Section 3 System Options Based upon Vegetated Treatment Areas

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Contents

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Topics

- Common plant based treatment options
- Common systems involving VTAs

Purpose

VTSs will be considered by permitting authorities under the Voluntary Alternative Performance Standards of the ELG CAFO regulations. VTS application will be based upon the ability of a large CAFO to document that this alternative technology will meet or exceed the performance of baseline technologies (containment and land application). Chapter 3 reviews several systems utilizing a VTA or VIB as part of a system for managing runoff for their potential to be permitted under the CAFO regulations.

The work group that prepared this report determined that successful applications of a VTA to CAFOs requires:

- Systems providing multiple levels of treatment
- Passive or active management of release of liquids into a VTA
- Some level of short-term storage

These features are illustrated in six systems described in this report, four of which are believed to provide the greatest opportunity for success in large CAFO applications.

Common plant-based treatment options

Ikenberry and Mankin (2000) defined a vegetated filter as a band of planted or indigenous vegetation situated downslope of cropland or animal production facilities that provide localized erosion protection and contaminant reduction. Pasture, grassed waterways, or cropland (preferably with perennial vegetation) with planted or indigenous vegetation may be used to treat runoff through filtration, adsorption, settling, and infiltration.

The terminology VTS is used to refer to plant-based treatment systems (typically perennial grass or forage crops) intended to reduce environmental risk associated with runoff and other process waters from an open lot livestock system. These systems perform treatment functions including solids settling, soil infiltration, and filtering (soil biological and chemical treatment), thus, the term *treatment* is used as opposed to *filter*.

Several alternative types of plant based treatment components may be used in a VTS:

- *VTAs*—Perennial grass and forage filters can be applied to lower sloping land (sec. 6). Woody plants, trees, and annual forages may provide alternative plant materials for VTA, although, there is less experience with these plant materials. Total treatment area should be designed to match: (1) crop nitrogen uptake with estimated N in runoff or (2) volume of water runoff with soil infiltration capacity. Typically, the nutrient balance approach is the limiting design sizing method. Uniform flow across the vegetated slope is necessary, possibly requiring laser-guided land leveling equipment and other design considerations for distributing flow, as well as field maintenance to limit erosion and channeling.
- *Terraced VTAs* have been used to contain runoff on sloped areas. Both overflow and serpentine terraces have been used. Overflow terraces move runoff from one terrace to a second by cascading of runoff over the terrace top or by plastic tile drains. Serpentine terraces move runoff back and forth across the face of a slope. In both situations, the upper terrace is typically used for solids settling with succeeding terraces intended to encourage infiltration of liquids into the soil. Terraced systems are considered a sub-category of VTAs and may provide an optional approach for open lot systems located in steeper terrain.
- *VIBs* have many similarities to VTAs with the exception that they include sub-surface drainage and complete enclosure by a berm designed to prevent surface discharges (sec. 7). Runoff from an open lot is allowed to infiltrate through a soil system within 72 hours or less. Soil systems allow plant uptake of nutrients and water and soil chemical and biological properties for treatment of many pollutants. Systems generally use tile drainage to recover partially treated runoff, thereby, reducing ground water contamination. The collected drainage can be discharged to a VTA or other treatment system. Typically VIBs have used soil as the infiltration media. However, sand and organic matter beds, possibly without vegetation, can also be utilized to filter many contaminants in runoff.
- *Constructed wetlands* have been utilized to treat open lot runoff. Design and management is challenged by intermittent flow from open lots with resulting difficulty in maintaining wetlands function. Seasonal open lots used for winter livestock housing and empty during the summer may be a preferred system for constructed wetlands. Constructed wetlands are recognized as an alternative but are not discussed in detail in this publication. (For additional information on constructed wetland application to animal effluents, see Payne, 1992 and Gulf of Mexico Program, 1997.)

Most VTA systems rely on sedimentation for reducing pollutant concentration and infiltration to reduce runoff and pollutant mass. However, these systems typically are not designed to prevent discharge for all storm events. Extensive research has been conducted on solids and nutrient removal by VTA systems. Typically, VTAs remove 50 to 90 percent of most contaminants associated with runoff. With careful sizing of a VTA and controlled release of runoff, a VTA can eliminate most releases of contaminants.

