Voluntary Clean Water Guidance for Agriculture Chapters

A phased approach is being used to develop these guidelines. During the first phase an overview of the guidance was produced along with its initial chapter which examines tillage and residue management practices. Additional chapters not completed though anticipated for inclusion in the overall guidance are listed below. These chapters will be completed in the following several years. Producers who are interested water quality guidance related to practices not yet addressed can contact Ecology's Agriculture and **Water Quality Planner Ron Cummings at ron.cummings@ecy.wa.gov or (360) 407-6600.**

Chapter 1 Cropping Methods: Tillage & Residue Management-Completed (December 2022)

Chapter 2 Cropping Methods: Crop System-***In development***

Chapter 3 Nutrient Management-***In development***

Chapter 4 Pesticide Management-***In development***

Chapter 5 Sediment Control: Soil Stabilization & Sediment Capture (Vegetative) -***In development***

Chapter 6 Sediment Control: Soil Stabilization & Sediment Capture (Structural)-Completed (December 2022)

Chapter 7 Water Management: Irrigation Systems & Management-***In development***

Chapter 8 Water Management: Field Drainage & Drain Tile Management-***In development***

Chapter 9 Water Management-Stormwater Control & Diversion-***In development***

Chapter 10 Livestock Management-Pasture & Rangeland Grazing-Completed (December 2022)

Chapter 11 Livestock Management-Animal Confinement, Manure Handling & Storage-***Draft*** (June 2023)

Chapter 12 Riparian Areas & Surface Water Protection-Completed (December 2022)

Chapter 13 Suites of Recommended Practices-***In development***

This report is available on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2010008.html

Chapter 11

Livestock Management: Animal Confinement, Manure Handling & Storage

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Voluntary Clean Water Guidance for Agriculture

Prepared by:
Washington State Department of Ecology
Water Quality Program

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Recommendations for Livestock Management: Animal Confinement, Manure Handling & Storage to Protect Water Quality

The Voluntary Clean Water Guidance introduction[1] provides overall goals and objectives, as well as information on how the guidance will be used. Readers are encouraged to read the overall introduction before this chapter.

Introduction

Animal agriculture is an important industry in Washington that contributes significantly to the state's economy and food supply chain. According to the National Agricultural Statistics Services, animal agriculture sales accounted for over 25 percent of the nearly $10 billion in agricultural products sold in Washington. Beef cattle and dairy milk products sales were the leading livestock sectors each generating about $1.1 billion in sales and combining for over 80% of animal product sales (USDA-NASS, 2017). Beef and dairy cattle also account for nearly 90% of the state's livestock. For example, there were approximately 1.14 million head of cattle, 50,000 sheep, 30,000 goats and 50,000 horses in the state in 2020 (USDA-NASS, 2021). Beyond contributing to the state's economy, animal agriculture also supports local jobs and rural economies and provides for a quality of life valued by many. Washington's livestock industry is a valuable part of state's economy and heritage.

Whether to produce food and fiber or for personal enjoyment, most livestock owners will confine animals either temporarily or permanently at some point. For grazing-based operations, livestock are typically confined when there is limited forage and when the use of pastures is likely to damage forage and soil quality. Conversely, animal feeding operations are designed to confine and raise animals in pens or other facilities as a method to efficiently grow livestock and produce animal products. Animal confinement areas can range from smaller sacrifice areas used to temporarily confine animals to large feedlots. Nevertheless, any time animals are confined, there is a risk that accumulated manure and other waste can cause polluted runoff to enter surface waters or negatively affect groundwater. Proper design and maintenance of confinement areas and manure storage facilities is crucial to prevent potential negative impacts to water quality that can result from confining livestock.

This chapter focuses on BMPs to help prevent impacts to water quality from these types of areas. As such, this chapter provides recommendations on where to locate, construction, and set-up of sacrifice and confinement areas. The goal is to prevent pollution from leaving the site by locating confinement areas, and waste storage facilities appropriately, diverting clean water

[1] https://apps.ecology.wa.gov/publications/documents/2010008.pdf

around these areas and containing stormwater that is generated within these areas to prevent it from discharging to surface water.

Scope of Guidance

The purpose of this chapter is to outline BMPs, that when implement, will help prevent negative impacts to water quality from animal confinement areas, manure management facilities and other high traffic areas used by livestock. As such, this chapter provides recommendations on how to site, construct and implement animal confinement areas and waste storage facilities along with additional practices used to collect, store, stabilize, and eventually use accumulated animal waste.

The practices outlined in this chapter are primarily source control BMPs that are intended to prevent pollutants from coming into contact with water or are designed to capture polluted runoff. Further, these practices should be implemented in suites as their efficacy often requires that all components are functioning properly. Ultimately, the goal is to prevent pollution from leaving the site or entering groundwater by locating confinement areas and waste storage facilities appropriately, diverting clean water from these areas and properly containing stormwater and leachate. While the primary focus of these recommendations are to protect water quality, many of these practices also provide operational benefits and animal health benefits as well.

It’s understood that in-ground liquid manure storage lagoons are a commonly used practice in Washington. Given the technical complexities associated with manure storage lagoons, they will be addressed by a subsequent chapter.

This guidance applies to non-permitted operations.

Definitions as Used in this Document

Aerobic: A state of biological activity requiring oxygen.

Composting: An aerobic bacterial-driven process of stabilizing organic materials such as livestock manure.

Composting bedded pack: These are permanently covered facilities where livestock are housed. The manure and bedding material builds up in the housing area to a design depth and is periodically removed. The facility is managed in such a way that the solids content of the manure is high enough that it will not flow.

Decomposition: A biological process (i.e. composting) through which organic materials are reduced to simpler organic and inorganic components.

Ephemeral (surface water): Flow that typically has a short-lived presence, more common to arid settings.

Footing (HUA): Material typically sand, wood chips, gravel or concrete that supports livestock hoof pressure while preventing the formation of muddy conditions.

Groundwater: As opposed to surface water, groundwater is water that has infiltrated from the land surface and is retained in the soil or in pores and crevices in rock.

Heavy Use Area (HUA): A designated area for temporary livestock residency with the type of base footing material a key consideration and the area ideally managed in such a way as to provide for animal health and environmental protection.

Intermittent (surface water): Flow that occurs at irregular intervals as opposed to perennial flow which has a continuous presence.

Leachate: A liquid emanating from a material (i.e. manure pile) that carries dissolved and suspended components.

Manure: The combination of livestock urine and feces.

Pathogens: A disease-causing micro-organism such as a bacterium or virus.

Perennial (surface water): Flow that occurs continuously, though of varying levels.

Riparian Buffer: A vegetative strip, of varying width, adjacent to a surface water, that provides for water quality benefits through shading and runoff pollutant removal.

Vegetative Filter Strip (VFS): A vegetative area, typically grass, that is designed to receive runoff for the purpose of pollutant removal.

Recommendations

How animal confinement areas and associated waste are managed will inevitably vary given site specific factors, and operator goals and needs. Given the site-specific nature and potential complexities of animal and manure management, the system and design of the BMPs recommended by this chapter needs to be tailored to the specific operation being addressed. This guidance serves as a start, presenting the main considerations when planning manure management systems and heavy use areas/confinement areas; it is advised to consult with technical experts such as an agricultural systems engineer or a conservation planner to develop an operation-specific plan.

Function/Purpose

The BMPs outlined in this chapter are largely source control BMPs. Source control is achieved through the proper siting of confinement areas, waste storage facilities and other heavy use areas (e.g., off-stream water facilities, supplemental feeding areas and salt licks), diverting clean water around these areas, covering manure storage facilities, and capturing polluted runoff from these areas.[2] If implemented and maintained correctly, the purpose of these BMPs is to prevent the discharge of pollutants from these areas.

Animal Confinement Areas

Key Location, Design, Construction and Management Considerations

Key design considerations for the construction of a heavy use animal confinement area include:

- Site selection – considering aspects such as soils, slope, surrounding drainage and proximity to surface waters or conduits to surface waters.
- Stabilization of the area—determine the appropriate pad surface area and footing/bedding material.
- Stormwater and drainage management – diversion of clean water and capture and treatment of polluted runoff.
- Site operation and maintenance – particularly manure collection and management.

Site Selection

Confinement areas siting recommendations include:

- Confinement areas and other heavy use area sites should be located away from any surface water (perennial, intermittent, or ephemeral). Consistent with the Riparian Areas & Surface Water Protection recommendations (Chapter 12), confinement areas and other heavy use areas should be located outside the riparian management zone (at least 215-feet away from surface waters for western Washington locations and 150-feet away from surface waters for eastern Washington locations).[3]
- The site should be situated on high level ground, not in depressional areas where water collects.
- Avoid locations near conduits to surface waters such as swales, tile lines or other natural or artificial drainage ways that outlet to surface waters.
- Avoid areas with shallow groundwater.

[2] Though the focus is on source control BMPs there can be some treatment of pollutants by composting which can kill off pathogens in manure.

[3] It is recognized that this in some cases it may not be feasible to achieve that setback distance at all sites particularly those with established structures and small sites. Farmers and implementers are expected to follow a stepwise process when determining feasibility. Fully consider whether the recommended setback distance can be implemented at the site. If there are existing structures, can they be moved? Consider grant programs and other incentives that could help cover the cost of relocating structures. At a minimum HUAs should be located outside of the core zone. It is not acceptable to default straight to the minimum core width. Determine the maximum extent that the HUA can located away from the surface water. We would expect to see documentation of how the maximum setback distance was selected. Farmers and implementors should also explore additional engineered stormwater solutions to prevent discharges from heavy use areas if they are located in the RMZ. It may be necessary to provide a roofed structure over all or a portion of the HUA (see composted bedding pack barns below) to prevent the discharge of pollution.

- Avoid areas with high leaching potential.[4] Sites characterized by shallow soil, or a high water table, or a sandy/gravelly soil with excessive drainage and high permeability are poor or unsuitable for heavy use areas. Soil type should be considered as one of the most important criteria for site selection.
- Locate and design the confinement area such that it is outside the 100-year floodplain unless site restrictions require locating it within the floodplain. If located in the floodplain, protect the facility from inundation or damage from a 25-year flood event.
- If there is the potential for ground water contamination from the heavy use area, select another site or provide an impervious surface to reduce infiltration of pollutants.
- The surface of the heavy use area should be slightly sloped (<=2%) to direct any generated runoff to an adjacent vegetated filter strip (VFS) or other wastewater collection and treatment system. The VFS provides a relatively low maintenance yet effective pollutant runoff capture alternative for most applications and should be considered a component of the overall HUA system.
- There should be sufficient adjacent space to incorporate pad runoff treatment options such as a vegetative filter strip or settling/storage basin, in the case of larger scale operations. The site, including the VFS, should be situated on slopes less than 5%.
- Locate confinement areas near manure storage facilities to optimize operational efficiencies and allowing for its more frequent collection.

Pad Surface Area, Foundation and Surface Treatment

The HUA pad size is dependent on the type, number, and age of livestock it will accommodate and the period of that accommodation. Key considerations for establishing or rehabilitating a heavy use area are the selection of foundation and footing/bedding materials. Chief considerations include materials that will meet the anticipated loads and frequency of use, provide for appropriate animal health and support (i.e., hoof protection), provides for efficient drainage, has longevity, and allows for routine manure collection.

Because of the site-specific nature of these considerations Ecology recommends consulting a conservation district, NRCS or other farm planner to determine the appropriate foundation and footing materials and determine the overall HUA footprint.

- Ecology recommends implementing FOTG 561—Heavy Use Area Protection practice**.**

Drainage Considerations

A key to the long-term success of the HUA protection practice is the diversion of all significant sources of off-site water (stormwater BMPs will be covered in Chapter 9), providing slope to the

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[4] For existing livestock confinement areas on poor sites with high leaching potential, the best options for protecting groundwater could be eliminating the confinement area and switching to either housed confinement (e.g. bedded pack barns) of livestock or providing an impervious surface. Alternatively, the confinement area could be relocated to a more suitable location.

footing surface to promote on-site drainage preferably to an adjacent vegetative filter strip or basin, and the frequent removal of manure – daily is ideal. Careful consideration of all these factors will significantly reduce the production of muddy conditions.

Diversion of Clean Water

The potential for drainage from upgradient areas and adjacent structures should be considered when planning heavy use areas. Any drainage that could potentially enter the HUA from up-gradient locations and adjacent structures should be diverted. Minimizing on and off-site clean flows allows for the site's increased longevity while limiting the generation of contaminated runoff.

Adjacent barns and shelters, whether existing or planned, should have gutters and downspouts that capture and direct rooftop-generated runoff away from the heavy use area to either dedicated curtain drains (French drain) or to adjacent grass filter strips for infiltration.

Treatment of On-site Runoff

Runoff is generated when precipitation, as either rain or melting snow, is of sufficient intensity and/or longevity as to generate overland flow which, in this context, is likely to entrain manure, bedding, and waste feed. For smaller HUAs, runoff from the pad surface should be directed to an adjacent vegetated filter strip or vegetated treatment area for infiltration and pollutant attenuation. This grassy area around the outside of the heavy use area will provide for treatment of pad surface runoff reducing the potential off-site export of sediment, bacteria, and nutrients (N and P). Runoff should enter the VFS as uniform flow and not allowed to concentrate, a situation that significantly reduces its effectiveness. The width of the treatment area will vary depending on the HUA pad area (a surrogate of runoff generation), soil type, vegetation density (thickness of grass) and slope, among other factors. There are limitations to the amount of stormwater and associated pollutants a treatment area can address. Larger operations will likely need to use a stormwater basins to collect on-site runoff.

- Supporting NRCS Field Office Technical Guides: Filter Strip (390), Vegetated Treatment Area (635)

Operation and Maintenance

It's recommended that an operation and maintenance (O&M) plan be created to document both construction specifics and the long-term maintenance needs of the greater HUA. An important aspect of writing such a plan is the thought process; having constructed the site, what are the critical aspects for maintaining its long-term effectiveness? The plan also provides a document for recording the type of maintenance undertaken and when it was undertaken allowing for a cost/benefit perspective over time. What maintenance practices are beneficial and what require changes? An additional component of the overall site plan should include addressing manure collection, storage, and utilization (i.e. aspects of a nutrient management plan).

The O&M plan should, at a minimum, include:

- Construction specifics and site layout.
- Criteria applied for optimizing the use of pastureland and the HUA.
- The quantity and timing of the replacement of upper footing layer.
- Activities undertaken to maintain on and off-site drainage infra-structure including vegetated berm areas.
- Maintenance for fencing and shelter.
- Manure collection frequency, storage (longevity and flow), utilization (application rates and timing) considerations.

Manure Collection

Among the most important maintenance activities for heavy use areas is regular manure collection. Methods of collection and transfer of solid forms of manure can range from a simple shovel and wheel barrow, for a very small farming operation, to the more typical tractor-equipped scraper and front-end loader. Frequent collection reduces mud production (saturated soil and intermingled urine and feces). In addition to protecting animal health, frequent manure collection limits the potential of its migration and potential to contaminate surface and ground waters.

Ideally, manure and soiled bedding is collected every one to three days from turnouts, barns, stalls, and confinement areas (Harwood, 2005). However, the frequency of manure collection will vary based on the needs of the operator, type and number of animals and other animal health considerations. Further, the timing and frequency of manure collection should be adjusted to avoid damage to the HUA foundation and footing materials, especially non-cemented materials, when soils are overly wet. This is especially true when tractors or dozers are used. Ecology recommends working with a farm planner to determine the ideal manure collection frequency and timing, and to document it in a manure management plan.

Additional High Traffic Areas

Key Location, Design, Construction and Management Considerations

Confinement areas are not the only areas that can receive more intense and/or frequent use. In pastures and range lands there are areas that livestock use more intensively including off-stream water locations, feeding areas and salt licks. Additionally, areas used to move livestock such as loading corrals and travel lanes often receive heavier use. Key design considerations for the construction these other heavy use areas include:

- Site selection – considering aspects such as soils, slope, and surrounding drainage.
- Stabilizing heavy use areas to minimize erosion and limit the transport of pollutants.

Site Selection

Select sites to locate off-stream water facilities, supplemental feeding areas, salt licks and other high traffic areas away from surface waters. Siting recommendations include:

- Heavy use area sites should be located away from any surface water (perennial, intermittent, or ephemeral). Consistent with the Riparian Areas & Surface Water Protection recommendations (Chapter 12) confinement areas and other heavy use areas should be located outside the riparian management zone (at least 215-feet away from surface waters for western Washington locations and 150-feet away from surface waters for eastern Washington locations).[5]
- The site should be situated on high level ground, not in depressional areas where water collects.
- Avoid locations where significant run-on is anticipated or areas with flow paths to surface waters.
- Avoid areas that are seasonally flooded or saturated for extended periods of time.
- Locate as far as possible from wellheads.
- Remove accumulated manure as needed.
- Use vegetated filter strips downgradient capture sediment and infiltrate runoff when needed.
- Conduct routine inspections especially after significant runoff events.
- See Chapter 10 (Pasture and Rangeland Grazing[6]) for additional guidance for the placement of off-stream watering facilities.

Stabilizing the area

Stabilizing heavy use areas helps prevent erosion, facilitates the movement of livestock and improve access to watering and feeding locations.

- Ecology recommends implementing FOTG 561—Heavy Use Area Protection or FOTG 575 - Trails and Walkways practices.

[5] It is recognized that this in some cases it may not be feasible to achieve that setback distance at all sites particularly those with established structures and small sites. Farmers and implementers are expected to follow a stepwise process when determining feasibility. Fully consider whether the recommended setback distance can be implemented at the site. If there are existing structures, can they be moved? Consider grant programs and other incentives that could help cover the cost of relocating structures. At a minimum HUAs should be located outside of the core zone. It is not acceptable to default straight to the minimum core width. Determine the maximum extent that the HUA can located away from the surface water. We would expect to see documentation of how the maximum setback distance was selected. Farmers and implementors should also explore additional engineered stormwater solutions to prevent discharges from heavy use areas if they are located in the RMZ.

[6] https://apps.ecology.wa.gov/publications/parts/2010008part4.pdf

Manure Storage (semi-solid/solid)

Key Location, Design, Construction and Management Considerations

Key design considerations for the construction of a Manure Storage include:

- Site selection
- Sizing
- Cover/Roofs
- Composting
- Leachate: Collection and Storage

Site Selection

Semi-solid/solid manure siting recommendations include:

- Manure storage sites should be located away from any surface water (perennial, intermittent, or ephemeral). Consistent with the Riparian Areas & Surface Water Protection recommendations (Chapter 12) manure storage facilities should be located outside the riparian management zone (at least 215-feet away from surface waters for western Washington locations and 150-feet away from surface waters for eastern Washington locations.[7]
- The site should be situated on high level ground, not in depressional areas where water collects.
- There should be sufficient adjacent space to incorporate pad runoff treatment options such as a vegetative filter strip or settling/storage basin.
- Located near confinement areas to optimize operational efficiencies and allowing for frequent manure collection.
- Locate and design the waste storage facility such that it is outside the 100-year floodplain unless site restrictions require locating it within the floodplain. If located in the floodplain, protect the facility from inundation or damage from a 25-year flood event.

