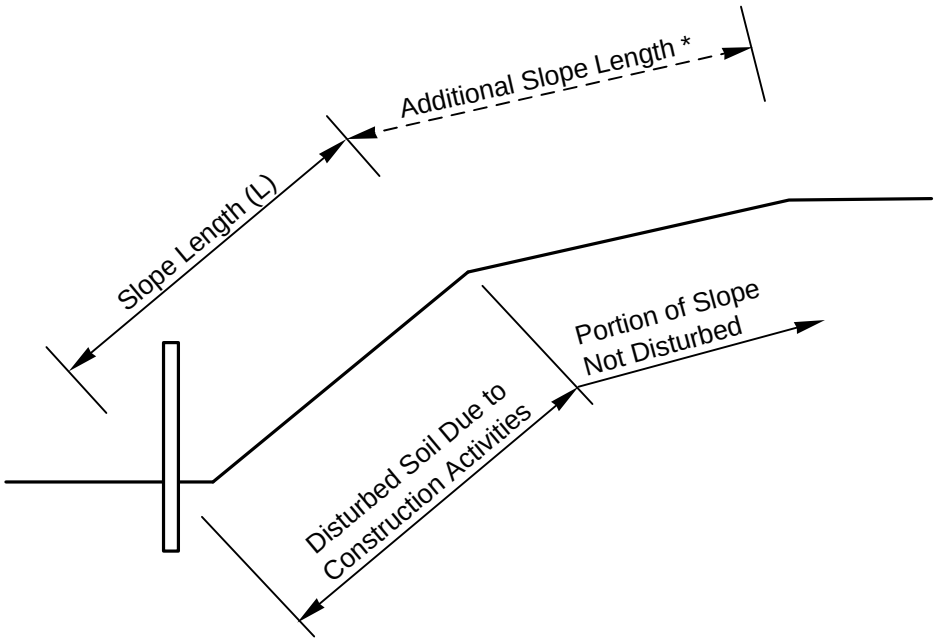
R. Geosynthetic Reinforced Embankment



S. Geosynthetic Subgrade Reinforcement for Temporary Roads

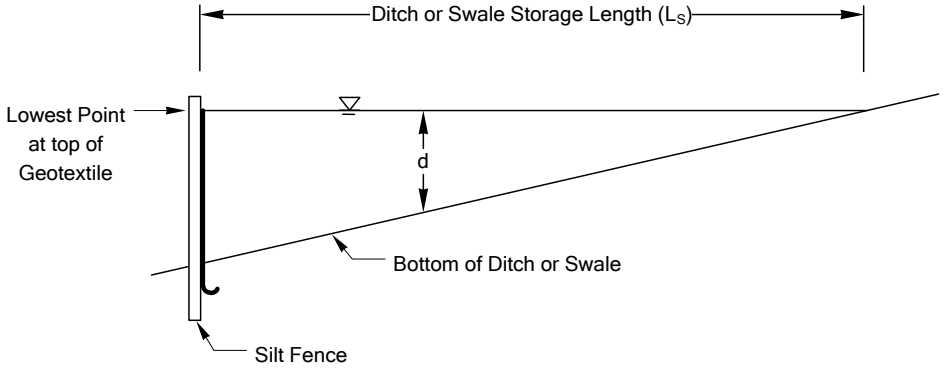
Geotextile Application Examples

Exhibit 630-7 (continued)

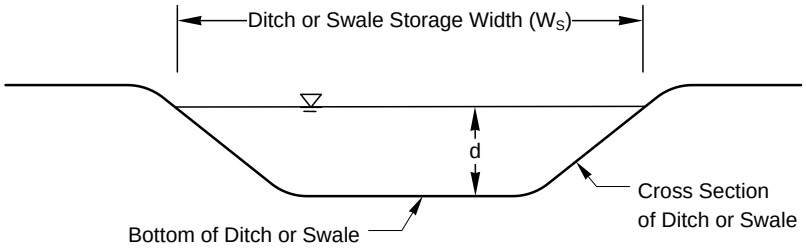


* May need to be included as part of slope length depending on vegetative cover, slope steepness, and degree of development above slope