Less research and field experience with VIBs is currently available. A 5-year study of a VIB on an Iowa State University feedlot has suggested removal of 70 to 90 percent of most contaminants from feedlot runoff prior to its collection of infiltrate by tile drain system.

The one exception to these reductions is with nitrate. In runoff, nitrate concentration is typically negligible. The aerobic environment in a VTA and VIB allows some conversion of ammonium to low concentrations of nitrate (commonly less than 10 ppm) during the treatment processes. Management of nitrate in the liquids released from a VTA and VIB will need to be considered. More detailed information on performance of VTAs and VIBs is presented in section 9, Literature Review.

Common VTS options

A VTS is a combination of treatment components, including plant-based treatment options and a management strategy. Assembling of an acceptable *system* is critical to minimizing environmental risk and obtaining a permit under the CAFO regulations. Permit requirements are more restrictive for VTS applications on large CAFOs than for small and medium CAFOs or unpermitted AFOs. Selecting an appropriate system for large CAFOs is the focus of this section.

The following discussion reviews six systems for their ability to minimize the potential for an unplanned release and to meet the CAFO requirements. Other options are possible including options that involve constructed wetlands. Ultimately, the opportunity for each option to be applied to a large CAFO will be based upon the site-specific performance comparison provided by the producer as part of the permit application. Thus, one limit on system options is the ability of the system to be modeled using weather data over a 25-year period.

All options will include pre-treatment by solids settling. Solids settling prior to a VTA or VIB is essential to sustaining performance within the vegetative area. Without solids settling, excess solids accumulation in the upper end of the VTA or VIB will lead to greater short circuiting of liquids, uneven distribution of nutrients, and loss of healthy vegetation.

Selecting the appropriate management strategy for controlling release of runoff is an important consideration for a successful system. The risk of a discharge from a VTA is significantly greater if feedlot runoff enters the VTA simultaneously with rainfall directly falling on the VTA. The infiltration rate of the soil can be overwhelmed with the two simultaneous sources of water. Delaying or limiting the release of runoff liquids until after the storm event reduces the potential of a discharge from a VTA. Three primary management strategies will be considered as part of the system:

- *Unrestricted runoff release.* The outlet of the settling basin is not restricted because of limited or no storage capacity in the settling basin. Runoff release is designed to match the peak flow rate of liquids into the settling basin when the basin is nearly full.
- *Passive runoff release control.* The outlet of the settling basin is restricted to delivering runoff slowly over a 36- to 72-hour period. The settling basin must be sized to handle a 25-year, 24-hour storm.

- *Active runoff release control.* The outlet of the settling basin can be physically controlled so that the manager determines the best timing for the release of basin liquids, presumably when the VTA soil conditions are most appropriate. This approach requires that the settling basin have sufficient capacity for normal runoff, as well as that necessary to handle a 25-year, 24-hour storm.

> Cost share assistance may be available for systems involving a VTA or VIB. The NRCS Environmental Quality Incentives Program (EQIP) and Conservation Innovation Grant programs provide competitive cost share assistance. Many State environmental agencies provide low interest rate loan programs to industry. Program guidance and technical assistance may also be available from the local NRCS office.

Option 1: VTA and solids settling

Our base system is a settling basin followed by a grass treatment area with modest storage in the system (fig. 3–1). Settling of solids is essential to the successful management of any VTS. The basin typically would be sized to hold runoff from a high intensity storm for a 1-hour period or less (sec. 5). The liquid level in the settling basin would be passively managed. Flow rate from the basin to the grass system is controlled by design of the outlet pipe(s). The manager would not have control over timing and release rate of runoff.

Following settling of most suspended manure solids and soil, runoff water would be distributed uniformly over a grass treatment area. Sizing of this system would be based upon either nutrient balance or water balance within the VTA. Potential alternative VTAs would include a constructed wetland or a terraced VTA.

Large CAFO application: Potential to discharge is high. Sizing of VTA is critical to minimizing treated releases from VTA. Model comparison of option 1 with baseline technology will provide final determination of potential for this option to be applied to large CAFOs.