[7] It is recognized that this in some cases it may not be feasible to achieve that setback distance at all sites particularly those with established structures and small sites. Farmers and implementers are expected to follow a stepwise process when determining feasibility. Fully consider whether the recommended setback distance can be implemented at the site. If there are existing storage structures/facilities, can they be moved? Consider grant programs and other incentives that could help cover the cost of relocating structures. At a minimum manure storage facilities should be located outside of the core zone. It is not acceptable to default straight to the minimum core width. Determine the maximum extent that the manure storage facility can located away from the surface water. We would expect to see documentation of how the maximum setback distance was selected. Farmers and implementors should also explore additional engineered stormwater solutions to prevent discharges from manure storage areas if they are located in the RMZ including secondary containment.

Design and Construction

There are a variety of manure storage facility designs that are effective at minimizing the potential for a discharge from these areas. Manure storage facilities will range in size depending on the operation. A professional engineer should be used to design larger facilities. Additionally, Ecology recommends that manure storage facilities are designed in accordance with NRCS's Agricultural Waste Management Field Handbook[8] (AWMFH). The AWMFH includes information on construction material types, and manure facility sizing considerations.

Manure storage requirements are based on the amount of manure generated which, is a function of the number and types of livestock present along with the type and amount of bedding material used, if applicable. Additionally, the storage period must be considered which is determined both by the length of time for complete composting and for when crop and weather conditions are more optimal for land application. As mentioned, typically a storage capacity should be able to accommodate up to a 7-month manure/bedding inflow level. This provides flexibility with the timing of land application of the compost gaining the greatest possible benefit from it while avoiding periods when saturated ground conditions occur, a situation that could lead to contaminated runoff to surface waters.

Ecology recommends that manure storage facilities include the following:

- Consist of a concrete slab with stub walls.
- Have a design storage capacity sufficient to accommodate manure generation until land application is suitable – typically a period of about 7-months, mid-September through mid-April.
- Have sufficient surface area to provide for storage requirements while allowing for handling equipment (tractor/loader) access and maneuverability.
- A hardened entrance to the structure (typically gravel) to limit the generation of mud in the more highly trafficked zones.
- Located as close as possible to the primary manure source areas, minimizing transport time, labor, and fuel costs.
- If excessive leachate is expected from fresh-manure then the slab should be designed using sloped surfaces to collect the leachate, directing it to down-wells to provide temporary storage. The leachate can be recycled to increase compost pile moisture levels, held in storage until conditions allow for field application, or directed to an adjacent treatment system such as a vegetated filter strip when weather and ground saturation conditions allow for its use.

[8] https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21430

Cover/Roofs

Covering manure storage facilities limits the amount of precipitation that will come in contact with manure. This limits the amount of polluted stormwater a facility must management and the risk of a discharge to surface or groundwater from these areas. The roofing system should include gutters and downspouts that direct collected precipitation away from the structure with off-site infiltration optimal (i.e. French drain or vegetative filter strip). For structures not having the ability to install a rain collection system (i.e. hoop-type roofing systems) then roof runoff should be sequestered from the storage pad through the use of berms or other water diversion and infiltration methods.

- Westside of the state—Ecology recommends roofed/covered structures to store manure.
- Eastside of the state—Ecology recommends roofed structures when they are located closer to surface water and in higher precipitation zones. If a roof is not used, an operation will need to control stormwater from manure storage areas to prevent discharges. Additional BMPs may be needed to prevent discharges from these areas.

Compost Bedded Pack Barns

Compost bedded pack barns may be used as an alternative to or in addition to manure storage facilities. Compost bedded pack barns are a strategy for managing livestock and manure during the winter months. It is a housing system where animals and their excreta are managed within covered housing through the continual addition of bedding materials which creates pack over time. The pack is then composted after winter ends and the animals are typically place back onto pastures. This practice can function as both a confinement area and covered manure storage.

The exterior walls of bedded pack barns should be designed to be manure tight and may be constructed of concrete or wood posts and plank. Floors may be concrete or aggregate.

Bedded pack barns should be designed to storage manure and bedding at least 24 inches to 30 inches high. Ecology recommends working with an NRCS or CD farm planner to determine the floor space and volume needed.

The following stocking densities may be considered with sizing a compost bedded pack barn:

Table 1. Stocking density that made be considered with sizing a compost bedded pack barn

Species/Type	Avg Weight (lb)	Surface Function	Stocking Density (ft2/head)
Feeder Cattle - Calf	600	Paved Floor in Barn Without Lot	25
Feeder Cattle - Finishing	1000	Paved Floor in Barn Without Lot	35

Species/Type	Avg Weight (lb)	Surface Function	Stocking Density (ft2/head)
Bred Heifer	800	Paved Floor in Barn Without Lot	35
Beef Cow	1000	Paved Floor in Barn Without Lot	40
Beef Cow	1300	Paved Floor in Barn Without Lot	50

*Composting Dairy Facility: Use recommendations from "Evaluating the Effectiveness of Dairy Bedded Pack Systems in Ohio" OSU Extension (11-1-2010-revised) or "Kentucky Compost-Bedded Pack Barn Project", University of Kentucky, April 2013.

Again, Ecology recommends consulting with a NRCS or CD farm planner to implement this practice. In addition, Ecology recommends following:

- Lay down 18 to 24 inches of dry sawdust material in the facility before cows are introduced and after each complete clean out.
- Bedding must be sawdust or shavings. Good quality, dry sawdust and/or shavings must be readily available for use in the composted bedding. Do NOT use green sawdust (from green lumber). Bedding must be no more than 18% moisture for use with dairy composted bedded pack.
- Expect to use a lot of sawdust or shavings. Add dry bedding when the pack begins to stick to the animals which will typically require adding 4 to 8 inches every 2 to 5 weeks. In spells of rainy or humid weather, more sawdust is required than in warm dry weather.
- Frequently turn at a depth of 10-12 inches is a must. The is a key management step for the concept of composting bedded pack barns. This not only removes manure and urine from the bedding surface, it incorporates oxygen into the pack allowing a faster aerobic decomposition important to optimizing the composting process.
- Keep pack level and dry. Additional sawdust material should be added along the concrete walls, to create a slightly higher area. A gradually sloped pathway will be needed for the livestock to move to the feed alley off the dry pack.
- Do not allow the composted bedded pack to become over saturated by either rainfall or mismanagement. Immediately apply additional dry bedding to over-saturated areas and mix thoroughly. In extreme cases, heavy equipment may be needed to turn the entire pack manage excess moisture and facilitate drying.
- To remove heat and maintain dry bedding surface, excellent ventilation is a must.
- The facility must be cleaned out during the growing season and material utilized as part of the on-farm manure management plan to ensure there is sufficient space for pack accumulation during the following winter or when livestock are confined.

- Use a properly designed manure storage facility if bedding and manure will be stored prior to utilization or off-site disposal.
- On-site use of compost material should be done is accordance with a nutrient management plan.

Composting

The preferred pathway[9] for manure, once collected, is composting; an aerobic bacterial-driven process that leads ultimately to organic matter stabilization – the reduction in the manure moisture content and mass. Additionally, a properly managed composting process can destroy weed seeds, plant and human pathogens, all of which present a liability when fresh manure is directly land applied.

Leachate: Containment and Treatment

In this context, leachate is contaminated water that drains from a manure pile during the storage/composting process with its production greatest when fresh manure is initially collected and stacked. Due to its high nutrient and bacterial levels, leachate, if uncontrolled, can potentially contaminate surface or groundwater with adverse impacts to animal and human health. Therefore, the leachate management must be a considered component of any storage/treatment manure composting process. The level of leachate generation is going to be operation-specific and dependent on factors such as fresh manure moisture levels, in-flow rate, and the level of bedding and sources of carbon added as part of the overall waste stream. This is a factor that should be evaluated in the initial design phases of a manure management system.

If leachate generation is expected, then the slab on which the compost pile will be situated should be designed for its collection and potential re-use. This can be accomplished through sloped surfaces that collect the leachate and direct it to a down-well for temporary storage. In areas of low annual precipitation, unroofed storages frequently are used. Despite lower precipitation, these situations still pose an environmental risk due to the expected increased leachate generation and should be collected and stored.

Once collected, leachate can be managed through several pathways including:

- Recycled as a source of moisture for the compost pile.
- Stored and applied to crops during the dry season (depending on the level of leachate production).

[9] While Ecology recommends composting, we recognize that not all livestock operations will undertake the more intensive management necessary to compost. In those cases where manure is not composted, if stored in accordance with Ecology's other recommendations in this chapter, discharges should be prevented from the manure storage area.

- Through controlled drainage, directed to a vegetative filter strip situated near the compost facility during the dry season (refer to Natural Resources Conservation Service (NRCS) field office technical guide (FTOG) number 393).

Above Ground Storage Tanks (Manure Storage)

Key Location, Design, Construction and Management Considerations

Key design considerations for the construction of a include:

- Site Selection
- Design and Construction
- Secondary Containment and Leak Detection

Site Selection

Above Ground Storage Tank (liquid manure storage) siting recommendations include:

- Manure storage sites should be located away from any surface water (perennial, intermittent, or ephemeral). Consistent with the Riparian Areas & Surface Water Protection recommendations (Chapter 12) manure storage facilities should be located outside the riparian management zone (at least 215-feet away from surface waters for western Washington locations and 150-feet away from surface waters for eastern Washington locations.[10]
- The site should be situated on high level ground, not in depressional areas where water collects.
- Located near confinement areas to optimize operational efficiencies and allowing for frequent manure collection.
- Locate and design the above ground storage tank such that it is outside the 100-year floodplain unless site restrictions require locating it within the floodplain. If located in the floodplain, protect the facility from inundation or damage from a 25-year flood event.

[10] It is recognized that this in some cases it may not be feasible to achieve that setback distance at all sites particularly those with established structures and small sites. Farmers and implementers are expected to follow a stepwise process when determining feasibility. Fully consider whether the recommended setback distance can be implemented at the site. If there are existing storage structures/facilities, can they be moved? Consider grant programs and other incentives that could help cover the cost of relocating structures. At a minimum above ground storage tanks should be located outside of the core zone. It is not acceptable to default straight to the minimum core width. Determine the maximum extent that the above ground storage tank can located away from the surface water. We would expect to see documentation of how the maximum setback distance was selected. Farmers and implementors should also explore additional engineered stormwater solutions to prevent discharges from manure storage areas if they are located in the RMZ including secondary containment.

Design and Construction

Above ground storage tanks should be designed by a professional engineer and constructed by experienced contractors. Additionally, Ecology recommends that storage tanks are designed in accordance with NRCS's Agricultural Waste Management Field Handbook[11] (AWMFH).

The AWMFH includes information on tank material types, and sizing. Above ground storage tanks can be covered. If uncovered, the tank must be sized to accommodate precipitation during the storage period.

Secondary Containment and Leak Detection

If above ground storage tanks are located in the RMZ or near surface water conveyances, Ecology recommends secondary containment. In other areas producers should consider implementing secondary containment and/or have a leak detection system in place. Regular weekly vision inspects are recommended for all tanks.

NRCS Practices

- Heavy Use Area Protection (NRCS practice code 61)
- Waste Storage Facility (NRCS practice code 313) and NRCS's Agricultural Waste Management Field Handbook[12] (AWMFH).
- Roofs and Covers (NRCS practice code 367)

Commonly Associated Practices:

- Nutrient Management
- Filter Strip/vegetative treatment area
- Mulching
- Nutrient Management
- Gutters and downspouts
- Underground Outlets
- Diversion channels
- Stormwater Basin
- Grassed Waterway
- Riparian Buffer
- Water Control Structure
- Level spreader

[11] https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21430
[12] https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21430

Chapter 11 Appendix Part A: Effectiveness Synthesis (Livestock Management: Animal Confinement, Manure Handling & Storage)

Effectiveness

Heavy Use Areas

Heavy use areas (HUAs) are established areas of animal congregation, whether by choice, in the case of access points to feed and water or through grouped sequestration, created to protect pasturelands during the wet winter months or when forage is limited. This paper presents several best management practices (BMPs), and their underlying design considerations, that directly address the negative impacts typically associated with animal points of congregation, the creation of mud – a mixture of soil and animal waste and its potential to negatively affect both animal health and the environment.

Congregation of Animals

Heavy use areas are commonly defined as designated areas used for animal residency with their primary purpose to provide an area, typically adjacent to shelter such as a barn, to minimize detrimental impacts to pasture and rangelands during the wet winter months. They are most applicable to cows and horses but can also apply to other animals (i.e. pigs, alpaca etc.). In this context, the major design considerations include the installation of footing material, fencing, and addressing on and off-site drainage.

At Points of Passive Animal Congregation

Within the larger context of the care and feeding of livestock, heavy use areas occur in locations of animal congregation, for instance, adjacent to feeding areas such as portable hay rings and feed bunks, watering facilities, mineral salt blocks, and transit pathways (gateways, and/or alleyways). The scale of application can vary significantly from a feed bunk in a cattle feedlot to protecting the area around a water trough in the middle of a pasture. Regardless of scale, the same fundamental concepts apply; protecting the areas of congregation with an engineered surface to minimize soil disturbance and the creation of mud.

Managing manure deposited in heavy use areas is a critical component in its effective implementation. In addition to addressing adjacent surface conditions to capture and treat contaminated runoff from the hardened surface, design considerations must also be made for the collection, storage, utilization, and treatment of manure and other operational waste streams. This context applies to both larger industrial scale animal production facilities (i.e. concentrated animal feeding operations (CAFOs)) in addition to smaller operations. As it will be discussed, this guidance advocates that an operation and maintenance plan be written for each heavy use area(s) and, in the case of more complex settings, to not only document site maintenance plans and records but also waste management practices (i.e. nutrient management plan). The plan and documented adherence to it, provides an increased assurance of HUA longevity and environmental protection.

Scope

This section addresses BMPs that help prevent pollutant export from high traffic areas and areas where animals are confined. For the purposes of discussing impacts from confined areas, their influence on water quality, and the BMPs that address these impacts, this guidance will be separated into two main categories: heavy use areas and waste storage facilities. (The waste storage facilities component will follow in an accompanying paper.) Both small and large operations will be considered.

This section presents the primary considerations when planning and constructing a heavy use area. Many of these considerations will be site and animal specific, therefore, consulting with a local conservation district planner is ultimately advised.

Finally, the guidance is applicable to operations not covered by an existing CAFO general permit (State – only permit or combined permit). If an animal feeding operation discharges to surface or groundwater, the facility is required to apply for coverage under those permits after which their operations are then bound by their individual permit requirements.

Relevance in Washington: Focus and Value

The suite of BMPs applicable to this practice have widespread relevance in Washington particularly for smaller farms with more limited pastureland where forage management must be optimized. Although this practice has state-wide relevance it has increased applicability to the western portions of the state where the winter period brings increased precipitation levels. The upper soil layers and forage are vulnerable to animal hoof pressure, especially when fields are wet. In addition, animals residing in wet, muddy conditions can lead to diminished health associated with fungal and bacterial infections. The conditions that result in the generation of muddy conditions, high animal densities and wet pastures, also tend to have high bacterial levels since animal waste is intermingled with the wet exposed soil. Under these conditions, the collection of manure is difficult. Collectively, these conditions result in an increased vulnerability to both animal health and surface and groundwater quality.

When and where this practice is most appropriate

HUA protection BMPs are appropriate anywhere animals are confined or congregate for longer periods of time. The application of HUAs for pasture management applies primarily from October through April, a period coinciding with increased precipitation levels. HUAs are also relevant to any operation where livestock are held and fed during times when forage is limited or when grazing is likely to damage soil and forage. Farms with limited pastureland, relative to stocking rate, may utilize animal confinement areas for longer periods especially when dependent on optimal forage availability during the spring and summer months. This practice also has broad application when used to address localized areas of heavy animal use such as feed and watering locations.

Water quality concerns reduced by practice

During the winter months when precipitation is at a maximum, animal hoof pressure can expose soil leading to muddy pasture conditions and increased surface runoff. Along with sediment, runoff can contain pathogenic bacteria, oxygen-demanding organic matter, and nutrients such as phosphorus and nitrogen, all associated with manure deposited on the land surface.

Precipitation can mix with manure and sediment resulting in its potential export to surface and groundwater. Elevated levels of nutrients and organic matter (BOD) discharged to surface water can result in excessive primary production (high algal growth) in addition to decreasing dissolved oxygen levels, diminishing habitat viability for most of the aquatic organisms present.

Design and Management Considerations – Heavy Use Areas (HUAs)

Key design considerations for the construction of a heavy use animal confinement area include:

- Site selection – considering aspects such as soils, slope, and surrounding drainage
- Determining pad surface area
- Footing – selecting the type of surface
- Considering site drainage – its diversion, capture, direction, and treatment
- Enclosure fencing - types and points of access for animals and equipment
- Shelter – cover for animals in proximity to the HUA
- Site operation and maintenance – particularly manure collection and management

Site Selection

HUA siting recommendations include:

- Heavy use area sites should be located away from any surface water (perennial, intermittent, or ephemeral) at least 215-feet for western Washington locations and 150-feet for eastern Washington locations, conforming to the riparian management zone recommendations.[13]
- The site should be situated on high level ground, not in depressional areas where water collects.
- Avoid areas with shallow groundwater.

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[13] It is recognized that this in some cases it may not be feasible to achieve that setback distance at all sites particularly those with established structures and small sites. Farmers and implementers are expected to follow a stepwise process when determining feasibility. Fully consider whether the recommended setback distance can be implemented at the site. If there are existing structures, can they be moved? Consider grant programs and other incentives that could help cover the cost of relocating structures. At a minimum HUAs should be located outside of the core zone. It is not acceptable to default straight to the minimum core width. Determine the maximum extent that the HUA can located away from the surface water. We would expect to see documentation of how the maximum setback distance was selected. Farmers and implementors should also explore additional engineered stormwater solutions to prevent discharges from heavy use areas if they are located in the RMZ. It may be necessary to provide a roofed structure over all or a portion of the HUA to prevent the discharge of pollution.