Definition of Slope Length
Exhibit 630-8



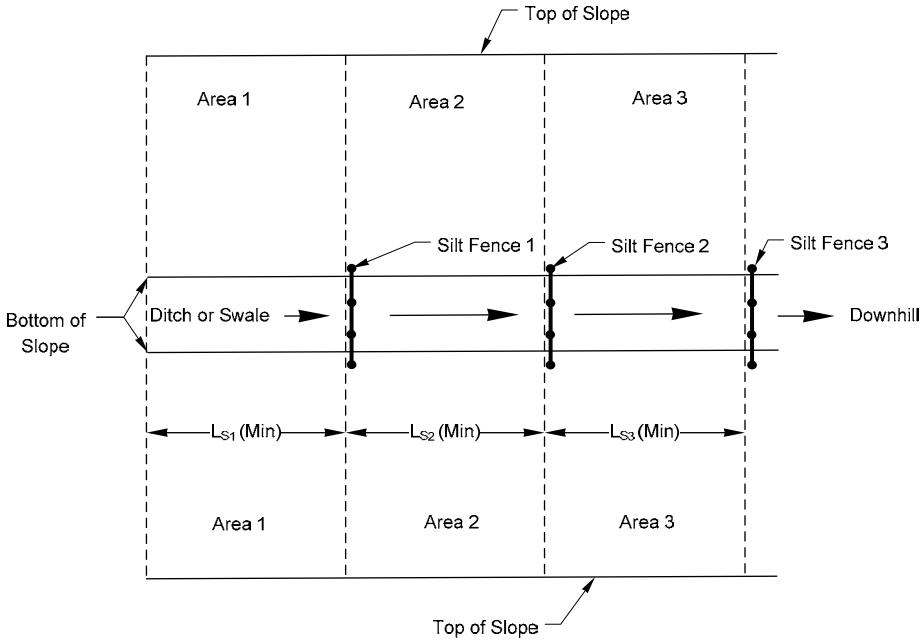
Storage Length



Storage Width

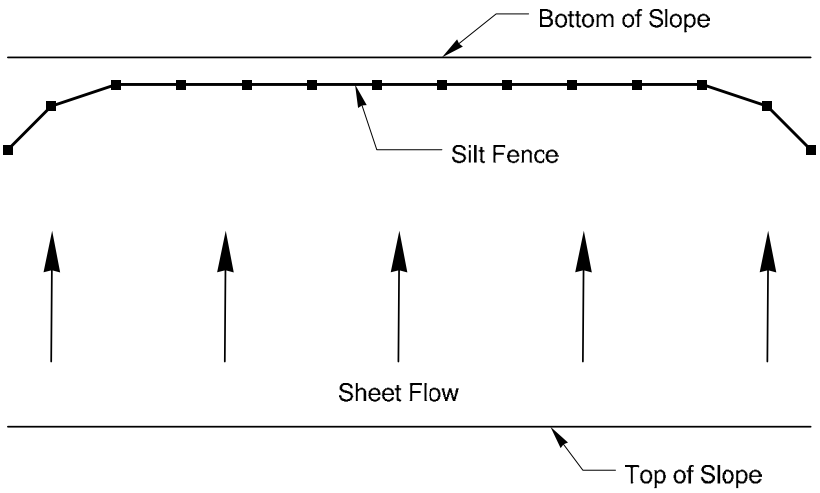
Definition of Ditch or Swale Storage Length and Width