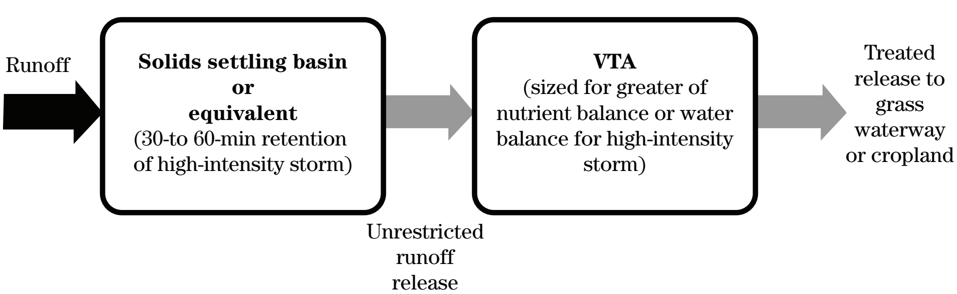
Small or medium CAFO application: Option 1 systems may reduce risk sufficiently to potentially prevent an AFO from being designated as a CAFO. The permitting authority should be consulted in any application of this system to AFOs that may have a direct connection to surface waters. This system alone may not be acceptable in all states or situations for cost share assistance from state or USDA conservation programs.

AFO application: For AFOs with sufficient distance or a lack of a direct connection to surface waters, the base system should be acceptable for most situations.

Advantages of option 1 system

- This system will eliminate some costs for land application of runoff from the open lot including management inputs for scheduling irrigation and equipment requirements for more expensive sprinkler irrigation system. However, a well-functioning VTA or VIB will require other critical management inputs (sec. 8), as well as similar levels of inputs associated with utilization of solids collected in the solids settling component.
- The cost of a settling basin component should be substantially less than the cost of a traditional storage basin.
- Because settling basins typically drain completely or with minimal retained volume, less potential for pollutant leaching (especially nitrate) to ground water and air emissions would be expected. In addition, abandonment of such facilities would likely present fewer costs and environmental challenges.

Figure 3–1 Option 1: VTA and solids settling



Disadvantages of option 1 system

- Treated discharges from this system are common, especially if size is not adequate. During major storms the grass treatment area will be receiving wastewater from the settling basin while saturated VTA conditions exist due to rainfall on the VTA. Open lot runoff events associated with frozen soil conditions would also produce potential conditions for runoff from the VTA. In many regions of the country, high-intensity rainfall events or extended wet periods during spring and summer produce the greatest potential for discharge.
- The footprint of a VTA will be greater than that of a runoff holding pond.
- Research has shown that small storms may not create sufficient flow to distribute the contaminated runoff over the VTA and will result in overloading of the VTA near the outlet from the settling basin.
- Grass systems tend to filter most solids and nutrients within the first 50 feet from the liquid inlet due to settling and contact with vegetation especially if solids settling is not included or undersized. This may contribute to high nutrient loads in the upper end of a VTA. Management considerations for monitoring and addressing nutrient loading issues are addressed in section 8.

Option 2: VTA replaced by VIB

Option 2 replaces the VTA with a VIB (fig. 3–2). No direct surface water discharge would result from this system for storm events up to a 25-year, 24-hour storm. Some discharge would be expected from the tile drain system of the VIB. The settling basin and VIB would provide better assurance of a consistent level of treatment (typically 90% or more of contaminant mass removal from feedlot runoff) even for major storm events or chronic wet periods. All runoff will infiltrate through 4 to 6 feet of soil prior to discharge.

The VIB also delays the start of the discharge to the grassed waterway or cropland for several hours and spreads the discharge out over a significantly longer time, thus reducing the chance that feedlot runoff will be discharged during the storm event.

Large CAFO application: Potential to discharge treated shallow ground water to surface water is high. The treatment efficiency of the VIB alone may not equal the performance of the baseline technology. Model comparison of Option 2 with baseline technology will provide final determination of potential for this option to be applied to large CAFOs.