- Avoid areas with high leaching potential.
- If there is the potential for ground water contamination from the heavy use area, select another site or provide an impervious surface to reduce infiltration of pollutants.
- Optimally, it should be situated adjacent to covered shelter (such as a barn) if existing, otherwise the space required for its construction should be considered.
- The surface of the heavy use area should be slightly sloped (<=2%) to direct any generated runoff to an adjacent vegetated filter strip (VFS) or other wastewater collection and treatment system. The VFS provides a relatively low maintenance yet effective pollutant runoff capture alternative for most applications and should be considered a component of the overall HUA system.
- There should be sufficient adjacent space to incorporate pad runoff treatment options such as the mentioned vegetative filter strip or settling/storage basin, in the case of larger scale operations. The site, including the VFS, should be situated on slopes less than 5%.
- Allow for the unencumbered movement of animals and equipment between the HUA and pasture lands.
- Located near manure storage facilities to optimize operational efficiencies and allowing for its more frequent collection.

Pad Surface Area

The HUA pad size is dependent on the type, number, and age of livestock it will accommodate and the period of that accommodation. In addition, there are considerations of animal health, territorial issues, the management of waste, and ready access to feed and water. There are also operational considerations such as providing for equipment access and maneuverability for operation and maintenance. Based on these varied considerations it is best to consult with a conservation district planner to determine the overall HUA footprint.

Footing

Among the more important considerations for establishing or rehabilitating a heavy use area is the selection of footing. Chief considerations include a material that will provide for appropriate animal health and support (i.e. hoof protection), provides for efficient drainage, has longevity, and allows for routine manure collection. One consideration related to manure collection and future maintenance is the amount of pressure equipment and animals will have on a surface. This should be considered when picking footing to prevent failure of the surface. According to Higgins et. al. (2017):

> When an animal is standing, it applies a certain amount of pressure to a surface. The standing pressure for several animals and farm equipment, measured in pounds per square inch (psi), is shown in Table [2]. From the table, it is clear that the foot pressure of standing cattle and horses places about 66 percent more pressure psi than a 50-ton dozer! For livestock producers who have been in operation for years, this point has likely been demonstrated already through visible field damage and soil compaction.

Table [3] shows the foot pressure for walking livestock, which shifts their weight to two feet rather than all four. This means more pressure is applied when the animal is moving, causing increased damage to the topsoil. Moreover, when an animal walks slowly and repeatedly over the same area, as is common in feeding and watering areas, it will sink deeper into non-cemented materials, possibly up to their knees and hocks ….

Table [4] provides information on the amount of strength various farm surfaces can provide before they fail. These data are for dry materials. It is important to note that applying moisture to these surfaces, as in the form of precipitation, will weaken non-cemented (natural) materials. When comparing the foot pressure of large livestock like cattle and horses to the resistance strength of typical topsoil, it is clear that these surfaces do not provide the strength needed to support the weight of the animals and heavy equipment traffic, especially if they become wet. To reduce the creation of mud and erosion, producers need to provide livestock with a sufficiently hard surface they can stand on that can support their weight.

Table 2. Pressure Created by Different Stressors

Stressors	Pressure (psi)
Sheep	12
Human	14
Utility terrain vehicle	14
50-ton dozer	16
Cattle	27
Horse	27
Tractor	175

Table 3. Pressure Created by walking humans and livestock

Stressors	Pressure (psi)
Human	28
Cattle	48
Horse	48

Table 4. Loading Carrying Capacities of Different Livestock Surfaces

Type of Surface	Pressure (psi)
Soft clay or sandy loam	14
Firm clay or fine sand	28
Dry clay or compact fine sand	42
Loose gravel or compact coarse sand	56
Compact sand and gravel mixture	83

Type of Surface	Pressure (psi)
Soil cement (12% mixture)	2,400
Concrete (6-inch reinforced)	6,000

Multiple options to provide improved surfaces are available and can be protective of water quality. The implementation section provides more information on footing options. Depending on the size of the heavy use area, material and construction costs also factor into the decision-making.

Drainage Considerations

Regardless of the footing material ultimately chosen, common to the long-term success of the HUA is the diversion of all significant sources of off-site water (will be covered in Chapter 9 of the VCWGA), providing slope to the footing surface to promote on-site drainage preferably to an adjacent vegetative filter strip or basin, and the frequent removal of manure – daily is ideal. Careful consideration of all these factors will significantly reduce the production of muddy conditions.

Diversion of Clean Water

The potential for drainage from upgradient areas and adjacent structures should be considered when planning heavy use areas. Any drainage that could potentially enter the HUA from up-gradient locations and adjacent structures should be diverted. Minimizing on and off-site clean flows allows for the site's increased longevity while limiting the generation of contaminated runoff.

Adjacent barns and shelters, whether existing or planned, should have gutters and downspouts that capture and direct rooftop-generated runoff away from the heavy use area to either dedicated curtain drains (French drain) or to adjacent grass filter strips for infiltration.

Treatment of On-site Runoff

Runoff is generated when precipitation, as either rain or melting snow, is of sufficient intensity and/or longevity as to generate overland flow which, in this context, is likely to entrain manure, bedding, and waste feed. For smaller HUAs, runoff from the pad surface should be directed to an adjacent vegetated filter strip (VFS) for infiltration. This grassy area around the outside of the heavy use area will provide for treatment of pad surface runoff reducing the potential off-site export of sediment, bacteria, and nutrients (N and P). Runoff should enter the VFS as uniform flow and not allowed to concentrate, a situation that significantly reduces its effectiveness. The width of the grass filter strip will vary depending on the HUA pad area (a surrogate of runoff generation), soil type, vegetation density (thickness of grass) and slope, among other factors. Larger operations may instead use a stormwater basis to collect on-site runoff.

Fencing and Access Considerations

Like the pad surface area determination, the fencing type and its layout will be an operation-specific consideration and best discussed with a conservation district planner. Fencing considerations beyond animal confinement are to provide for the ingress and egress of both animals and equipment. Access gate(s) should be of sufficient width to allow equipment entry for manure removal, supply feed, and allow for maintenance. There should also be at least one gated access from the HUA to adjacent pasturelands. Removable fencing, such as livestock panels, allow for easy access for maintenance (allow for a minimum gate width of 12-feet).

Operation and Maintenance

It's recommended that an operation and maintenance (O&M) plan be created to document both construction specifics and the long-term maintenance needs of the greater HUA. An important aspect of writing such a plan is the thought process; having constructed the site, what are the critical aspects for maintaining its long-term effectiveness? The plan also provides a document for recording the type of maintenance undertaken and when it was undertaken allowing for a cost/benefit perspective over time. What maintenance practices are beneficial and what require changes? An additional component of the overall site plan should include addressing manure collection, storage, and utilization (i.e. aspects of a nutrient management plan). Operation and maintenance plans should also consider the impact of equipment may have on the heavy use area surface. For example, tractors exert significant pressure and could damage the HUA foundation if manure collection is not timed appropriately or if the area is not designed to hold up against the equipment used. See above tables from Higgins et. al. (2017).

The O&M plan should, at a minimum, include:

- Construction specifics and site layout
- Criteria applied for optimizing the use of pastureland and the HUA
- The quantity and timing of the replacement of upper footing layer
- Activities undertaken to maintain on and off-site drainage infra-structure including vegetated berm areas
- Maintenance for fencing and shelter
- Manure collection frequency, storage (longevity and flow), utilization (application rates and timing) considerations

Manure Management

Among the most important maintenance activities for heavy use areas is regular manure collection. Heavy use pads should be scraped clean with a front-end loader or manure pick to avoid build-up of manure, hay, and other materials collected on its surface. Manure should be removed at least every 3-days though daily removal is ideal. However, consideration should be given to weather and surface conditions. Try to avoid times when surface is saturated or otherwise susceptible to damage.

Fine organic materials like manure and hay will plug the footing layers and, over time, result in increasingly diminished pad drainage resulting in its failure (re-emergence of muddy conditions) undermining the original intent of the pad. For this reason, feeding on top of the footing layer should be avoided (in addition to protecting livestock from inadvertently ingesting sand or gravel).

Relate NRCS Practice

Heavy Use Area Protection (FOTG 561)

Effectiveness

When considering the effectiveness of an HUA in reducing nonpoint source pollution runoff, the perspective comes from the change in runoff quality having corrected an existing muddy situation or ensuring the problem is never created in the first place. From both perspectives, the elimination of the generation of mud – the combination of soil and manure - and its potential to migrate to surface waters is a corrective action and why this best management practice is so well used and proven in its effectiveness.

Additional measures that ensure for its long-term effectiveness include off-site drainage diversion, a properly installed foundation that supports anticipated loads, footing maintenance and the frequent removal of manure along with any bedding or feed deposited on its surface. The lack of attention to these factors will eventually lead to the return of muddy conditions. However, even with proper maintenance the HUA surface will still generate runoff with elevated nutrient and bacterial quality and additional methods are required to provide for an overall treatment effectiveness. Subsequent chapters will address stormwater basins and vegetative filter strips (VFS).

HUA Runoff Treatment Effectiveness Measures

The effectiveness of various runoff treatment options depends on many factors chief among them are those that are site-specific such as soils, topography, and the intensity and frequency of storm-events. Additionally important are facility operational factors such as the area of the HUA, animal number and type, and the frequency of manure collection. The design specifics of the treatment measures also must be considered. Given this, Table 1C provides the reported relative treatment effectiveness of various commonly applied waste stream treatment practices with reducing pollutant loading based on several water quality metrics. Again, worth noting is that site specific and operational factors will affect the ultimate effectiveness observed.

Table 5. Relative effectiveness of constituent removal by management measure examined individually unless noted (USEPA, 1993)

BMP Approach	Information Source	Total Solids reduction %	Chemical Oxygen Demand reduction %	Total Nitrogen reduction %	Total Phosphorus reduction %	Fecal Coliform reduction %
Basin	Adam et al., 1986	56	38	14 (as TKN)	===	===
Basin	Edward et al., 1986/ Edward et al, 1983	52	54	35	31	===
Basin	Pennsylvania State University, 1992	70	===	65	60	90
Basin w/vegetated filter strip (VFS)	Adam et al., 1986	90+	90+	90+	90+	===
Basin w/vegetated filter strip (VFS)	Dickey, 1981	73	===	80 (as TKN)	78	===
Basin w/vegetated filter strip (VFS)	Edward et al., 1986	82	85	===	80	===
VFS	Edward et al, 1983	87	89	83	84	===
VFS	Pennsylvania State University, 1992	60	===	===	85	55

Overall, of the treatment options examined by these studies, the most effective is the vegetated filter strip (VFS) providing an over 80% reduction to the pollutant inputs (on average). In comparison, the detention basin was significantly lower at around the 50% effectiveness level. The combined detention/vegetated filter strip really only provided a small additional increase to treatment effectiveness, when compared to the vegetated filter strip (as a sole application), and that applying primarily to the total solids parameter (an increase in effectiveness of about 8% was observed).

Perspective is important when assessing these effectiveness numbers. Only relatively small operations can solely apply a vegetative strip treatment option despite its high effectiveness level. That has to do with runoff volume levels and its quality. For larger operations where runoff levels can be high and quality low (i.e. CAFO), settling and storage is the most optimal pre-treatment option. The benefits provided by vegetation comes once that stored wastewater and settled solids are then distributed (at appropriate times and levels) to the landscape, adhering to a well-constructed nutrient management plan.

Construction Aspects of HUA

Construction Timing

The optimal construction window for an HUA in Washington is during the driest period of the year when little sustained precipitation is expected, and the upper soil horizon is dry. In Washington these conditions tend to occur from mid-June to mid-October. The heavy use area pad should not be constructed when conditions are wet, a situation that would lead to the generation of muddy conditions undermining its proper construction.

A variety of HUA surface types are commonly used in Washington including geotextile/gravel, sand, and wood chips (hog-fuel) and less commonly concrete. The following is brief description of a construction sequence for a pad comprised of geotextile and gravel. It's among the most common methods to construct a HUA because it has low engineering requirements with high applicability and longevity while being scalable from small to moderately sized operations.

Excavation

Once the location and area of the HUA pad have been determined and the perimeter staked, the first step in its construction is the removal of the sod and upper organic soil layers to a more compressed solid low-organic layer. This becomes the base layer of the pad. Approximately 8 to 11 inches of gravel backfill will eventually be used in the pad's construction with the final upper elevation being slightly higher than the surroundings to allow for settling and drainage. There is a balance to the extent of the gravel fill in that the intent is to provide a short flow path to any on-site drainage either through direct infiltration or preferably to an adjacent vegetative filter strip for treatment and infiltration. The HUA is not designed to function as a gravel trough that would provide some level of storage, a situation that could lead to its failure. The base of the excavated layer should have a slope of around 2% that will be carried through to the upper gravel layers to direct drainage to an adjacent vegetated filter strip. Alternatively, the HUA can be mounded (crowned) and slightly sloped to allow for full peripheral drainage. In this case the runoff is more distributed requiring a lower overall treatment buffer width.

Geotextile (Filter Fabric)

A sheet of geotextile fabric is then installed over the base soil layer and staked down to prevent any movement during construction (at 5-foot centers). The geotextile fabric is constructed of polypropylene fibers and separates the underlying soil and the eventual gravel backfill, increasing the stability of the ground and drainage of the site. The fabric spreads the surface weight more evenly, making the pad durable enough to support livestock as well as tractors and other farm equipment. The geotextile fabric also allows water transmission while restricting any upward movement of the underlying soil. Importantly, it keeps the gravel from sinking into the underlying soil over time, prolonging the life of the HUA. Without a geotextile fabric separation, over time, the gravel will settle into the underlying soil increasing maintenance requirements while decreasing its longevity.

The Natural Resources Conservation Service (NRCS) recommends using a minimum thickness of 6-ounces per square yard (oz/yd^2) with an 8-10 oz/yd^2 thickness providing increased stability if heavy equipment traffic is expected. A minimum overlap of the geotextile panels is 12-inches at all joints and staked.

Gravel – Base Layer

A base gravel layer is then placed over the geotextile fabric to provide a foundation for the pad. A minimum of 6 to 8 inches of compacted gravel should be applied. The gravel size will vary but commonly has a range between 3/8 and 5/8-inch minus. The gravel aggregate is comprised of multiple sizes of stone that interlock. If the pad is expected to see heavy use by both animals and equipment then an 8-inch gravel depth is recommended, and it should be compacted in 4-inch lifts.

Gravel – Top Footing Layer

Over the course gravel layer a 2 to 3 inch depth layer of finer gravel is added (dense grade aggregate). This is, in a sense, a sacrificial layer and will require replenishment due to its continual loss associated with practices such as manure removal. In addition, there is some loss initially as this finer gravel will settle into the underlying course base layer due to the rain and traffic, ultimately providing for a more durable surface. When scraping the pad, the fine layer will aid in knowing how deep one is scraping the pad. The finely crushed gravel reduces any impacts to animal feet while allowing for the collection and ultimately spreading of manure on pastures without causing any equipment concerns.

HUA Surface Maintenance

By design, the replacement of the upper fine aggregate layer of the pad is expected to require the most frequent maintenance among the complexities of the overall site. This layer typically has a useful life of around 3 to 5 years following the construction of the pad but that will depend on several factors among them: how often the surface is used by animals, the weight and frequency of heavy equipment access, and importantly, how often and thorough the pad is scraped (manure removed).

The upper gravel layer is considered sacrificial as the smaller gravel tends to become entrained with each surface scraping undertaken to remove manure. However, this layer should never be allowed to thin to the extent that is breaks through to the underlying coarse gravel layer. Protecting this lower layer minimizes its maintenance needs. If the pad is constructed, cleaned well, and maintained, the coarse aggregate layer should not need to be replaced.

In terms of maintaining the footing surface the best time to make an assessment is in the fall prior to the onset of wet winter conditions – as the condition of the footing and whether replenishment or other maintenance measures need to be undertaken.

Manure Management

Livestock manure generation can take two general forms based on water content: high-water content manure generally associated with dairy production is typically stored in a lagoon and lower water content manure generated from a horse farm, cattle feedlot, or a poultry operation. This guidance will focus on this latter group while an additional section will discuss liquid-based manure operations.

The recommended pathway for the storage and stabilization of solid forms of manure is through composting, a managed biological process that converts organic matter into a stable humus-like material that can be land applied and serve as a supplemental nutrient source for crops while also providing benefits to soil quality. This net value can only be realized if an effective manure management system is in place allowing for the ultimate distribution of the manure to the land surface in a manner that minimizes environmental risk. That system is the focus of this guidance.

A comprehensive livestock manure management system considers the following components:

- Production – an operation-specific accounting of manure generation and other stored materials such as bedding or spoiled feed
- Collection – the methods and routines of manure collection
- Storage – infrastructure used to store and stabilize accumulated manure
- Treatment – stabilization methods, typically through composting, for reducing the water content, weed seeds, pathogens, and the overall mass of the manure
- Transfer – method of moving the stabilized manure from storage/treatment to the place of use
- Utilization – the application of the composted waste, typically to the land surface, supplementing crop nutrients and building soil health

Given this complexity, the system needs to be tailored to the specific operation being addressed. This guidance serves as a start, presenting the main considerations when planning a manure management system; it is advised to consult with technical experts such as an agricultural systems engineer or conservation planner to develop an operation-specific plan.

Water Quality Concerns Addressed by Practice

A poorly executed manure management system (or lack of one) can lead to adverse surface and ground waters. The primary pollutants associated with manure affecting surface water quality include pathogenic bacteria, nutrients (nitrogen and phosphorus), and organic-based oxygen demanding materials. Nitrate leaching to groundwater is a concern and can contaminate drinking water supplies. The impacts on ground and surface water associated with poorly managed animal wastes and excessive fertilizer applications can have both local and regional implications to drinking water supplies and aquatic resources.

Manure based nutrients, primarily in the form of nitrogen and phosphorus compounds, can be major pollutants if introduced to lakes, rivers, and estuaries. Excess N and P in aquatic systems can stimulate production of plant (including algae and vascular plants) and microbial biomass, which leads to depletion of dissolved oxygen, reduced transparency, and changes in biotic community composition -- this is called eutrophication. In addition to the impacts on aquatic life, excess nutrients can also degrade aesthetics of recreational waters, and increase the incidence of harmful algal blooms, which may endanger human health through the production of toxins that can contaminate recreational and drinking water resources. Phosphorus may reach waterways directly through surface runoff or wind deposition and indirectly in a dissolved form leaching through the soil to groundwater (though this pathway is less common due to the dissolved forms of phosphorus having reduced transmission through soil due to their ionic charge). In freshwater systems phosphorus is commonly a limiting nutrient and its availability serves as a determinant of the level of primary productivity, the amount of aquatic plant and algae growth present. (Nitrogen tends to be the limiting nutrient in marine waters, a situation not commonly observed for freshwater systems.) The scientific literature demonstrates that nutrient concentrations vary across a landscape as a result of a multitude of factors, including climate, flow, geology, soils, biological processes, and human activities. This variability in concentration means that the relative contribution of and limitation by N and P can change spatially and temporally - even within the same watershed. Therefore, it is important to control both N and P and not concentrate on only one. (EPA, 2015).