Exhibit 630-9

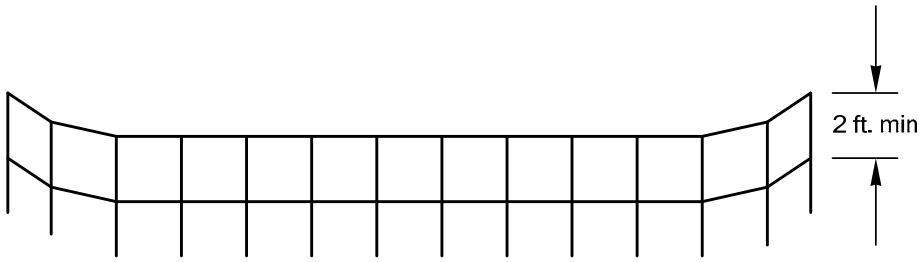


Method to keep contributing area to ditch or swale within allowable limits if contributing area is too large based on Exhibit 630-3.

Silt Fences for Large Contributing Area
Exhibit 630-10



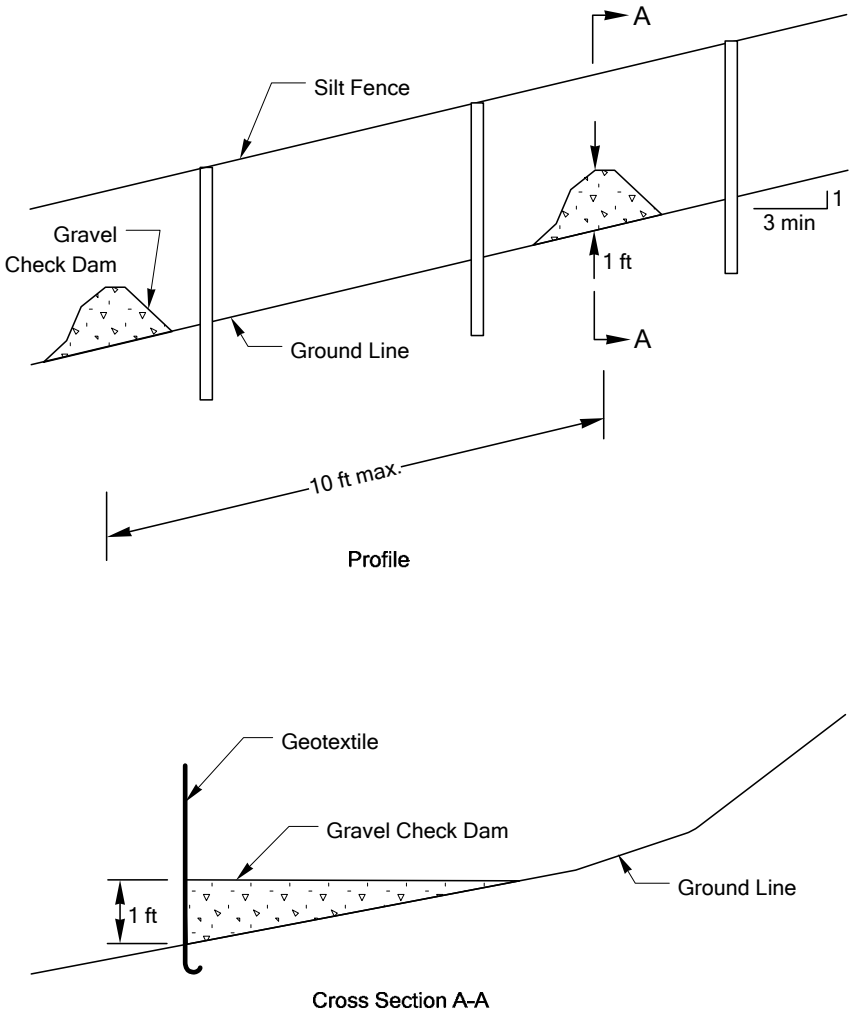
Silt Fence Plan



Silt Fence Profile

Silt fence plan and profile illustrating how silt fence will capture runoff water and not allow water to run around ends of fence.

Silt Fence End Treatment
Exhibit 630-11



Gravel Check Dams for Silt Fences
Exhibit 630-12