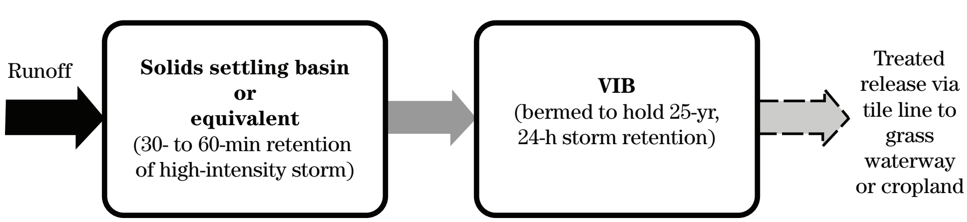
Small or medium CAFO application: This option should provide more consistent treatment than Option 1 and be applicable to many AFOs, preventing their definition or designation as a CAFO. The permitting authority should be consulted in any application of this system to AFOs that may have a direct connection to surface waters. The VIB may not be acceptable in all states or situations for cost share assistance from state or USDA conservation programs.

AFO application: For AFOs, option 2 should be acceptable for most situations.

Advantages of option 2 system

- This system should provide a more consistent level of pollutant reduction in all pollutants for a wide range of storm events, chronic wet periods, and frozen soil conditions.
- This system retains most of the advantages of Option 1 including low capital cost, low operation and maintenance cost for land application of runoff, minimal air quality concerns, and, if appropriate sites are selected for VIB, limited risk to ground water (see sec. 7 on VIBs).

Figure 3–2 Option 2: VTA replaced by VIB



Disadvantages of option 2 system

- Discharges from this system would be expected, but only after runoff has passed through settling basin and 4 to 6 feet of soil filtration.
- Ground water discharge from VIB will contain some pollutants, likely only 10 percent or less of the mass of pollutants in the original feedlot runoff. However, discharge from the VIB will still exceed concentrations acceptable for surface waters.
- Site-specific conditions will not allow VIBs to function in all soil conditions. Generally, a more restrictive soil layer is needed below the tile line within the VIB.

Option 3: Option 1 plus VIB

Option 1 has been enhanced with the addition of a VIB to the system (fig. 3–3). This approach is to ensure that no feedlot runoff is discharged from the system without first having three levels of treatment. In addition, no direct surface water discharge of runoff would be anticipated for storm events less than a 25-year, 24-hour storm due to the storage capacity in the VIB.

The VIB also delays the start of the discharge from the VIB to the VTA for several hours and spreads the discharge out over a significantly longer time (passive runoff release), thus reducing the opportunity for feedlot runoff to enter the VTA during the storm event.

Large CAFO application: Option 3 meets the ELG design size requirements of the CAFO ELG for baseline systems. It is attractive option for some large CAFOs because of its ability to minimize the risk of a discharge from the VTA plus provide substantial treatment for any releases that might occur. The permitting authority should be consulted early in the process to see if this system meets the requirements of the baseline ELG or will need to qualify under the voluntary alternative performance standards.

Small or medium CAFO application: Option 3 should be an acceptable option for many potential small or medium CAFOs. The permitting authority should be consulted in any application of option 3.

AFO application: Option 3 should be acceptable for all AFOs.