Lakes, in addition to rivers and streams, are vulnerable to excessive levels of primary production associated with the introduction of excess nutrients, a process known as eutrophication. Elevated algae growth and its eventual die-off and decomposition results in declining dissolved oxygen concentrations directly impacting aquatic organisms and their habitat.

Additionally, manure having a high organic content, if allowed to directly enter surface waters can result in a high biochemical oxygen demand (BOD) resulting in a relatively rapid loss of dissolved oxygen, limiting the viability of aquatic resources. In addition to the concerns regarding nutrients and BOD, bacterial pathogens present in manure such as *E. coli*, *Salmonella*, and *Cryptosporidium parvum* impair surface waters and pose human health risks. An additional environmental concern is the emission of “greenhouse” gases such as ammonia, nitrous oxide, and methane associated with livestock production overall but particularly during the manure management phases.

Design Considerations: Production, Collection, Storage, and Treatment

Production (Manure Generation and Its Quality)

Planning a manure management system begins with an understanding of the manure production level characteristic of a particular operation. That includes not only the quantity of manure generated but also accounting for other sources of the overall waste-stream such as bedding, and waste feed, if applicable. Tables 1 and 2 provide typical levels of daily manure generation (on a wet weight basis), by animal type, along with associated nutrient quality levels

(USDA, 2008). The data presented in the tables provides a rough guide of manure production recognizing that variations can be expected due to animal type, weight and age, feed characteristics, type of confinement, among other factors, leading to the operational-based specificity mentioned previously.

Table 6. Fresh manure characteristics, by animal type (imperial units) (USDA, 2008)

Animal Type	Animal Weight-Pounds (#)	Raw Manure (wet)[1] #/d	Raw Manure (wet)[1] ton/yr	Raw Manure (wet)[1]	Raw Manure (wet)[1] ft^3/d	Raw Manure (wet)[1] Moisture level (%)	BOD #/d	COD #/d	Total Solids #/d	Total Solids ton/y	Volatile Solids #/d
Dairy Cow	1,300	107.00	19.500	15.000	2.000	80-90	2.000	11.800	13.500	2.500	11.200
Dairy Cow	1,600	132.00	24.000	18.000	2.400	80-90	2.460	14.500	16.600	3.100	13.800
Dairy Heifer	1,000	85.00	15.500	11.200	1.500	80-90	===	===	9.200	1.700	===
Beef Stocker	500	45.00	8.200	5.200	0.700	80-90	===	===	5.800	1.000	===
Beef Feeder	1,000	60.00	11.000	7.500	1.000	80-90	1.600	6.600	6.900	1.300	5.900
Horse	1,000	45.00	8.200	6.700	0.900	65	===	===	9.400	1.700	7.500
Hog Feeder	100	6.50	1.200	1.100	0.150	75-80	0.210	0.570	0.600	0.110	0.480
Hog Feeder	200	13.00	2.400	2.200	0.300	75-80	0.420	1.140	1.200	0.220	0.960
Hog Breeder	500	25.00	4.600	3.000	0.400	75-80	0.650	2.600	2.200	0.400	1.600
Sheep Feeder	100	4.00	0.730	0.750	0.100	70	0.090	1.180	1.000	0.180	0.850
Laying Hen	4	0.21	0.038	0.024	0.003	55-75	0.014	0.048	0.054	0.010	0.038
Broiler	4	0.28	0.051	0.029	0.004	55-75	===	===	0.068	0.012	0.048

1. Raw manure includes urine and feces

Table 7. Typical fresh manure nutrient levels, by animal type (imperial units) (USDA, 2008)

Animal Type	Weight-Pounds (#)	Total Nitrogen #/day	Total Nitrogen #/yr	Phosphate #/day	Phosphate #/yr	Potash #/day	Potash #/yr
Dairy Cow	1,300	0.5300	193.00	0.2170	79.20	0.4200	153.00
Dairy Cow	1,600	0.6500	238.00	0.2670	97.50	0.5200	188.00
Dairy Heifer	1,000	0.3100	113.00	0.0820	29.90	===	===
Beef Stocker	500	0.2000	73.00	===	===	===	===
Beef Feeder	1,000	0.3400	124.00	0.2520	92.00	0.3000	110.00
Horse	1,000	0.2700	99.00	0.1050	38.30	0.2100	76.60
Hog-Feeder	100	0.0450	16.40	0.0340	12.40	0.0360	13.10
Hog-Feeder	200	0.0900	32.80	0.0680	24.80	0.0720	26.30
Sheep-Feeder	100	0.0450	16.40	0.0150	5.48	0.0390	14.20
Laying Hen	4	0.0029	1.06	0.0026	0.95	0.0015	0.55
Broiler	4	0.0047	1.72	0.0024	0.88	0.0017	0.62

Manure generation in Washington State

Table 3 provides estimates of the annual quantity and nutrient quality associated with manure generated by the primary types of livestock in Washington State. These estimates are based on the United States Department of Agriculture's 2017 census data (USDA, 2019) along with application of the data contained in Tables 1 and 2. In total, about 10 million tons (imperial units) of manure are generated annually which equates to about 1.7 million tons when considered on a dry weight basis. (Typical levels of moisture content being about 80%.) The overwhelming majority of the manure is generated by dairy-associated cattle (44% of annual total) followed by feedlot-based cattle (27%) and beef cattle (19%). Overall, nitrogen and phosphorus represent about 4% and 2%, respectively, of the manure (on a dry weight basis). (Nitrogen representation will decline somewhat with waste stabilization (i.e. composting) due to losses associated bacterial-based processes – air emissions).

The scale of manure generation in Washington State underlines the importance of its proper collection, stabilization, and utilization limiting its potential to pollute Washington's surface and ground waters.

Table 8. Manure generation in Washington State along with N and P content (weight and percent representation), by animal type (imperial units)

Animal Type	Population – 2017	Manure Generation-Wet Weight tons/yr	Manure Generation-Dry Weight tons/yr	Nitrogen-Dry Weight tons/yr	Phosphorus-Dry Weight tons/yr
Chicken (broilers)	3,917,848	200,202	70,071	3,369 (4.8%)	1,724 (2.5%)
Chicken (layers)	7,128,683	273,207	95,622	3,778 (4.0%)	3,386 (3.5%)
Pullets	1,703,852	===	===	===	===
Cattle and Calves	1,155,544	===	===	===	===
Cattle (beef)	224,013	1,839,710	275,956	13,889 (5.0%)	10,305 (3.7%)
Cattle (milk)	282,804	4,387,000	658,050	33,654 (5.1%)	13,787 (2.1%)
Cattle (on feed)	243,272	2,663,833	399,575	15,083 (3.8%)	11,191 (2.8%)
Goats	29,392	===	===	===	===
Hogs	19,809	46,997	10,809	325 (3.0%)	246 (2.3%)
Horses	52,694	432,749	151,462	2,608 (1.7%)	1,009 (0.7%)
Sheep and Lambs	52,329	38,200	11,460	429 (3.7%)	143 (1.3%)
Turkeys	5,902	===	===	===	===
Totals		9,881,898	1,673,006	73,135 (4.4%)	41,790 (2.5%)

Collection

Manure moisture level determines collection and storage pathways

As presented in Table 1, typical manure moisture levels range from around 90% for dairy cows to around 50% for poultry. Aside from animal type, moisture levels also vary depending on factors such as feed type, and operation specific characteristics such the representation of water and bedding in the overall waste stream. Given this, manure may be in the form of a liquid, slurry, semi-solid, or solid. This factor, in turn, dictates how it can be handled influencing its pathways of collection, transfer, storage, and selection of spreading equipment.

In general, manure in the 85-92% moisture range is handled as a liquid/slurry and commonly uses lagoon storage while manure with a moisture content less than 80 – 85% tends to be handled as a solid and stored in stacks/piles for storage or composting. Following storage and stabilization, both pathways ultimately converge with land application.

As discussed previously, this section of the manure guidance will focus on manure in a solid form following a composting pathway for storage and stabilization. The alternative pathway with lagoon storage will follow in supplementary guidance. From Table 1, animals (and operations) producing lower moisture manure in a more solid form include: beef cattle, horses, and poultry. Livestock production with typically higher moisture levels that commonly use lagoon storage are associated with dairy and hog production. (Hog production has a low presence in Washington.)

Collection Methods and Frequency

Methods of collection and transfer of solid forms of manure can range from a simple shovel and wheel barrow, for a very small farming operation, to the more typical tractor-equipped scraper and front-end loader. Ideally, manure (and soiled bedding) should be collected every one to three days from turnouts, barns, and stalls, and confinement areas (Harwood, 2005). Frequent collection reduces mud production (saturated soil and intermingled urine and feces), an ideal breeding ground for parasites, flies, mosquitoes and other pests. In addition to protecting animal health, frequent manure collection limits the potential of its migration and potential to contaminate surface and ground waters.

Storage – Design Considerations

Once solid manure is collected it follows two common pathways: storage or direct land-application. In western Washington, the period when manure can be directly land applied, without environmental risk, is limited due to relatively high and persistent precipitation which extends from approximately mid-September to mid-April. This is a period when surface water is most vulnerable to pollutant runoff and the reason the capacity to store and stabilize manure becomes a necessity.

Manure storage systems range from the simple - stacked onto the ground and covered with a weighted-tarp (“pasture stacking”) to a dedicated structure with central elements a concrete slab and stem-walls, and an overhead roof equipped with gutters and downspouts. This guidance advocates that manure be stored in a covered structure because it allows for the proper management of moisture levels, facilitating aerobic decomposition, in addition to providing control of leachate migration. Pasture stacking of manure is not advised due to the potential leaching of nitrate to groundwater, despite a cover being present, and the additional loss of nitrogen (i.e. air emissions) due to the generation of anaerobic conditions. (Pasture stacking is described by the Natural Resources Conservation Service (NRCS) as Short term storage of animal waste and by-products – code 318.)

An additional benefit of a covered structure is that it provides flexibility with scheduling field spreading, avoiding periods when wet ground conditions occur and can instead target an optimal window for crop nutrient uptake and soil enhancement. A covered composting structure has added benefits because it allows for the management of pile moisture levels, a critical attribute in optimizing composting processes.

Factors to consider when locating and eventually operating the storage structure include:

- Ideally, the site should be located away from any surface water (perennial, intermittent, or ephemeral) at least 215-feet for western Washington locations and 150-feet for eastern Washington locations, conforming to the riparian buffer guidance recommendations.
- Consist of a concrete slab with stub walls and roof coverage
- The roofing system should include gutters and downspouts that direct collected precipitation away from the structure with off-site infiltration optimal (i.e. French drain or vegetative filter strip). For structures not having the ability to install a rain collection system (i.e. hoop-type roofing systems) then roof runoff should be sequestered from the storage pad through the use of berms
- Have a design storage capacity sufficient to accommodate manure generation until land application is suitable – typically a period of about 7-months, mid-September through mid-April
- Have sufficient surface area to provide for storage requirements while allowing for handling equipment (tractor/loader) access and maneuverability
- A hardened entrance to the structure (typically gravel) to limit the generation of mud in the more highly trafficked zones
- Located as close as possible to the primary manure source areas, minimizing transport time, labor, and fuel costs
- If excessive leachate is expected from fresh-manure then the slab should be designed using sloped surfaces to collect the leachate, directing it to down-wells to provide temporary storage. The leachate can be recycled to increase compost pile moisture levels, held in storage until conditions allow for field application, or directed to an adjacent treatment system such as a vegetated filter strip when weather and ground saturation conditions allow for its use

It's recognized that some livestock operations may not take the recommended more involved composting pathway and instead just collect and store manure until it can be field spread in the spring. This guidance recommends that the same storage structural and environmental considerations, as outlined for composting, still be applied.

Storage Area/Volume Required

Manure storage requirements are based on the amount of manure generated which, as previously discussed, is a function of the number and types of livestock present along with the type and amount of bedding material used, if applicable. Additionally, the storage period must be considered which is determined both by the length of time for complete composting and for when crop and weather conditions are more optimal for land application. As mentioned, typically a storage capacity should be able to accommodate up to a 7-month manure/bedding inflow level. This provides flexibility with the timing of land application of the compost gaining the greatest possible benefit from it while avoiding periods when saturated ground conditions occur, a situation that could lead to contaminated runoff to surface waters.

Treatment (Composting Considerations)

The preferred pathway for manure, once collected, is composting; an aerobic bacterial-driven process that leads ultimately to organic matter stabilization – the reduction in the manure moisture content and mass. Additionally, a properly managed composting process can destroy weed seeds, plant and human pathogens, all of which present a liability when fresh manure is directly land applied.

The benefits of a manure composting pathway include:

- It reduces the volume and mass of manure through bacterial-based decomposition
- Provides for the inactivation of weed seeds and pathogens
- Enables the use of a drier, stabilized organic nutrient source at optimal times to maximize soil and crop enhancement while minimizing the risk of pollutant migration to surface waters

Optimizing the Composting Process: managing carbon, moisture, air, and heat

The composting process is based on maintaining a balance of carbon (C) and nitrogen (N) availability while supplying both sufficient oxygen and moisture levels, all directed toward providing an optimal environment for aerobic bacterial growth.

Optimized composting has the following characteristics:

- A carbon to nitrogen (C:N) ratio of between 20 - 40 to 1
- A moisture content between 40 - 60%, by weight
- pH maintained between 6.5 and 8.0
- A sustained pile heat level of between 110°F - 150°F

Carbon to Nitrogen Ratio

In terms of nutrient levels, an ideal carbon to nitrogen (C:N) ratio for manure composting is between 20 and 40:1 (Chen, 2011). Manure that contains more nitrogen than bacterial decomposers can use results in the release of nitrogen as ammonia gas (NH_3) or as soluble nitrate (NO_3^-), depending on the pile water and oxygen levels, potentially reducing air and water quality while also reducing its value as a source for plant nutrients. With too little nitrogen, much of the carbon is not used due to bacterial growth limitations, a consequence being that the manure compost may not heat up (heat is an indicator of bacterial activity) enough to kill weed seeds and pathogens.

Some manures, such as those derived from pig or poultry sources, can be too wet and contain too much nitrogen to compost well on their own. This imbalance is often corrected by adding dry, high carbon materials such as wood chips, straw, or organic bedding. (Manure provides most of the nitrogen with bedding providing the carbon in many poultry composting situations.) These additions also provide structure to the pile, maintaining adequate pore space for aeration. Sheep, goat, horse, and cow manures tend to have C:N ratios that do not require carbon additions.

Aeration
Common methods of aeration for composting systems include:

- Passive aeration
- Turning - mechanical mixing
- Forced aeration/aerated static pile
- In-vessel systems (composting reactors)

Composting is an aerobic process and the most efficient method to ensure an adequate supply of oxygen throughout the manure pile is to turn it mechanically. Aeration keeps the biological processes from becoming anaerobic and allows the compost to reach and maintain optimum temperatures. Internal pile temperatures provide a good indicator on when turning should occur – it being an indicator of the level of bacterial activity.

The maximum composting rate occurs when the internal pile temperature is between 110°F and 150°F. Temperatures should remain within that range for at least 15-days to ensure the elimination of pathogens, weed seeds, and parasites (Bradley, 2019). The Washington Advisory Code (WAC) 173-350-220 stipulates compost temperatures achieve at or above 131°F for at least 3-days, between each of five consecutive turning events. Turning ensures that all parts of the pile are exposed to these temperatures while providing aeration and the release of trapped heat and gases. An indicator of when a pile should be turned is when the internal temperature drops below 110°F, a sign of declining microbial activity.

The compost process enters the curing phase of composting once temperatures can no longer be maintained within the 110°F and 150°F range and the process approaches completion when pile temperatures do not rise more than 15 degrees above the ambient air temperature following turning.

In less managed settings, a static (unturned) pile composting approach can be used but it requires increased attention to facilitating air flow within the stack typically using perforated pipes placed vertically into the pile or horizontally under the pile along with increased pile porosity through the addition of straw or wood chips. A more active approach to supplying air is to use a pumping system to blow or suck air through the pile / piping system. This process allows for a more expedient composting process (3 to 5 weeks) but is often burdened by pipe clogging and increased costs.

The adoption of other composting methods will depend on the scale of the operation in terms of manure production and level of effort an operation has dedicated to the compost process. For relatively small operations, mechanical rotating drums can be used to store and turn the compost. For large operations (i.e. feedlot) the manure / compost pile can take the form of a windrow which is turned by specialized machinery or a front-end loader. Despite scale differences the same fundamental biological principals and management actions apply.

Moisture

Having the correct moisture level is a critical variable in compost management. Without enough water, even with ideal carbon to nitrogen ratios, the composting process will be sub-optimal or non-existent. The moisture content of the compost pile ideally should be around 40 to 60% after the original mixing (Chen, 2011). Moisture levels above 60% limit air movement resulting in potentially anaerobic conditions. Below about a 40% moisture level becomes a limiting factor for bacterial growth. Given this ideal range, it may be necessary to add water or recycled leachate if the compost becomes too dry. Having a roof cover over the compost pile allows for controlled management of moisture levels. Additional factors include sun exposure, relative humidity, and ambient air temperature, all affecting moisture retention.

The “squeeze test” provides a rough guide on appropriate moisture conditions. When a handful of the blended compost material is squeezed that that has a moisture level of around 50%, it will feel damp but not soggy. As pile turning facilitates aeration and temperature distribution it also redistributes moisture.

Leachate: Containment and Treatment

In this context, leachate is contaminated water that drains from a manure pile during the storage/composting process with its production greatest when fresh manure is initially collected and stacked. Due to its high nutrient and bacterial levels, leachate, if uncontrolled, can potentially contaminate surface or groundwater with adverse impacts to animal and human health. Therefore, the leachate management must be a considered component of any storage/treatment manure composting process. The level of leachate generation is going to be operation-specific and dependent on factors such as fresh manure moisture levels, in-flow rate, and the level of bedding and sources of carbon added as part of the overall waste stream. This is a factor that should be evaluated in the initial design phases of a manure management system.

If leachate generation is expected, then the slab on which the compost pile will be situated should be designed for its collection and potential re-use. This can be accomplished through sloped surfaces that collect the leachate and direct it to a down-well for temporary storage. In areas of low annual precipitation, unroofed storages frequently are used. Despite lower precipitation, these situations still pose an environmental risk due to the expected increased leachate generation and should be collected and stored.

Once collected, leachate can be managed through several pathways including:

- Recycled as a source of moisture for the compost pile
- Stored and applied to crops during the dry season (depending on the level of leachate production)
- Through controlled drainage, directed to a vegetative filter strip situated near the compost facility during the dry season (refer to Natural Resources Conservation Service (NRCS) field office technical guide (FTOG) number 393).