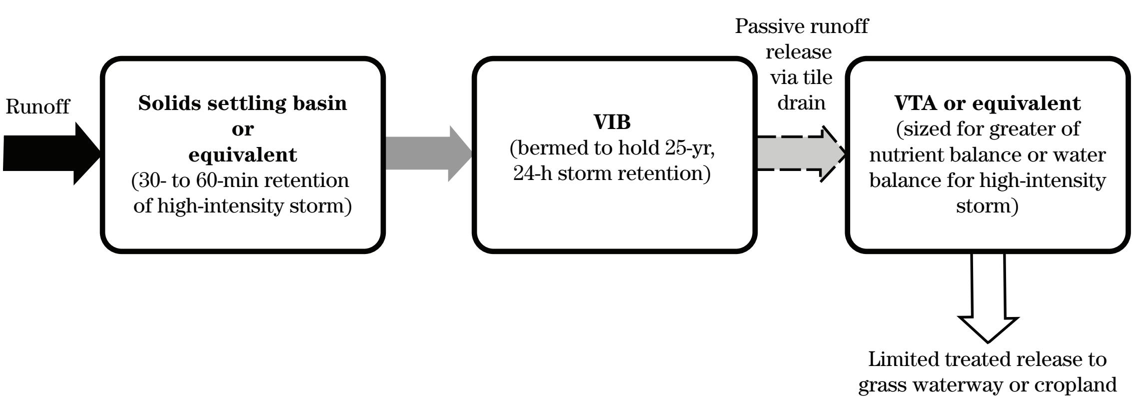
Advantages of option 3

- This system retains most of the advantages of option 1 including low operation and maintenance cost for land application of runoff, minimal air quality concerns, and limited risk to ground water if only appropriate sites are selected for VIB (see sec. 7 on VIBs).
- Potential for surface water discharges of feedlot runoff should be far less than with options 1 and 2 and equal to or less that potential for discharge from a baseline basin and irrigation system for many open lots.

Disadvantages of option 3

- The increased complexity of this system has likely eliminated some of the capital cost benefits of plant based treatment systems.
- Site-specific conditions will not allow VIBs to function in all soil conditions. Generally, a more restrictive soil layer is needed below the tile line within the VIB.

Figure 3–3 Option 3: Option 1 plus VIB



Option 4: Option 1 with storage included in settling basin

This system is similar to option 1, but design of the solid settling basin has two distinctive differences (fig. 3–4):

- Storage is included in the solids settling basin. Storage volume sized to meet the needs for a 25-year, 24-hour storm event and/or winter and early spring runoff could be included depending upon safety factor desired. The settling basin now has a volume of similar size to that of a standard runoff retention pond. However, this storage and settling basin may be a long, relatively shallow channel located down elevation from the bottom edge of the open lots for some systems as opposed to a rectangular pond.
- The outlet system for the settling basin allows the manager to control timing of runoff release to the VTA (active release control) or be carefully restricted to allow a release over a 36- to 72-hour period (passive release control).

Large CAFO application: Option 4 meets the ELG design size requirements of the CAFO ELG for baseline systems. It is attractive option for many large CAFOs because of its ability to minimize the risk of a discharge from the VTA. The permitting authority should be consulted early in the process to see if this system meets the requirements of the baseline ELG or will need to qualify under the voluntary alternative performance standards.

Small or medium CAFO application: Option 4 should be an acceptable option for many potential small or medium CAFOs. The permitting authority should be consulted in any application of option 4.

AFO application: Option 4 should be acceptable for most situations fitting this category.

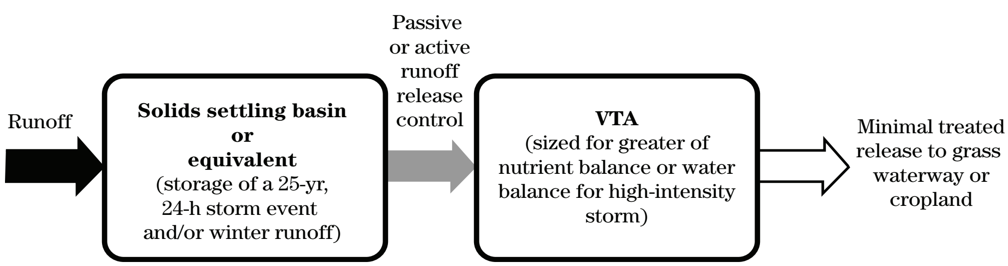
Advantages of option 4

- This system retains some of the advantages of option 1 including low operation and maintenance cost for land application of runoff (especially for a passive runoff release control) and minimal air quality concerns (passive runoff release control only).
- Storage in the settling basin will delay most (passive release control) or all (active release control) runoff addition to the VTA until the storm event has passed, minimizing discharges from the VTA during major or chronic storms or during frozen soil conditions.
- If sized correctly, the solids separation and storage basin could serve as a traditional storage basin if the VTA failed to perform as planned.

Disadvantages of option 4 (active release control)

- The size of the settling and storage basin will approach the size of the traditional storage basin and may have the same liner requirements and similar construction cost.
- The settling and storage basin will require a commitment to managing runoff release and maintenance of level gauges and records as required for traditional runoff control systems.
- The combination of settling and storage in the same structure has many management problems (difficulty with timely solids removal, damage to liner during solids removal, increased odors) and is typically not recommended for traditional systems.

Figure 3–4 Option 4: Option 1 with storage included in settling basin



Disadvantages of option 4 (passive release control)

- The size of the settling and storage basin will approach the size of the traditional storage basin.
- The settling and storage basin would require similar level gauges and records as required for traditional runoff control systems.
- The combination of settling and storage in the same structure has many management problems (difficulty with timely solids removal, damage to liner during solids removal, increased odors) and is typically not recommended for traditional systems.

Option 5: Option 1 with storage included in VTA

A partial or total berm around the VTA (similar to a VIB with no tile drainage) would be designed to minimize discharges from the system. The berm would need to create sufficient storage capacity for the open lot runoff, as well as the runoff from the settling basin and grass treatment area. Vegetation capable of withstanding occasional flooding would need to be selected.

Large CAFO application: Option 5 should minimize risk of discharge and improve the opportunity for this option to be approved under the ELG voluntary alternative performance standards. Ponding of effluent can create greater ground water risks causing concerns for state agencies that regulated ground water. The permitting authority should be consulted in any application of this system to a CAFO.

Small or medium CAFO application: Option 5 should be an acceptable option for most small or medium CAFOs. The permitting authority should be consulted in any application of option 5, especially where ground water issues are regulated.

AFO application: Option 5 should be acceptable for most situations fitting this category.

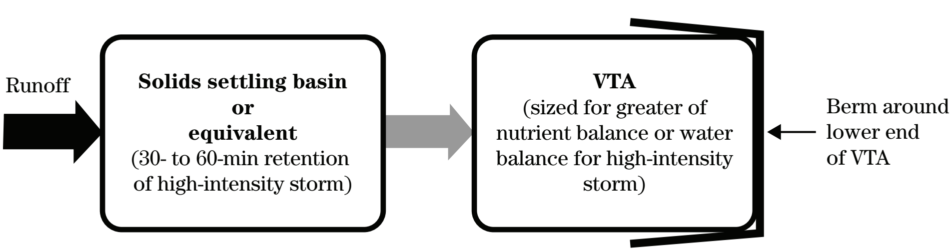
Advantages of option 5

- If the berm is sized properly for the 25-year, 24-hour storm, option 5 may meet the design size requirements of the ELG.
- This system retains most of the advantages of option 1 including low capital costs, low operation and maintenance cost for land application of runoff, and minimal air quality concerns.
- If the VTA has minimal slope, the storage within the VTA will provide improved distribution of the storm flows during major and chronic rainfall events.

Disadvantages of option 5

- Crop damage is possible if water due to ponding during major and chronic storms. Accumulated runoff during frozen soil conditions may also expose crop to submerged conditions for extended periods of time. During these periods, grass-based systems may become stressed, fail completely, or become displaced with undesirable species.
- The VTA may infiltrate runoff at times and rates that could lead to contamination of ground water (especially systems designed on a water balance as opposed to a nutrient balance).

Figure 3–5 Option 5: Option 1 with storage included in VTA



Option 6: Option 1 followed by storage basin

This system places the storage component after the VTA. It will also require a mechanical pumping and distribution system for transferring runoff back to the VTA. The active management of the irrigation of the VTA and the placement of the storage after the VTA should result in a truly *no-discharge* system.

Large CAFO application: Option 6 presents an additional alternative for most CAFOs that could meet all ELG requirements of the baseline technology. Nearly all risk of surface water discharge should be eliminated by this approach. The permitting authority should be consulted in any application of this system to a CAFO.

Small or medium CAFO application: Option 6 should be an acceptable option for most small or medium CAFOs. The permitting authority should be consulted in any application of option 6 to higher risk small and medium CAFOs.

AFO Application: Option 6 should be acceptable for most situations fitting this category.