Effectiveness

Fresh manure has elevated bacteria, nutrient, and organic content and its application to fields during the wet winter months presents an unacceptably high risk of contamination to both surface and groundwater. In comparison, the stabilization of manure, preferably through composting, reduces its volume, water, and nutrient content while eliminating pathogens and weed seeds. Importantly, it also provides flexibility for the timing of its land application avoiding periods when wet ground conditions occur, instead allows for a targeted window for crop nutrient and soil enhancement opportunities, reducing the potential for adverse environmental outcomes.

Aboveground Storage Tanks-Liquid Manure

For challenging settings such as chronically elevated water table elevations, shallow depth to bedrock, fabricated manure storage tanks provide an effective storage alternative. Tank construction is either concrete or, more commonly, coated metal (glass-lined steel). They are typically situated above ground but can also be fully or partially below ground. The decision making involves environmental constraints and considerations for manure collection and transport (i.e. pumping costs). A benefit of tank storage is that they occupy less area in comparison to typical sub-grade lagoons and that for above ground siting that they allow a visual confirmation of wastewater containment. The floor of an above ground steel tank is comprised of poured in place concrete. Since the tanks tend to be deeper than lagoons agitation of bottom sludge is integral to the tank design.

Confinement, Manure Handling and Storage References

Annotated Bibliography—Heavy Use Area

1) Briggs, Nathan, R. Lemenager. April 2020. Heavy Use Area Pads for Cattle. Penn State Extension – College of Agricultural Sciences. Heavy Use Area Pads for Cattle (psu.edu)[14]

   This Penn State Extension paper advocates for the construction of a geotextile / gravel pad for livestock heavy use areas based on its reduced cost (in comparison to concrete) while it effectively addressing the generation of muddy conditions, a situation that compromises animal health and the environment. A sequenced construction method is provided.

2) Clark Conservation District. Washington State University Extension. – Clark County Clean Water Program. N.D. Sacrifice Areas – Reduce Mud and Keep Water Clean. Living on the Land Series.

   This Clark Conservation District informational paper discusses key considerations in the creation of a sacrifice area including it area, footing type, fencing, and drainage. The paper advocates the use of a surrounding grass buffer (vegetative filter strip) that receives pad runoff. A grass buffer width of 25-feet, for a low slope setting, is

[14] https://extension.psu.edu/heavy-use-area-pads-for-cattle

recommended. A table is included that compares several commonly applied footing types based on longevity, cost, and applicability.

3) Frazier, Jeffery. N.D. Heavy Use Areas for Livestock. Skagit Conservation District.

This informational pamphlet produced by the Skagit Conservation District is directed toward small landowners with livestock. It advocates for the creation of confinement / sacrifice areas to protect animal health and water quality. A confinement area is a gravel, concrete, or wood chip ("hog-fuel") area that is used to contain animals and keep them off pastureland from late fall through early spring (October through March). A sacrifice area is defined as a small enclosure, such as a corral, run or pen, a small portion of land (previously used for grazing) for forage protection and recovery. Sacrifice areas are best applied during the rainy season and when pastures can be overgrazed.

4) Higgins, Steve. July 2008. Using Dry Lots to Preserve Pastures and Reduce Pollution Potential. University of Kentucky, College of Agriculture – Cooperative Extension. ID-171.

This University of Kentucky College of Agriculture paper advocates the use of designed dry lots for permanent heavy traffic (use) areas. (In this context a dry lot is synonymous with a pasture sacrifice area.) The dry lot keeps animals in a confined area to prevent them from damaging pasturelands. A typical dry lot contains water sources, feeders, and mineral supplement. The area can be used for wintering animals, handling animals for medical treatments, reducing calorie intake for obese horses, and additional uses.

5) Higgins, Steve, Stephanie Mehlhope, Lee Moser, and Sarah Wightman. October 2017. Appropriate All Weather Surfaces for Livestock. University of Kentucky College of Agriculture, Food and Environment Cooperative Extension Service. AEN-115.

This University of Kentucky College of Agriculture paper discusses various livestock heavy use area surfaces to prevent muddy conditions. The paper presents the case that by providing for a livestock heavy use area (i.e. installation of a hardened surface) increases production and profitability by decreasing unhealthy conditions (generation of mud). In addition to discussing various footing surface types, additional topics include siting and site preparation. Footing materials considered include concrete, geotextile fabric and gravel, and gravel paver grids.

6) Midwest Plan Service. July 1999. Using All-Weather Geotextile Lanes and Pads. Agricultural Engineers Digest, AED 45.

This Midwest Plan Service publication discusses the benefits of installing a geotextile/gravel pad in livestock heavy trafficked areas. In comparison to concrete as a surface for lanes and pads, geotextiles require increased maintenance and not able to withstand as much heavy equipment traffic or cleaning, but they provide many of the benefits of concrete and can be installed for about one-third the initial cost. Sample layouts are provided for feeding and watering areas, feed and manure stacks, flooring for equipment and animal sheds, and traffic lanes. Key considerations in the installation of a geotextile/gravel pad are presented. An example is provided for assessing costs associated with the installation of various pad types including gravel, geotextile/gravel, asphalt, and concrete in a dairy setting.

7) Snohomish Conservation District. ND. Fact Sheet – Sound Farm Resources, Heavy Use Areas.

https://snohomishcd.org/sound-farms-resources/2016/3/17/livestock

This informational bulletin, produced by the Snohomish Conservation District, provides useful considerations for the siting and construction of a livestock heavy use area for a small livestock operation. In terms of pad sizing, it is suggested to provide for a minimum area of 400-square feet per animal. It suggests that manure should be removed from the pad surface every one to three days.

8) Turner, Larry. August 1997. Using Geotextiles for Feeding and Traffic Surfaces. University of Kentucky – College of Agriculture. Cooperative Extensive Service. AEN-79.

This University of Kentucky College of Agriculture paper advocates the use of a geotextile fabric foundation with overlying gravel aggregate as a footing surface for areas of animal congregation (feeding and high traffic zones). An all-weather surface can be constructed of geotextile fabric, rock, and fine surface cover for less than one-third of the cost of concrete (an alternative footing type). Rock over bare soil in Kentucky requires approximately 12 inches of depth for stability, but using rock over geotextile fabrics can reduce rock depth by half. Repeated maintenance usually required for rock pads is also reduced because the fabric keeps the rock in place. The cost of geotextile pads is about \$0.49/ft^2, while concrete costs in the range of \$1.50/ft^2. One reason for the lesser cost is that less rock is required for stability when geotextile fabrics are used. An example of a feeding pad layout applying geotextile fabric and aggregate are provided.

9) United States Environmental Protection Agency (USEPA). 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters. Chapter 2: Management Measures for Agriculture Sources. EPA 840-B-92-002.

https://www.epa.gov/nps/guidance-specifying-management-measures-sources-nonpoint-pollution-coastal-waters

Chapter 2 in the United States Environmental Protection Agency document: Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Water provides, among other considerations, the relative effectiveness of pollutant removal based on varying types of best management practices. The setting is surface runoff from a livestock confinement area and the best management practices examined included storage basins, storage basins followed by vegetated filter strips, and vegetated filter strips solely. Average pollutant removal efficiencies were reported in two tables based on the citations included below. It is acknowledged that effectiveness depends on many factors including: the contaminant(s) and their likely pathways in surface, subsurface, and groundwater flows and site-specific variables such as soil type, topography, precipitation characteristics, type of animal housing and waste storage facilities, method of waste collection, handling and disposal, and seasonal variations.

a. Adam, Real. 1986. Evaluation of Beef Feedlot Runoff Treatment by a Vegetative Filter Strip. ASAE North Atlantic Regional Meeting. Paper No. NAR 86-208.

b. Edwards, W.M., L.B. Owens, and R.K. White. 1983. Managing Runoff from a Small, Paved Beef Feedlot. Journal of Environmental Quality, 12(2).

c. Edwards, W.M., L.B. Owens, R.K. White, and N.R. Fausey. 1986. Managing Feedlot Runoff with a Settling Basin Plus Tiled Infiltration Bed. Transactions of the ASAE, 29(1):243-247.

d. Pennsylvania State University. 1992a Nonpoint Source Database. Pennsylvania State University, Dept of Agricultural and Biological Engineering, University Park, PA.

e. Pennsylvania State University. 1992b. College of Agriculture, Merkle Laboratory-Soil & Forage Testing, University Park, PA.

Annotated Bibliography—Manure Management

1) Andersen, Daniel, Jay Harmon, Steven Hoff, Angela Rieck-Hinz. 2014. Manure Storage and Handling- Composting Overview. Iowa State University Extension and Outreach. Air Management Practices Assessment Tool (AMPT) - 16.

   This Iowa State University Extension and Outreach paper advocates for a composting pathway for manure storage and stabilization. Composting produces less odor than stockpiling, creates a more stabilized and uniform product for land-application, reduces the presence of pathogens and weed seeds, and creates a more nutrient dense product that is more economical to haul. An overview of the primary metrics for efficient composing are discussed including carbon to nitrogen ratios, moisture, temperature and turning considerations.

2) Bary, Andy, Craig Cogger, Dan Sullivan. July 2004. Fertilizing with Manure. Washington State University Extension. Farming West of the Cascades Series. A Pacific Northwest Extension Publication – PNW0533.

   This Washington State University Extension publication, oriented toward small to mid-sized crop producers, discusses how to manage solid animal manures to provide a supplemental nutrient source. Methods to determine manure application rates based on the type of manure and the crops it will be applied to are presented. The paper identifies three main sources of variability and uncertainty when using manure including: the nutrient content of the manure, the actual availability of manure nutrients to crops, and application rates. To reduce this variability, it is advised that the nutrient content of the manure be initially determined through laboratory testing. Application rates will be based on the nitrogen content of the manure and its availability which is determined by the type of manure, and handling methods. This information provides the basis for land application. It is advised that soil testing be used as a feedback loop to better inform the effect of manure applications on crop production and soil nutrient levels.

3) Bradley, Athena Lee. May 2019. Manure Management for Small and Hobby Farms. Northeast Recycling Council Inc.

This Northwest Recycling publication outlines principal considerations for the management of manure for small farming operations. The stated goals of a manure management system are to utilize manure nutrients for enhancing soil quality, protecting the health and safety of the public and livestock, and preventing surface and groundwater contamination. It is advised that these goals can best be met through the adoption of a manure management and utilization plan. That plan would take into consideration the following: manure and bedding inflow rates, manure handling and collection methods, storage infrastructure, drainage sequestration, manure (compost) nutrient understanding for effective utilization, records of application and soil analyses serving as an information feedback loop. The paper then discusses each of these various aspects of the manure plan including composting methods.

4) Brewer, Linda, Nick Andrews, Dan Sullivan, Will Gehr. June 2013. Agricultural Composting and Water Quality. Oregon State University Extension Service. EM 9053.

This Oregon State University Extension Service publication presents the case for composting manure as a means of protecting water quality while also providing an on-farm source for soil enhancement. When applied to the soil, compost improves soil physical properties like water infiltration, aggregate stability, and water-holding capacity; soil chemical properties like nutrient content and cation exchange capacity; and soil biological properties like disease suppression and nutrient cycling.

Planning aspects for a composing system are presented including site selection, layout and design, and pile turning methods. Additionally, indicators for compost optimization are discussed including carbon to nitrogen ratios, temperature, and moisture levels.

5) Chen, L., A. Moore, M. de-Haro-Marti. On Farm Composting Management. University of Idaho Extension. CIS 1190.

This University of Idaho Extension document examines optimal feedstock mixes and how to manage manure compost for aeration, moisture, and odor levels. A series of tables and sample calculations are provided that examine feedstock mixes (manure and bedding) carbon to nitrogen ratios, porosity, and bulk density.

6) Chen, L., M. de-Haro-Marti, A. Moore. 2011. The Composting Process. University of Idaho Extension. CIS 1179.

This University of Idaho Extension paper initially describes the composting process from a biological perspective and transitions to what attributes are best managed to optimize the process. Those factors include the monitoring of carbon to nitrogen ratios, moisture, oxygen, and temperature levels. Ideally, the carbon to nitrogen level should initially be in the range of 25 to 35:1. Moisture levels should be maintained in the range of 50-60% by weight. Oxygen levels, largely maintained through pile turning, should be held more than 10%. The internal temperatures should be maintained at 130-150^{o}F.

7) Cooperband, Leslie. March 2002. The Art and Science of Composting. University of Wisconsin-Madison. Center for Integrated Agricultural Systems.

This University of Wisconsin-Madison document presents the basics of setting up an optimal manure composting environment with chief attributes including ideal feedstock carbon to nitrogen ratios, particle size and bulk density, pile moisture and oxygen levels and temperature. Additionally, composting technologies are discussed including static piles, windrow composting, passively aerated windrows, forced aeration, and in-vessel composting.

8) Dougherty, Mark. Field Guide to On-Farm Composting. Plant and Life Sciences Publishing. NRAES-114.

9) EPA Office of Water. Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria. EPA – 820-S-15-011, February 2015.

   Fact sheet that describes the scientific basis supporting controlling both N and P to prevent eutrophication and the proliferation of harmful algal blooms.

10) Gamroth, Mike. May 2012. Composting: An Alternative for Livestock Manure Management and Disposal of Dead Animals. Oregon State University Extension Service. EM 8825.

    This publication by the Oregon State University Extension Service presents the benefits of composting of livestock manure. The paper presents a discussion of the four main factors to consider in optimizing composting including: aeration, nutrient balance (carbon to nitrogen balance), moisture, and temperature. Composting methods and pile turning options are also presented.

11) Goodwin, D., J. Moore. 1997. Manure Management in Small Farm Livestock Operations. Oregon State University Extension Service. EM-8649.

    This publication from the Oregon State University Extension Service provides small landowners, with livestock, advice on effective best management practices that protect water quality. The focus is not on manure management but on considerations for protecting water quality from livestock waste in general. Best management practices discussed include limiting animal access to surface waters, use of vegetative filter strips, manure pile storage and covering, precipitation collection and diversion, and winter period pasture management.

12) Harwood, Erin. December 2005. Managing Manure – Strategies for Collection, Storage, and Disposal. Washington State University Extension – Clark County; Clark Conservation District; Clark County Clean Water Program.

    This Clark County Conservation District publication describes practical information for the management of manure for small farms. Topics covered include manure collection (frequency), storage (based on animal type and number along with bedding considerations. Composting methods are described.

13) Higgins, Stephen, Stephen Workman, V. Nicole Gallagher, Donald Stamper, Robert Coleman. 2008. University of Kentucky Cooperative Extension. College of Agriculture. Composting Horse Muck. ID-168.

This University of Kentucky Cooperative Extension paper outlines the principal considerations when undertaking the composting of horse manure. Those considerations include optimizing compost carbon to nitrogen ratios, moisture, oxygen, and temperatures levels. It was observed that horse manure has a carbon to nitrogen ratio typically around 10 – 18:1 whereas optimal compost is around 30:1. The inclusion of bedding (straw / wood shavings) can offset this carbon deficiency to some extent. "Muck", horse manure and bedding, typically has a carbon to nitrogen ratio of around 50:1. Suggested means to increase carbon include the addition of straw, dried leaves, wood shavings, sawdust, and dried grass. Sources for nitrogen include green grass, ammonium nitrate, and beef / dairy manure (without bedding).

Moisture levels during composting should be maintained around 40 to 60%. It is suggested that water or recycled pile leachate be used to maintain optimal levels should they fall below 40% and pile turning be used to regulate moisture when they exceed 60%. Turning in addition to regulating moisture also allows for oxygen transfer to occur throughout the pile. It is suggested that the pile be turned 3-5 times every 2-3 days when the moisture content is between 40 and 70 percent.

Internal pile temperature provides an indication of the level of biological activity. The ideal temperature range is 135°F to 160°F. It is suggested that pile temperatures be maintained at approximately 150°F to kill the eggs of parasites, oocysts (dormant larvae in a capsule-like sac), and flies. (No suggested period is provided.)

14) Miner, R. 1995. Livestock Manure Management – Reducing the Risk of Groundwater Contamination. Oregon State University Extension. EM-8597.

    This Oregon State University Extension paper examines the use of manure to provide for crop supplemental nitrogen and phosphorus while preventing losses associated with surface runoff and infiltration to groundwater (beyond the root zone). A series of tables are provided to estimate nitrogen and phosphorus availability based on animal type, manure storage method, method of land application, and proximity (within Oregon).

15) United States Department of Agriculture, Natural Resources Conservation Service (NRCS). March 2008. Part 651 Agricultural Waste Management Field Handbook. Chapter 4, Agricultural Waste Characteristics.

    Chapter 4 of the United States Department of Agriculture, Natural Resources Conservation Service Agricultural Waste Management Field Handbook presents typical physical and chemical characteristics for a variety of common livestock manures. Animal waste streams discussed include dairy, beef, swine, poultry, veal, sheep, horse, and rabbit. Operational influences on waste quality are presented which include wasted feed, wash/flush water, and bedding. Additional influences discussed include the level of precipitation/evaporation, intermingled soil, and biological activity. Base information is provided in a series of tables. Numerous sample calculations are provided that apply the table data to determine common livestock-related concerns.

16) United States Department of Agriculture (USDA). April 2019. 2017 – Census of Agriculture. United States – Summary and State Data. Volume 1. Geographic Area Series. Part 51. AC-17-A-51.

Census 2017 Report (usda.gov)[15]

Every five years the United States Department of Agriculture conducts a comprehensive assessment of national farms (i.e. size), farmers (i.e. age, gender, race), and production (i.e. quantity and value of crop and livestock output). The data are reported at the county level and remain generalized, not tied to specific farming operations. Since much of the reported data remains consistent census to census it is useful for trend analysis.

[15] https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

Chapter 11 Appendix Part B: Implementation Considerations (Livestock Management: Animal Confinement, Manure Handling & Storage)

Animal Confinement Areas

Introduction

Any time animals are confined (temporarily or permanently), there is a risk of manure and other waste build up that, when left unmanaged, can lead to runoff of pollutants in nearby water bodies and increase the potential for leaching to groundwater. This chapter focuses on best management practices (BMPs) to help prevent impacts to water quality from these types of areas. Confinement areas can range from smaller sacrifice areas (temporary animal confinement) to large feedlots. Inclusion of sacrifice areas as part of a pasture and rangeland management plan is considered a BMP. As such, this chapter provides more information on implementation, construction, and maintenance of sacrifice and confinement areas. The goal is to prevent pollution from leaving the site by appropriately locating confinement areas, diverting clean water around these areas, and containing stormwater to prevent discharge to surface water.[16]

Sacrifice areas are defined by the Natural Resources Conservation Service (NRCS) NRCS as "fenced-off, small portions of a grazing management unit intentionally overgrazed and heavily trafficked to prevent lasting damage to the entire unit".[17] Sacrifice areas are typically employed by producers in Washington state between October and May when precipitation is high and when grazing can be detrimental to plants, soils, and water quality. Depending on the time of year, sacrifice areas could qualify as winter feeding operations and be subject to state or federal permitting requirements if there is discharge of pollutants to water bodies. Sacrifice areas may also be used late in the grazing season or during periods of drought to either avoid damage to recovering plants or separate sick or injured animals while they recover. The main goals of sacrifice areas are (1) to ensure the majority of grazing lands are rested to stay productive; and (2) to prevent negative impacts to water quality. Sacrifice areas can be utilized for various animals, including cattle, horses, sheep, and others.