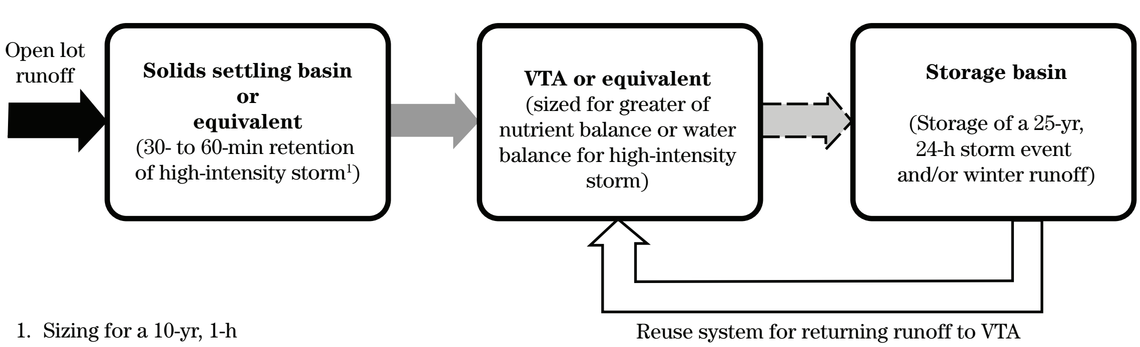
Advantages of option 6

- The system may be a true no-discharge system with advantages for surface water over the base system, as well as the traditional containment system. Option 6 meets the ELG design requirements of the CAFO regulations for beef and dairy systems and may not need to be permitted under the voluntary alternative performance standard.
- The treated wastewater stored in the storage basin will have little potential for odors or less potential for ground water contamination due to two stages of treatment before runoff is held in storage.

Disadvantages of option 6

- This system will have some significant cost and management time requirement associated with land application, possibly similar or greater than traditional systems.
- Remote power will be needed to recycle storage pond contents to VTA.
- The storage basin will have to be sized to store the effluent from the open lot, settling basin and the runoff from the VTA. This will require a larger storage basin than a traditional system.

Figure 3–6 Option 6: Option 1 followed by storage basin



1. Sizing for a 10-yr, 1-h storm may be preferable

Minimizing the potential to discharge

Two situations are commonly raised as having potential for producing a discharge from a VTS. First, during a storm event that last over an extended period, the runoff released from the solids settling into the VTA would coincide with precipitation falling on the VTA. The combination of feedlot runoff and direct precipitation could overwhelm the infiltration rate of the soil causing a potential discharge of diluted and partially treated feedlot runoff. Second, winter runoff events are a common concern, especially when soils are frozen.

To address the first situation when feedlot runoff and direct precipitation enter the VTA simultaneously, preferred system options will include significant storage in advance of the VTA (settling basin sized for a minimum 10-yr, 1-h storm or, preferably, a 25-yr, 24-h storm event) and either passive or active control of the settling basin release of liquid to the VTA (fig. 3–7). A VIB also slows the release of liquid into the VTA (similar to a passive runoff release) and extends the release over a much longer period of time, much of it after the storm event. A settling basin with an active runoff release can delay most runoff entry into the VTA until after the end of the storm events. Options 3 and 4 offer the preferred systems for controlling and delaying the runoff release into the VTA. Options 5 and 6 also minimize the risk of discharge by simply adding additional storage.

Winter runoff is typically associated with snowmelt or low-intensity rainfall events when the feedlot surface and VTA soils are frozen. The literature suggests that runoff associated with frozen soil conditions can be characterized as typically high in solids and low in volume. VTS options that include some storage should minimize a winter related runoff release into a VTA. System options 3, 4, 5, and 6 all include significant storage and may meet these criteria. A review of local weather records should provide additional insight as to a system's ability to store winter runoff. Comparing the precipitation related runoff for winter conditions with a settling basin capacity based upon a 10-year, 1-hour or 25-year, 24-hour storm event should provide some insight as to the need to release liquid into a VTA under frozen soil conditions.

A comparison for three sites in Nebraska (table 3–1) would suggest that the settling basin sized for a 25-year, 24-hour storm would be almost sufficient to handle all winter precipitation assuming 100 percent runoff and no release until spring. In reality, the average runoff of precipitation during December through March is less than 10 percent in Nebraska. A reasonable storage capacity of the settling basin or VIB in advance of a VTA should be able to minimize releases of liquid into a VTA under frozen soil conditions in Nebraska. A similar check for other sites should provide insight as the risk associated with frozen soil conditions.