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[16] Many projects that require ground-disturbing remedial action are funded with state, capital budget, or NRSDA funds. These funding sources require a cultural resources review by the Department of Archaeology and Historic Preservation and Tribes to identify any potential impacts to cultural resources before the project begins. This is required by Executive Order 21-02 (https://www.governor.wa.gov/sites/default/files/exe_order/eo_21-02.pdf) and once the cultural resource permit as well as a cost share application is submitted, there is a 30-day comment period before construction can begin. In addition, a contractor is needed and there will be project inspections throughout the process.

[17] NRCS Conservation Practice Standard, Prescribed Grazing, Code 528, 2019 (https://efotg.sc.egov.usda.gov/api/CPSFile/23095/528_NC_CPS_Prescribed_Grazing_2019)

Feedlots, and other animal feeding operations (AFOs) are typically larger operations—concentrated, confined animal growing operations for meat, milk, or egg production, or stabling where the animals are fed in the place of confinement without crop or forage production in the confinement area. The United States Environmental Protection Agency (EPA) defines an AFO as a lot or facility (other than an aquatic animal production facility) where the following conditions are met.[18]

- Animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period.
- Crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

AFOs that meet the regulatory definition of a concentrated animal feeding operation (CAFO) are regulated under the National Pollutant Discharge Elimination System (NPDES) permitting program. The NPDES program regulates the discharge of pollutants from point sources to waters of the United States and CAFOs are point sources, as defined by the CWA [Section 502(14)]. This guidance only applies to non-permitted operations.

Animal Confinement Area BMPs for Clean Water

There are various BMPs to stop water from running off areas where animals are confined. These BMPs can divert clean water from initially entering the animal confinement area, filter, settle, or infiltrate water that is already in the animal confinement area. Additionally, these BMPs can support efforts to stabilize areas to reduce soil erosion, improve water quality, and facilitate manure collection. The table below lists BMPs by method of limiting runoff and erosion. This table is meant to provide an overview of options that producers can implement and more detailed implementation information will be provided in other chapters of this guidance.

Table 9. Summary of Methods to Limit Runoff and Erosion in Animal Confinement Areas

Method of Limiting Runoff and Limiting erosion	Best Management Practice	Description
Diversion of Clean Water	Diversion Channels (362)	Earthen channel constructed with long slopes and supporting ridge on either side.
Diversion of Clean Water	Field Borders (386)	A strip of permanent vegetation established at the edge or around the perimeter of an animal confinement area.

[18] NPDES Permit Writers' Manual for CAFOs; https://www3.epa.gov/npdes/pubs/cafo_permitmanual_chapter2.pdf

Method of Limiting Runoff and Limiting erosion	Best Management Practice	Description
Diversion of Clean Water	Grass Waterway (412)	Shaped or graded channel established with suitable vegetation to carry surface water at non-erosive velocity to a stable outlet.
Diversion of Clean Water	Roof gutters (558)	Structure consisting of gutters, downspouts, and outline line.
Diversion of Clean Water	Underground Outlet (620)	A system of conduits installed under the ground surface to convey surface water to a suitable outlet.
Filtration, Settling or Infiltration of Runoff	Riparian Buffers (391)	A buffer of trees and shrubs established along the riparian corridor to provide stability, filtration, and shade.
Filtration, Settling or Infiltration of Runoff	Vegetation Filter Strips (393)	A strip or area of herbaceous vegetation that removes contaminants from overland flow. Practice includes seedbed preparation and planting of introduced species.
Filtration, Settling or Infiltration of Runoff	Stormwater Basins (350)	A basin to collect and store polluted stormwater.
Stabilizing areas	Heavy Use Area Protection (561)	Practice that helps address soil erosion, provide stable surfaces for areas used by animals, facilitates manure collection, and promote water quality.
Stabilizing areas	Trails and Walkways (575)	Practice that helps address soil erosion, and provide stable surfaces for areas traveled by animals.

Benefits of Adopting Animal Confinement Area Best Management Practices

Sacrifice Areas

Adoption and inclusion of sacrifice areas in a grazing management plan can lead to environmental benefits as well benefits to producers' operations. Environmental benefits include improved desired specifies composition of forage across the pasture and rangeland, subsurface water quality, riparian and/or watershed function, and soil health. Sacrifice areas can also reduce soil erosion from grazing areas.[19]

Sacrifice areas can strengthen producers' operations through the following pathways.[20]

- Contain livestock in non-grassy areas to reduce intake of parasite larvae;
- Provide time for pasture regrowth prior to summer grazing;
- More easily isolate animals for injuries or other reasons;
- Dry-lotting of horses that overheat;
- And provide shelter during inclement weather.

Managing stormwater

Practices that limit the amount of runoff and standing water through and in the area of operation have several benefits. For example, proper management of runoff and standing water in feedlot areas can reduce the amount of standing water and/or potholes, which lowers the likelihood of injury or diseases such as hoof rot.

Mortality Management

Managing mortality is an important aspect of animal operations that has its own associated costs, implementation considerations, and requirements. Producers should refer to NRCS Guidance[21] on animal mortality management to reduce impacts to surface water and groundwater, reduce odor, and decrease spread of pathogens.

Costs of Adopting Animal Confinement Area Best Management Practices

Costs for animal confinement area BMPs can include both construction costs (i.e., fences, covered areas, water delivery and feed systems), implementation costs of clean water BMPs (i.e., establishing methods of diverting clean water and filtration/settling of runoff), animal mortality systems, and manure management systems (described more fully in a later section of this chapter). Below are general costs ranges for selected clean water BMPs according to the NRCS 2023 Washington Scenario[22] payment rates. Costs for materials and labor change regularly, and the costs below reflect 2023 rates.

Table 10. Costs of Adopting Animal Confinement Areas Best Management Practices

Best Management Practice	Costs
Diversion Channels	• A small diversion, less than or equal to 0.5 CY per LF is estimated to cost $3,327.78.

[19] NRCS Conservation Practice Standard, Prescribed Grazing, Code 528, 2019; https://efotg.sc.egov.usda.gov/api/CPSFile/23095/528_NC_CPS_Prescribed_Grazing_2019

[20] Using Sacrifice Areas to Protect Pastures, Oregon State University, 2016; https://smallfarms.oregonstate.edu/smallfarms/using-sacrifice-areas-protect-pastures

[21] Animal Mortality Facility (316) and Emergency Animal Mortality Management (368).

[22] https://www.nrcs.usda.gov/sites/default/files/2022-11/Washington-Scenarios-23-payment-rates.pdf

Best Management Practice	Costs
	• A large diversion, at >2 CY per LF is estimated to cost $20,748.71
Field Borders	• A one-acre field border is estimated to cost between $188.12 and $504.08 depending on the plant species selected for planting.
Grass Waterway	• A one-acre grass waterway is estimated to cost between $1,710.75 and $2,845.05. • A small grass waterway (<= .2 acres) is estimated to cost $1,271.55 or less.
Roof gutters	• There are a range of costs provided for roof runoff structures, depending on size of the operation, type of runoff system employed, and type of water storage utilized. • For very small systems, gutters can be installed for less than $2,000. • More sophisticated systems (e.g., underground outlets that divert roof water away from a facility) can run over $10,000 for large animal confinement operations.
Vegetation Filter Strips	• A vegetated filter strip can range from about $231.95 to $271.01 for a one-acre lot, depending on the plant species selected.

Implementation Considerations for Animal Confinement Areas

There are a number of considerations, including operations and maintenance and technical requirements, when establishing sacrifice areas or animal confinement areas. Whereas the table in the previous section provides general cost ranges for implementing associated clean water BMPs, the table below provides implementation considerations for animal confinement areas.

Table 11. Implementation Considerations for Animal Confinement areas

Considerations	Details
Costs (See table above for individual confinement area BMP costs.)	Footing Materials • Woven geotextile fabric: $1.47/square yard • Sand: $40.08/cubic yard • Gravel: $41.11 per cubic yard Watering Troughs

Considerations	Details
	• Watering troughs and tanks will be needed for animal confinement areas. • The cost of installing watering facilities can range from $1.50 per gallon capacity for a bottomless steel tank with liner to $40.67 per gallon capacity for a frost-free watering system. Fencing (Cost of Gate Included in Scenario Price per Unit) • Heavy use scenario where livestock pressure is expected: $9.28 per foot. • Fenced winter feeding or confined area scenario: $28.15 per foot.
Operational and Maintenance Requirements	Facilities (i.e., covered areas, footings, fences) • Maintenance of fencing (Refer to Chapter 10 - Livestock Management: Pasture & Rangeland Grazing). • Regular maintenance of downspouts and drainage systems. • Replacement of hogfuel, gravel, sand, and geotextile fabric as needed. • Regular checking of fences for damage. Manure Management • Sacrifice Areas: Clean manure daily or at least every three days for horses. • Feedlots: Stocking rate will drive the frequency of manure scraping needed; frequency can range from once a week to once a month. • Typically, horse owners clean sacrifice areas by hand whereas cattle owners use machines to clean animal waste.
Technical Requirements	Site Selection[23] • Choose an area that drains well and away from streams, ponds, swales, wetlands, or other clean water sources. Ideally, the area should on higher ground or graded to a slight slope (1-2% grade) to help drain water away. • Proper drainage will improve lifespan of footing materials. • Ideally, sites should be located at least 215 feet away from surface water (perennial, intermittent, or ephemeral) in western Washington and 150 feet away in eastern Washington. • In sites where this distance is not possible, surface water treatment is recommended. • The selection of surface water treatment can be determined based on the needs of the producer and on a site-by-site basis. • If developing a *sacrifice area* for the first time, keep chore-efficiency in mind, and try to locate confinement areas near stalls, feeding areas, and manure storage.

[23] Snohomish CD (https://s3.wp.wsu.edu/uploads/sites/2079/2014/02/sacrifice-areas.pdf)

Considerations	Details
	Fencing • Electric fencing can be used with horses and is recommended for hogs in place of barbed wire fencing. • Typically, barbed or tight fencing is used for cows since they may lean on/damage smooth fence. Footing Materials • In areas with quick, high flooding, have a raised farm pad in the sacrifice area. • Lining can be from several materials, including hogfuel, gravel and sand, and geotextile fabric. • If hogfuel is being used alone, it is recommended to use small sized hogfuel to easily remove manure and should be 18" to 24" in depth. • Gravel and sand are more long lasting than hogfuel, and should be at a depth of 6" to 12". Gravel and sand can be trampled and sink into the soil if directly applied and will need to be replaced periodically. Geotextile fabric can be used with other footings to improve drainage. A common footing application is a layer of geotextile fabric, 6" of gravel, 6" of sand, and topped with hogfuel.[24,25] • Sacrifice area surface materials should be added when the ground is dry and firm to avoid mixing of mud and material.[26] • Some horses are allergic to cedar which is a common component of hogfuel. If designing a sacrifice area for horses, avoid selecting cedar footings to avoid reactions.[27] • Woodchips can be appropriate for short-term use (1 to2 years). For example, some landowners may build large piles of woodchips for cattle to lie on which could take years to breakdown. Woodchips will breakdown quickly in areas that get more water. • Goats and sheep prefer deep sand which makes it easier for landowners to rake off manure, in comparison to using gravel and woodchips. • There have been cases where siltstone is suitable for sacrifice areas. • When there is a high percentage of silt or clay, geotextile fabric helps create a barrier between the clean, organic footing and native soil. • In some situations, such as gravelly soils or rocky substrate may be conducive to mechanical compaction. In these cases, geotextile fabric may not needed.
Lifespan	Footing Materials[28] • Hogfuel: Generally, 2 to 3 years, but can vary by quality of material. • Gravel: Indefinite but will require replacement material over time. • Sand: Indefinite but will need replacement over time. • Geotextile fabric with hogfuel, gravel, or sand: Indefinite but will need replacement over time. • Woodchips: 1 to 2 years.

Considerations	Details
	Fencing • 10 to 15 years but longer with proper maintenance and selection of appropriate fencing types for animal/level of use. Other Clean Water BMPs • Diversions, settling basins, retention ponds, and filtration areas: 20 years.[29]
Land Area Requirements	Sacrifice Areas • Proper sizing of the sacrifice area is essential and will be determined by the number of livestock being managed and the amount of land available.[30] • Area should be large enough for animal movement and comfort, but small enough for easier maintenance (i.e., manure removal). • The minimum size of A confinement area depends on the type, number, and size of the animals. NRCS can assist in determining sizes on a case-by-case basis. • For general information on sizing, producers can refer to the Midwest Plan Service[31] as a starting point. • Some Conservation Districts (CD) have their own resource and recommendations for sizing confinement areas. For example, a minimum size of 400 ft^2 per animal is recommended for livestock by Snohomish CD.[32] Feedlots • Generally, feedlots should be sized 200 to 500 ft^2 per head of cattle.

[24] WSU-Pasture Sacrifice Areas (https://extension.wsu.edu/clark/naturalresources/smallacreageprogram/pasture-sacrifice-areas/)

[25] Snohomish CD (https://snohomishcd.org/sound-farms-resources/2016/3/17/livestock)
[26] WSU Extension (https://s3.wp.wsu.edu/uploads/sites/2079/2014/02/sacrifice-areas.pdf)
[27] Snohomish CD (https://s3.wp.wsu.edu/uploads/sites/2079/2014/02/sacrifice-areas.pdf)
[28] WSU Clark County Extension (https://s3.wp.wsu.edu/uploads/sites/2079/2014/02/sacrifice-areas.pdf)
[29] EPA Guidance on Animal Feeding Operations (AFOs), 2015 (https://www.epa.gov/sites/default/files/2015-10/documents/chap4d.pdf)
[30] WSU Extension (https://s3.wp.wsu.edu/uploads/sites/2079/2014/02/sacrifice-areas.pdf)
[31] https://www.mwps.iastate.edu/catalog/livestock-operations
[32] Snohomish CD (https://snohomishcd.org/sound-farms-resources/2016/3/17/livestock)

Considerations	Details
Other implementation factors	• The design and construction of a confinement area will be informed by the type, number, and size of animals. • Livestock can be hard on fences, so it is important to select a sturdy, safe fencing for your sacrifice area. • Be sure there are no protruding objects that could harm livestock, such as bolt ends or nails. • Low building overhangs and roof corners may also pose a danger to livestock. • Gates need to be large enough to accommodate farm equipment and deliveries of footing materials, feed, and hay (WSU Extension). • Animals in sacrifice areas, particularly horses, need to be exercised and all animals can be turned out on hard, frozen ground when plants are dormant (OR State)[33] • It can be difficult to find hogfuel in some areas due to reduced mill production. Additionally, drop offs from chipping services can contain plants that are toxic to livestock. Producers should ensure the products they are receiving are suitable for their animals. • Producers should avoid feeding horses directly on sandy surfaces to avoid sand colic.
Resources	• Horses for Clean Water: Creating and Using a Sacrifice Area for Horses.[34]

Heavy Use Area Protection

Introduction

Heavy Use Areas (HUA) promote the "stabilization or protection of an intensively used area" and can help address soil erosion, provide stable surfaces for areas used by animals, facilitate manure collection, and promote water quality.[35] HUAs are used in a wide range of scenarios:

- Areas of congregation in pastures and rangeland areas (e.g., around watering stations and feeding area/salt licks).
- High traffic areas.
- Confinement areas.

HUA protection is heavily dependent on-site conditions and relies on the producer's preferences and knowledge of land conditions and livestock behavior. Please note, the previous

[33] https://smallfarms.oregonstate.edu/smallfarms/using-sacrifice-areas-protect-pastures

[34] Tualatin Soil and Water Conservation District, 2020 (https://tualatinswcd.org/wp-content/uploads/2020/09/Creating_Using_Sacrifice_Area_HCW.pdf)

[35] NRCS Conservation Practice Standard, Heavy Use Area Protection, Code 561, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28859/561_WA_CPS_Heavy_Use_Area_Protection_2021)

section focuses on sacrifice areas and feedlots, whereas this section focuses on other HUAs, including watering locations, gates, livestock trails, and other high traffic areas that may be prone to mud. For more information on watering facilities, see Chapter 10 - Livestock Management: Pasture & Rangeland Grazing.[36] Other BMPs may need to be implemented with HUAs, including fencing to confine animals and adequate cross fencing for rotational grazing. Practices to reduce mud/manure runoff in the winter and underground roof runoff diversion can also be implemented with HUAs.

Benefits of Heavy Use Areas

HUAs provide various benefits for pastures, livestock, manure management, and grazing. Spokane CD detailed the following benefits of HUAs for producers.[37]

Table 12. Benefits of Heavy Use Areas

Category	Benefits
Pastures Conditions	• Prevents livestock from accessing rain-soaked pastures to avoid soil compaction, erosion, and damage to forage within pastures. • Prevents livestock from removing vegetation which could lead to erosion in nearby waterways.
Livestock Health	• Prevents livestock injuries/illness from living in mud (e.g., mud rot, rain scald, thrush).
Manure Management	• Provides easier year-round cleaning since manure significantly contributes to mud problems during wet months.
Grazing Management	• Rotating livestock increases grass production and promotes pasture health. • Confine livestock in HUAs until pastures are ready for more grazing.

The NRCS Conservation Practice Network Diagram provides a useful overview of implementing HUAs and the various effects that HUA protection has on land conditions, livestock, and water quality.[38] Direct effects include stable or non-eroding surfaces and improved water quality.

Motivators for HUA implementation depends on the type of animals in the HUA. For example, the dairy industry is regulated by the Washington Department of Agriculture which contributes to stronger objectives to ensure that mud is effectively managed by producers.

Cost is a significant barrier to HUA implementation/maintenance and finding contractor support for design and construction is an ongoing challenge. While Washington CDs aim to connect producers to reliable resources and contractors, some CDs continue to struggle with

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[36] https://apps.ecology.wa.gov/publications/parts/2010008part4.pdf
[37] Spokane CD, Heavy Use Areas: A Guide for Planning & Building Heavy Use Areas for Horses & Livestock (https://www.marionswcd.net/wp-content/uploads/2022/01/Heavy-Use-Areas-SCD.pdf)
[38] RCS CONSERVATION PRACTICE EFFECTS - NETWORK DIAGRAM, 2020 (https://www.nrcs.usda.gov/sites/default/files/2022-09/Heavy_Use_Area_Protection_561_Network_Diagram_9_2020.pdf)

providing technical guidance. Producers are encouraged to work with their CD to implement HUAs.

Heavy Use Area Case Example – Snohomish CD

A landowner worked with the Snohomish CD to develop a HUA off an existing barn. The CD provided technical assistance with designing the downslope, soil drainage system, and other elements of the HUA. The State Conservation Commission allowed the CD to also secure funding for this project. The CD has often recommended that landowners implement HUAs off their barns, if possible. Throughout the development process, the CD worked with Tribes and local archaeologists on site visits to survey the land.

During the construction process, the producer worked with the CD on preparing the site to lay down fabric and 5/8-inch crushed gravel. Pins were used to hold the fabric down and some trenching was used around the HUA to tuck down the fabric. After implementing the HUA, the CD continues to conduct annual site visits to ensure the site follows NRCS standards. The cost of the project was approximately $19,000 which included technical assistance provided by the CD.

Implementation and Design Considerations for Heavy Use Areas

Site conditions, size, livestock, and accessibility affect the design of a HUA. Animal health, territorial issues, and waste management should also be incorporated into the design of a HUA. This section summarizes design considerations for a HUA, however more information is available in NRCS Practice Standards.[39]

Table 13. Design Considerations for Heavy Use Areas

Considerations	Details
Sizing	• Reduce the HUA size to help minimize long-term maintenance activities and improve efficiency. • The pad size depends on material, age/size of livestock, and usage. • Identify the type of livestock that will primarily use the HUA when designing the pad size. • In some cases, sizing of the HUA should be based on 400 ft^2 per 1 animal unit (this will vary depending on the type of livestock in the HUA).
Location	• Locate the HUA as far as possible from water bodies to protect water quality. • Build the HUA on the highest, direst ground away from streams/wetlands.[40]

[39] Natural Resources Conservation Service Heavy Use Area Protection, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28859/561_WA_CPS_Heavy_Use_Area_Protection_2021)

[40] Spokane CD, Heavy Use Areas: A Guide for Planning & Building Heavy Use Areas for Horses & Livestock (https://www.marionswcd.net/wp-content/uploads/2022/01/Heavy-Use-Areas-SCD.pdf)

Considerations	Details
	• Place the HUA away from wells, water sources, septic drain fields, and other existing infrastructure. • Select a site that will promote even grazing distribution and reduce grazing pressure on sensitive areas.
Site Conditions	• Assess which parts of the land produce mud and eliminate any water coming off buildings where animals are confined.
Accessibility	• Ensure that feed/delivery trucks can easily access the HUA (gates should be about 12 feet wide). • If relevant, alleys and pathways should be large enough for equipment such as tractors or wheelbarrows. • Provide Easy access from the HUA to pastures. • Align the HUA with rotational grazing system. • Livestock should have access to fresh water.
HUA Plan	• The following information should also be included in HUA plans: ○ Location and extent of the HUA ○ Distances to adjacent utilities ○ Grading plan (if appropriate) ○ Required structural details ○ Methods and materials to stabilize areas disturbed by construction ○ Site-specific installation requirements ○ And vegetative establishment specifications (as applicable)

Table 14. Implementation Considerations for Heavy Use Areas

Considerations	Details
Construction	• When constructing an HUA, slope the HUA away from buildings by using a 1-2% slope and include a grass filter strip. • HUAs should not be built when a site is already muddy and any water flowing into the HUA should be eliminated. • From a high-level, the following steps are taken to construct a HUA: ○ Grade the area by removing any organic material; ○ Cover the bare ground with geotextile fabric; ○ Build a perimeter to retain the footing; ○ Spread the base footing; ○ Apply top footing if necessary; ○ Leave a grass filter strip around the HUA.
Materials	• Examples of suitable foundation materials are bedrock, concrete, compacted gravel, and stable, well-compacted soils. • Concrete: Concrete and compact gravel are more commonly used around watering facilities and trails/walkways. When concrete is used

Considerations	Details
	for livestock, texture concrete can provide traction in wet or freezing conditions.[41] • Woodchips: Woodchip HUAs use large, screened woodchips instead of concrete which can be beneficial for small-scale livestock farms who want to protect pastures and promote water quality. In comparison to concrete, woodchips are less expensive and increase animal comfort.[42] Woodchips need to be replaced once per season. • Gravel: If you are using gravel, consider including a 2'x6' kickboard to prevent gravel from leaving the HUA. For HUAs used by animals, avoid the use of angular aggregates that might injure livestock. • Fencing: Prioritize safety when choosing fencing material. Different fencing materials can be supplemented with electric fencing to protect livestock and the fence. Electric wire provides the most flexibility in terms of maintenance and adjusting the size of the area. Other fencing materials can be supplemented with electric fencing to protect both the livestock and the fence.[43] • Pad: The pad should extend 12 ft. from the edge of the object of interest that causes high traffic (feeder, water, etc.). If multiple feeders are used, then add to the length of the pad to ensure that it extends 12 ft. past the feeders on either end. A slight slope (1/4 in. per 1 ft.) should be incorporated into the pad to prevent water from puddling on the pad, but not too steep that the slope causes erosion within the pad. If building on a slope, the entire pad should be leveled to ensure that water does not channel and increase erosion.[44] ○ Concrete Pad: One durable technique is to pour a concrete pad, redirect any 'clean' water flow around the pad, and redirect pad runoff towards dense vegetation. This vegetation will help in the absorption of water pollutants, so water sources stay clean. If using an AFO/CAFO permit, diverted water toward dense vegetation must not discharge to a surface water. • Fabric: Geotextile fabric and gravel can be used to reconstruct the HUA, which is less expensive than concrete. This method will require maintenance every few years but is a feasible solution to muddy areas.

[41] NRCS Conservation Practice Standard, Heavy Use Area Protection, Code 561, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28859/561_WA_CPS_Heavy_Use_Area_Protection_2021)

[42] Woodchip HUA Effluent Quality, Quantity, and Hydrologic Design Considerations, American Society of Agricultural and Biological Engineers, 2015 (https://elibrary.asabe.org/abstract.asp?aid=46398&t=2&redir=&redirType=)

[43] Livestock Heavy Use Areas, Snohomish CD (https://snohomishcd.org/sound-farms-resources/2016/3/17/livestock)

[44] Heavy Use Area Pads for Cattle, PennState Extension, 2023 (https://extension.psu.edu/heavy-use-area-pads-for-cattle)

Considerations	Details
	Geotextile fabric can be used with rock and sand. Vegetation should still be at the edges of the pad to absorb water and potential water pollutants. The ease in constructing the pad, in addition to the lower costs, makes the gravel heavy use area pad an attractive solution to improve animal efficiency and the environment.[45] ○ Without geotextile fabric, time will cause stone and soil to mix, and longevity of the pad will decrease. Any water that permeates the pad will eventually reach the soil, turn to mud, and seep up through the stone, which can cause the muddy area to reoccur. ○ There are two different types of geotextile fabric, woven and nonwoven. ▪ A variety of thicknesses are available for geotextile fabric. The NRCS recommends using a minimum thickness of 6 oz./yd^2, but 8-10 oz. is ideal if the pad will be driven over. ▪ A local NRCS conservationist can help select the proper geotextile fabric. • Vegetated HUAs: These HUAs may need geogrids or other reinforcing techniques to support vegetative stabilization.
Maintenance	• Landowners are encouraged to think about efficiency and how they can site the HUA so that daily maintenance activities are feasible even in poor weather conditions. • This guidance advocates that an operation and maintenance (O&M) plan be written for each HUA. The O&M plan, and documented adherence to it, provides an increased assurance of HUA longevity and environmental protection. • In the case of more complex settings, document site maintenance plans/records and waste management practices (i.e., nutrient management plan). • Maintenance activities will depend on the materials used for the HUA (e.g., concrete or geotextile fabric). • NRCS provides minimum requirements for a HUA O&M plan.[46] O&M activities include: ○ Periodic inspections; ○ Repair/replace damaged components; ○ Regularly remove/manage manure for livestock in HUAs; ○ And restrict uses to allow vegetative recovery.

[45] Heavy Use Area Pads for Cattle, PennState Extension, 2023 (https://extension.psu.edu/heavy-use-area-pads-for-cattle)
[46] NRCS Conservation Practice Standard, Heavy Use Area Protection, Code 561, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28859/561_WA_CPS_Heavy_Use_Area_Protection_2021)

Considerations	Details

	• If a landowner is not scraping the HUA, woodchips are not suitable for the site. If a landowner can scrape/pick and replenish woodchips, then gravel or sand is appropriate. If a landowner is scraping the HUA every season, then woodchips are easier to pull out and replenish.
	• Maintenance should not be needed for 3 to5 years after construction of the pad. This depends on how often and well the pad is scraped and how often it is used.
	  ○ Replacing the fine aggregate to the top of the pad should be the only maintenance that is required. If the pad is constructed, cleaned well, and maintained, the coarse aggregate layer should not need to be replaced.
	  ○ Water or loader buckets that scrape too deeply can cause damage to the coarse aggregate, causing pad integrity issues.
	  ○ Other maintenance activities include filling holes/low areas to ensure that the geotextile fabric is always covered; replacing/adding footing; maintaining a grassy filter strip; and ensuring that water is not draining into the HUA.

Costs	• The NRCS Practice Scenarios provide detailed cost information.[47] Costs for materials and labor change regularly, and the costs below reflect the most recent rates published by NRCS. • Costs are primarily impacted by materials for the HUA (e.g., gravel, concrete, fabric, etc.). • Note that other practices may need to be implemented to ensure the effectiveness of the HUA. Practices could include any needed stream crossing treatment, critical area planting, waste storage/treatment, and any treatment for contaminated runoff. • Reinforced Concrete Scenario ($10.29/yd^3) – HUA includes 6" thick reinforced concrete slab with a 6" base of sand or gravel material. • Non-reinforced Concrete with Sand or Gravel Foundation Scenario ($5.91/yd^3) – HUA includes 6" thick non-reinforced concrete slab with a 6" base of sand or gravel material. • Rock/Gravel on Geotextile, Pacific Region Scenario ($1/68/yd^3) – HUA stabilized with rock and/or gravel on a geotextile fabric foundation material. ○ Other scenarios include “Rock/Gravel-Geocell on Geotextile” and “Sand-topped rock/Gravel on Geotextile”. Costs for these scenarios are similar to those listed above and mainly include additional costs for GeoCell (4-inch-thick cellular confinement system) or sand.

[47] NRCS Practice Scenarios, 2023 (https://www.nrcs.usda.gov/sites/default/files/2022-11/Washington-Scenarios-23-payment-rates.pdf)

Considerations	Details
	• Organic Surfacing Scenario ($2.87/yd^3) - HUA stabilized with wood chips on a geotextile fabric foundation material. • Rock/Gravel Pad in Floodplain Scenario ($6.08/yd^3) - Typical scenario is a 100'x100' treated area with a 10-foot-thick base. Side slopes are 2.5:1. A raised pad is stable in all conditions, especially when inundation within the grazed field occurs. Geotextile fabric is placed under the protective material for added strength during times of livestock use.
Resources	• Refer to NRCS Technical Note (Title 210), Design Engineering, Design Note 24, "Guide for the Use of Geotextiles," or other State-approved reference for geotextile.

Waste Storage

Introduction

Agricultural waste storage facilities are multipurpose facilities to support agricultural operations management. There are many types of waste storage options, including tanks, lagoons, and solid waste dry-stacking structures.[48] These facilities can be used to store manure, agricultural by-products, wastewater, and contaminated runoff.[49] Waste storage facilities can be designed and constructed depending on their intended purpose and land conditions. The facilities can be customized depending on the storage period, location, operational volume, emergency volume (for liquid waste), and/or freeboard volume (for liquid or slurry waste that is exposed to rain). The NRCS Field Office Technical Guides (FOTG) provide additional details on constructing waste storage. Waste storage facilities are commonly implemented with other conservation practices.[50] This guidance provides information on the implementation of the following practices:

- Above Ground Structures/Containment for Solid Waste.
- Above Ground Tanks for Liquid/Semi-Solid Waste.
- Lagoons for Semi-solid/Liquid Waste will be covered in a subsequent chapter.

[48] US Department of Agriculture, Conservation Practice Overview, Waste Storage Facility (Code 313), 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33784/313_WA_PO_Waste_Storage_Facility_2022)
[49] NRCS Conservation Practice Standard, Waste Storage Facility, Code 313, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33782/313_WA_CPS_Waste_Storage_Facility_2022)
[50] US Department of Agriculture, Conservation Practice Overview, Waste Storage Facility (Code 313), 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33784/313_WA_PO_Waste_Storage_Facility_2022)

Benefits of Waste Management

Waste management allows for the effective use of animal waste to support crop growth and promote water quality and can provide the following benefits.[51]

- Waste management is necessary for preventing contamination of surface and groundwater. Animal waste can also negatively impact animals, plants, and air quality.
- Animal waste can provide crops with nutrients, when applied at acceptable rates, and help landowners save costs on commercial fertilizer. Applying waste at high rates can lead to nitrate toxicity and other nitrogen-related diseases in grazing livestock, and can become a human health concern as well.
- When animal waste is incorporated into soil, soil erosion can be reduced, and the water-holding capacity of soil can be improved with organic matter from the waste.

Uncontrolled animal waste can lead to negative impacts on water quality, air quality, soil, human health, and animal health. For example, uncontrolled animal waste can contaminate well water due to bacteria and nitrates leaching through soil. Animals and humans can also be exposed to ammonia and other gasses from uncontrolled waste which would result in health issues (e.g., respiratory or eye-related illnesses). Parasite infestation or reinfestation can also be an issue if waste is consumed by livestock. Runoff from open feedlots or from fields where livestock waste is spread can lead to eutrophic conditions in downstream water. Eutrophic conditions could then contribute to excess algae, weeds, and nitrite poisoning in fish. Lastly, leaching from poorly sealed lagoons could contaminate groundwater or enter streams as interflow.[52]

Limitations of Waste Management

Permitting, high costs (including associated with permitting), and finding contractors are among some of the limitations to implementing waste management facilities. Permitting processes may take between 6 to 10 months. It can be especially difficult for smaller farmers to find affordable contractors. Cost share programs through local CDs are a valuable resource for producers. Decisions of which waste management method is most suitable for a producer may vary based on cost, field and nutrient conditions, soil type, collection and transportation methods available, animals, and land size.

Managing liquid manure storage can be a lot more challenging and many dairies with liquid manure are in the floodplain and can experience challenges and costs related to permitting. Keeping liquid and solid manure separated is an ongoing challenge, which can affect above

[51] NRCS Agricultural Waste Management Field Handbook, Chapter 3, Agricultural Wastes and Water, Air, and Animal Resources, 2012 (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31441.wba)
[52] NRCS Agricultural Waste Management Field Handbook, Chapter 3, Agricultural Wastes and Water, Air, and Animal Resources, 2012 (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31441.wba)

ground tank storage maintenance. In some cases, producers could more easily transport the liquid manure through a pipe.[53]

Implementation Considerations for Liquid/Semi-solid and Solid Waste

The tables below provide specific considerations for the storage of liquid/semi-solid and solid waste. The NRCS provides the following general considerations for waste storage facilities:

- When choosing the site for a manure storage facility, consider how efficiently you will be able to complete maintenance activities. The site should allow you easily and quickly store the manure in the facility.
- Follow any guidance from your public health agency. Typically, the facility should be placed 100’ away from wells, streams, and drainage.
- The facility should have a roof since there are rare scenarios where a pile of manure with bedding will breakdown without being covered. If the manure is exposed to too much moisture, then it will not compost. Western Washington receives a lot more precipitation than eastern Washington and this may affect the priority of implementing roofs.
- Permitting for waste storage facilities varies across counties and depends on the facility’s size. In some cases, larger facilities can result in needing additional permitting (e.g., a facility above 10-acre feet may require a dam safety permit).
- The storage period of the facility should be determined using the timing required for safe waste utilization. Factors that affect the storage period include climate, crops, soil, and equipment.
- The operational volume is informed by the type of waste that is stored in the facility (e.g., manure, wastewater, bedding).
- Ensure that erosion protection is incorporated into the facility’s design.
- Gates, pipes, docks, wet wells, or other mechanisms should be included in the design for removing waste.
- Incorporate safety features including warning signs, fences, ladders, ropes, etc. Ventilation and warning signs should be provided for covered waste facilities to prevent explosion, poisoning, or asphyxiation.
- Outlets that automatically release stored waste are not permitted in Washington except for septic tanks that feed a treatment system. With this, design a permanent outlet that will resist corrosion/plugging and provide a backflow prevention measure for an outlet that pumps wastewater to facilities at higher elevations.
- Evaluate the location of the waste storage facility before construction to better understand the soil material, location of any seeps, depth to high water table, depth to bedrock, and presence of sink holes.

[53] Snohomish Conservation District. Interview. May 15, 2023.

- The structural design should use materials that are compatible with the waste that will be stored. Tank openings should be designed to accommodate loading, agitating, and emptying.
- Lastly, determine the costs of closing the waste storage facility since the risks associated with waste storage facilities are high. Costs should include removal of waste accumulation and waste stored at the maximum operating volume.

Consider that manure will accumulate in storage during growing season and during periods of excessive rainfall (September through March), when the manure cannot be applied to the field or to prevent runoff from the field. Provide a buffer of space to store additional manure during these times. [54]Construction will likely occur during spring and early summer. While these practices have similar approaches and implementation factors to consider, the designs for liquid/semi-solid waste storage facilities versus solid waste storage facilities can vary. For example, the foundation, bottom elevation, outlet, and embankments are different depending on the type of waste.

Implementation Considerations for Above Ground Tanks for Liquid/Semi-solid Waste

Above ground tanks can be used to store slurry or liquid livestock waste and can be loaded with a pump that moves manure from a reception pit. Below are considerations for implementing above ground tanks for liquid/semi-solid waste.

Location for Above Ground Tanks for Liquid/Semi-solid Waste

Producers should properly locate the storage facility outside the 100-year floodplain unless site restrictions require locating it within the floodplain. If located in the floodplain, protect the facility from inundation or damage from a 25-year flood event.[55] Tanks should be located at least 300 feet from water wells. [56] Site conditions must be compatible with design assumptions. Structures can be designed on an individual site-specific basis. [57] Place storage facilities on the highest and driest location possible to avoid manure runoff. Open tanks should be as close to the source of the waste as practical to maximize efficiency.