If runoff must be release into the VTA under winter conditions, the sedimentation treatment role of a VTA is generally not restricted by dormant vegetation assuming that the VTA enters winter with thick vegetation. Some researchers have suggested thick matted vegetation in winter will equal or out-perform growing summer vegetation performance for encouraging settling. Fall VTA management is critical to achieving a desirable thick matted vegetation for winter treatment.

The infiltration treatment function of a VTA is lost if soils are frozen. Thus, all runoff would experience the normal reductions of solids and nutrients in the settling basin (about 50%) and VTA due to sedimentation (60 to 80%) for the few situations when runoff is released into a VTA when soil is frozen. However, frozen VTA soils create a significant potential for a discharge of the treated liquid runoff.

Thus, a VTS that includes some storage capacity and the ability to control release of runoff from the VIB or settling basin to the VTA should minimize the risk associated with these two more common higher risk situations.

Figure 3–7 Role of pre-treatment components of a vegetative treatment system (see options 3 and 4) for delaying and restricting flow in the VTA component

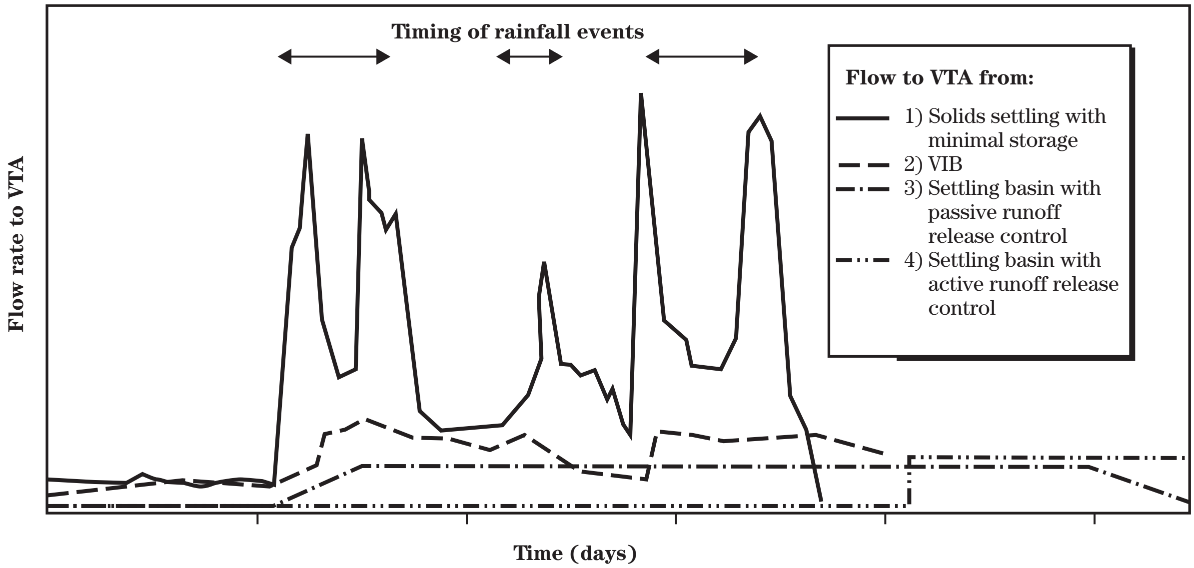


Table 3–1 Comparison of winter precipitation versus 25-yr, 24-h storm assuming settling basin was designed to contain such an event (references Soil Conservation Service 1992). Note settling basin capacity compares favorable to anticipated winter runoff.

	Eastern NE	Central NE	Western NE
Average winter runoff characteristics			
Precipitation (Dec – Mar)	4.4 in	3.6 in	2.6 in
Average runoff (Dec – Mar)	10%	<10%	<10%
Minimum settling basin capacity designed for:			
25-yr, 24-h storm	3.9 in	3.4 in	2.4 in
10-yr, 1-h storm	1.5 in	1.4 in	1.0 in

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