Design for Above Ground Tanks for Liquid/Semi-solid Waste

In some cases, landowners may have to work with their local CD to navigate the planning and permitting process for above ground storage tanks. Landowners should determine how they will collect and transport the manure and assess how liquid versus solid manure will affect their

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[54] Snohomish CD Interview. May 15,2023.
[55] NRCS Conservation Practice Standard, Waste Storage Facility, Code 313, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33782/313_WA_CPS_Waste_Storage_Facility_2022)
[56] Agricultural Waste Management Field Handbook, Chapter 10, Agricultural Waste Management System Component Design (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)
[57] Livestock and Poultry Environmental Learning Community, Liquid Manure Storage Ponds, Pits, and Tanks, 2019 (https://lpelc.org/liquid-manure-storage-ponds-pits-and-tanks/)

storage options. Tanks must be designed by a professional engineer and constructed by experienced contractors. A variety of manufactured, modular, and cast-in-place tanks are available from commercial suppliers.

Storage volume design considerations should include all possible external influences such as external hydrostatic pressure, flotation and drainage, live loads from equipment and animals, and dead loads from covers and supports. Volume considerations must also include daily animal manure and related wash/flush water inputs. Keep open tanks fenced to keep out animals and children. [58] If possible, include curbs around the facility to help contain leachate.

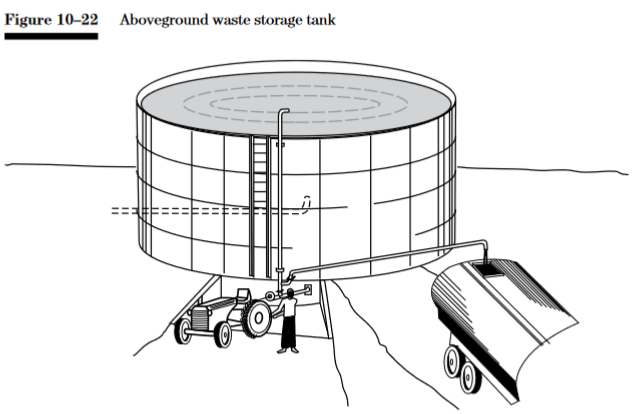

Figure 1. Aboveground storage tank

Storage tanks must be sized to store all manure, bedding, wash water from milkhouses, flushing, and contaminated runoff. It is recommended to work with NRCS to calculate the proper storage capacity. See NRCS Appendix 10C for methods on estimating contaminated runoff volume.

Volume must account for manure storage volume, wash water volume, net rainfall/evaporation on the tank surface for open tanks, runoff from roofs and concrete lots, and freeboard. Plans are usually made to exclude outside runoff from storage tanks because of a high storage cost. If outside runoff is included, storage accommodation must be included in the volume. Storage tanks must provide a depth of 0.5 feet for material not removed during emptying. This is considered the residual volume. A depth freeboard of 0.5 feet is recommended.

[58] Livestock and Poultry Environmental Learning Community, Liquid Manure Storage Ponds, Pits, and Tanks, 2019 (https://lpelc.org/liquid-manure-storage-ponds-pits-and-tanks/)

Table 15. Implementation Considerations for Above Ground Tanks for Liquid/Semi-solid Waste

Considerations	Details
Construction	• Liquid manure storage tanks are usually made of concrete or glass-lined steel. • Concrete tanks ○ Concrete tank designs should conform to the American Concrete Institute's Building Code for Reinforced Concrete (ACI 318). ○ Cast-in-place concrete or precast concrete panels bolted together can also be used.[59] ○ Circular tank panels are held together with metal hoops to withstand pressure. Panels are positioned on a concrete foundation or have footings in the panel. ○ A circular configuration is the most efficient structural design, and are commonly 120 feet in diameter, 20 feet deep, and 8-16 feet tall.[60] ○ Noncircular tanks require highly reinforced, costly walls, limited to 12 feet tall with 40-50 feet walls. • Glass-lined steel tanks ○ These are typically purchased by a company that provides a tank to withstand 60 pounds per square foot per foot hydrostatic load imposed by the contained liquid and exterior wind loads. ○ Steel tanks should follow the American Institute of Steel Construction Specifications for the Design, Fabrication, and Erection of Structural Steel for Steel Buildings. ○ Depths range from 10-25 feet with up to 200 feet diameters, and 4–6-million-gallon volumes. ○ Other tanks are constructed of metal with glass-fused steel panels. These are manufactured commercially and must be constructed by trained crews. Other types of metal panels can be used.[61]

[59] NRCS Agricultural Waste Management (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)
[60] Utah State University, Types of Manure Storage: Process Improvement for Animal Feeding Operations (https://extension.usu.edu/smallfarms/files/ManureStorage_Types.pdf)
[61] NRCS Agricultural Waste Management (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)

Considerations	Details

	• Base: The floor of an above ground steel tank is comprised of poured in place concrete and should follow the same design/construction requirements for concrete liners.[62]
	• Covers
	  ○ Tension Cover: This type of cover has a hardwood center column and stainless-steel straps that keep the cover in place. The hood has two manhole covered openings for mixing the manure.[63]
	  ○ Floating Cover: This is a less expensive option but requires more maintenance. Water will need to be pumped off the top. It can be made of PVC foil stretched around a PVC pressure pipe by hammered rings behind a cord and stainless-steel carabiner hooks. It can be installed either outside the tank or inside a clean and empty tank. The cover is approved for about 10 years depending on the manufacturer.[64]
	• Access Ramps[65]
	  ○ Access ramps should be provided for all weather access to the tank with agitating, pumping, or hauling equipment.
	  ○ Ramps should be no steeper than 5-1 for tractor/pump or tractor/agitator access. Access ramps for tankers should not be steeper than 10-1. 20-1 is preferred.
	  ○ 1-inch-deep grooves or ridges should form into ramp concrete before it sets to improve traction across the ramp.

Maintenance	• Operation & maintenance
	  ○ Pumps are required for filling tanks.
	  ○ Tanks should be filled with 6 inches of water before manure is introduced into the tank to prevent drying of the manure.
	  ○ Pumping operations should begin before the tank is full to ensure space is available to hold a 25-year, 24-hour storm.
	  ○ The tank should be pumped when the water level is one or more feet below the full pool level.
	  ○ Any damaged panels/hardware in the storage tank that is deteriorating should be replaced.
	  ○ Agitation

[62] Minnesota Pollution Control Agency, Liquid Manure Storage Areas (https://www.pca.state.mn.us/sites/default/files/wq-f8-04.pdf)
[63] PAS Manure Storage: Tensioned Cover (https://pasmanurestorage.com/tensioned-cover/)
[64] PAS Manure Storage: Floating Cover (https://pasmanurestorage.com/floating-cover/)
[65] University of Missouri, Storage Tanks for Liquid Livestock Manure

Considerations	Details
	▪ It is advised to agitate while the tank is being pumped down to prevent settling of sludge and solids. ▪ High-horsepower, propeller-type agitators or high-capacity pumps are used for agitation. Some pumps combine these for recirculation. ○ Transferring to manure storage ▪ Manure is typically scraped or pumped into a reception pit, which typically can contain one day's manure production. The reception pit is then pumped into a storage tank. ▪ Above ground tanks are loaded either from the top or bottom of the tank depending on factors such as desired agitation, minimized pumping head, weather conditions, and system management.[66] ▪ When using tractors, ensure the tires and scooping does not create ruts in the ground that would cause the area to be difficult to access. • Advantages and Related Considerations ○ Ability to agitate the full contents to create consistent nutrient balance. This maximizes overall value for crop production needs, allowing for less purchased fertilizer and utilization of waste.[67] ○ Minimization of runoff so there is less maintenance concerns. ○ There is less odor to maintain due to a chimney effect that the tank creates, releasing odors above ground level into higher air currents. A crust is formed on the top that holds odor in as well. • Safety and appearance ○ Post warning signs, keep a fence around the tank, and keep the gate locked to keep children, trespassers, and animals out. [68] See NRCS Code 382[69] on Fences. ○ If it is necessary to enter a storage tank, OSHA regulations require the use of safety equipment including a supplied-air respirator which supplies Grade D breathing air. This will prevent death by asphyxiation from lack of oxygen in the presence of lethal gases. Alternatively, a self-contained breathing apparatus may be used.

[66] NRCS Agricultural Waste Management (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)
[67] CST Industries: Manure Slurry Storage Tanks (https://www.cstindustries.com/manure-slurry-storage-tanks-manufacturer/)
[68] University of Missouri, Storage Tanks for Liquid Livestock Manure (https://extension.missouri.edu/publications/eq389)
[69] https://efotg.sc.egov.usda.gov/api/CPSFile/34707/382_WA_CPS_Fence_2022

Considerations	Details

	○ Any person entering a tank should wear a rescue harness with a rope to persons outside the tank and with a block and tackle for emergency extrication.
	○ A consideration is to establish a row of trees as a screen from public view that might attract attention or controversy.
	○ Uncontrolled access to above ground tanks can lead to injury or death. The following rules should be enforced:
	  ▪ Permanent ladders on the outside of aboveground tanks should have entry guards locked in place or the ladder should be terminated above the reach of individuals.
	  ▪ A ladder must never be left standing against an aboveground tank.[70]
	○ If at all feasible, construct lids for manure tanks and keep access covers in place to prevent manure gas accumulation. Move all the animals out of the building, if possible when agitating manure stored beneath that building.[71]

Costs	• Tanks tend to have a high cost of storage volume. Glass lined steel (14 ft. deep) is the most expensive followed by precast concrete panels (12 ft. deep), and then followed by poured concrete (8 ft. deep).[72]
	• Costs can be impacted by permitting requirements since facilities that are above 10 acre feet require dam safety permits. In this case, landowners can build facilities with smaller surface areas to avoid additional permit requirements.
	• Consider the separate costs of fencing and vegetative filter strips.
	• See USDA NRCS WA State 2023 Practice Scenarios[73] for a list of very detailed construction scenarios and their associated costs
	  ○ An above ground steel tank ranges from $3.64/cubic foot to $8.45/cubic foot. (Practice 313 Scenario #5-7) Scenarios depend on equipment installation, materials, and size. They can include foundation improvements.
	  ○ An above ground concrete tank (Practice 313 Scenario #8-12) ranges from $1.37/cubic foot to $1.94 per cubic foot. Scenarios depend on size, equipment installation, and materials. They can include

[70] NRCS Agricultural Waste Management (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)
[71] NRCS Agricultural Waste Management (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31529.wba)
[72] Livestock and Poultry Environmental Learning Community (https://lpelc.org/what-does-manure-collection-and-storage-look-like/)
[73] https://www.nrcs.usda.gov/sites/default/files/2022-11/Washington-Scenarios-23-payment-rates.pdf

Considerations	Details
	preloaded or improved foundations, elevated pads, or extra reinforced slabs. ○ A Concrete Tank with a Lid (Practice 313 Scenario #42) costs $15.29/cubic foot based on equipment installation, labor, materials, and mobilization of equipment.

Implementation Considerations for Above Ground Manure Structure/Containment (Solids)

Solid storage methods vary based on size, manure type, materials, cost considerations, and management practices. Solid manure has approximately 80% or less moisture and 20% or more solids. Solid manure can be stacked into piles and handled with equipment like front end loaders and box scrapers and semi-solid manure (15% solids) is handled and stored the same as solid manure.[74] Advantages of solid manure storage, in comparison to liquid storage, include less volume (higher solids content), less odor, less runoff potential, high nutrient retention, and ability for composting. Disadvantages include intensive manual labor, equipment requirements, runoff management, and potentially high cost.

Location for Above Ground Manure Structure/Containment (Solids)

Locate the facility outside of the 100-year floodplain unless restrictions prevent this, and on the highest and driest land possible to prevent manure runoff. If the facility is within the floodplain, protect the facility from inundation or damage from a 25-year flood event and follow NRCS General Manual (GM) 190, Part 410.25.[75]Aim to locate the facility outside the Riparian Management Zone (at least 215-feet for western Washington locations and 150-feet for eastern Washington locations, to be consistent with the riparian management zone guidance recommendations). Producers are encouraged to locate the storage facility as close to the waste source as possible to maximize efficiency.[76] Overall, the location of these facilities will vary due to various factors including property size, natural features, and soil type.

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[74] Livestock and Poultry Environmental Learning Community, What Does Manure Collection and Storage Look Like?, 2019 (https://lpelc.org/what-does-manure-collection-and-storage-look-like/)
[75] NRCS Conservation Practice Standard, Waste Storage Facility, Code 313, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33782/313_WA_CPS_Waste_Storage_Facility_2022)
[76] Skagit County Conservation District. Interview. May 12, 2023.

Bedded Pack Barns

Bedded Pack Barns are another practice used in Washington State. These double as waste and animal storage, as old bedding gets turned over and new bedding is stacked on top to provide a fresh layer for the animals. Bedding will be applied starting in the fall when livestock are confined, will be packed down and continuously added to in the winter, and will be taken out in the spring.

Design for Above Ground Manure Structure/Containment (Solids)

Use the NRCS USDA requirements to build a design plan and guide construction and if possible, work with NRCS or a licensed engineer to design the facility and ensure it meets necessary regulations. NRCS services are available at no charge and without discrimination. NRCS also developed a tool for producers to determine how much storage is needed based on livestock management practices.[77] At a minimum, include in the engineering plans, specification, and reports listed in the Plans and Specifications section of the NRCS guidance.[78] When determining the size of a storage facility, the main considerations are number of animals, amount of bedding and length of storage needed.[79] Other factors may include projected herd expansion, breed, production level, feed intake, and ration balance. Along with volume of manure produced, local characteristics, timing of application, and management approach will also inform the facility's design. Six months of storage is optimal, but three months is more realistic given budget and size constraints. If possible, an additional 1 to 2 months of storage capacity should be included as a buffer.

Table 16. Implementation Considerations for the Storage of Solid Waste

Considerations	Details
Construction	• Base Material Options Recommendations ○ The storage structure should have a solid floor so nutrients cannot leach into the surrounding soil. Concrete slabs are the best option and are highly recommended because it allows for easy manure removal, prevents nitrogen build up, and creates a watertight flooring to prevent runoff. For more substantial flooring, place 4-inch-thick concrete over six inches of coarse gravel or crushed rock, or two inches of sand. • Packed gravel or crushed and compacted limestone base may be suitable for limited livestock including horses, goats, llamas, pigs, and sheep or other solid

[77] Pierce CD, Manure Management (https://piercecd.org/607/Manure-Management)
[78] NRCS Conservation Practice Standard, Short term Storage Of Animal Waste And By-Products, Code 318, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28719/318_WA_CPS_Short_Term_Storage_of_Animal_Waste_and_By-Products_2021)
[79] Thurston County Conservation District. Interview. May 19, 2023.

Considerations	Details
	manure. An impermeable liner can also be used in addition to prevent runoff.[80] ○ Concrete diversions or curbs around the slab area will direct manure and water to a collection point for transfer to the liquid manure storage facility. ○ If possible, elevate the floor slightly above the surrounding ground with one side of the structure sloped to be at ground level for easy dumping and removal. ○ Slightly slope or grade the floor to one or both sides to allow leachate to be diverted to a vegetated buffer. This diverts surface runoff and reduces soil erosion around the area. • Sidewalls ○ Concrete or wood walls[81] ○ Number of walls can vary – see costs below for specific construction information. Two side wall is beneficial to protect against wind and rain. Three side walls is optimal for the storage structure to allow stacking of solids. Three walls allows better piling of manure, supporting more weight, also allowing for easier removal. See options above under "costs." ○ See the section on "Dry Stacking Facility" below for more information. • Manure Covering ○ Use NRCS CPS Roofs and Covers (Code 367)[82] for design of waste storage facility covers or roofs.[83] ○ Places with frequent rainfall or snowmelt are highly recommended to have roofs.[84] ○ An option of no covering is more likely to occur in farms in arid areas. If the manure storage area is to be left uncovered, it may be necessary to install channels, floor drains, and/or drainage pipes to divert and capture run-off to a liquid storage tank, holding basin, or treatment system. ○ Material use is site specific depending on factors such as cost and structure size ○ Tin/Wood Roof

[80] NERC Manure Management Handbook (https://nerc.org/documents/manure_management/manure_management_handbook.pdf)
[81] http://whatcom.wsu.edu/ag/nutrient/guidel_1.pdf
[82] https://efotg.sc.egov.usda.gov/api/CPSFile/33774/367_WA_CPS_Roofs_and_Covers_2022
[83] NRCS Conservation Practice Standard, Roofs and Covers, Code 367, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33774/367_WA_CPS_Roofs_and_Covers_2022)
[84] Livestock and Poultry Environmental Learning Community, What Does Manure Collection and Storage Look Like?, 2019 (https://lpelc.org/what-does-manure-collection-and-storage-look-like/)

Considerations	Details
	▪ Roofs are usually made with timber or a steel sheet (see cost section below) and are recommended for keeping manure dry and preventing runoff. ▪ Flexible membrane covers can also be used (Code 367). ○ Gutters and Downspouts (Code 558) ▪ Roofs should collect water from gutters via downspouts and transfer away the water from the confinement area into a downspout discharge area via an underground outlet. Discharge designs may include a valve system so collected precipitation can be added to manure storage facilities as a source of dilution or can be pumped to a facility cistern or watering trough.[85] ▪ Install gutters and downspouts and underground outlets so they to prevent contact between livestock and machinery. ▪ Install screens on gutters to keep debris and silt out. ○ High-tension fabric ▪ Newer option that is more affordable for much larger structures that has ability for expansion and are often easier to clean. The cost is often too high to be practical for very small structures. High tension fabric can be used for roofs or as the whole building structure and is optimal for larger storing facilities. ▪ Keep open end walls to allow for airflow. Tunnel ventilation can be added in the form of exhaust fans to help with air flow. Doors can be added for access. ▪ Steel, roll up doors are the go-to for composting facilities. For larger facilities manufactures supply fabric doors. These can be motor operated. ▪ Use with a building that has a galvanized steel frame to provide structural strength and ability to withstand corrosive environments. ▪ Different structures have varying longevity. Take this into consideration. Most manufacturers offer warranties, so look for one with at least a 20-year shelf life. ▪ One downside is that fabric roofs are not as strong as standard wood or metal roofs and can tear easier and be difficult to repair.[86] • Ramps[87]

[85] Skagit County Conservation District. Interview. 5/12/2023.
[86] Thurston County Conservation District. Interview. May 19, 2023. [87] NERC Manure Management for Small and Hobby Farms, 2019 (https://nerc.org/documents/manure_management/manure_management_handbook.pdf)
[87] NERC Manure Management for Small and Hobby Farms, 2019 (https://nerc.org/documents/manure_management/manure_management_handbook.pdf)

Considerations	Details
	○ A ramp makes the path more stable, less prone to mud, and makes dumping easier. Whether using a small tractor or wheelbarrow, consider the space necessary to maneuver in and out when unloading or loading. ○ Slope the entrance ramp upward to keep surface water from entering. ○ A rough-surfaced ramp should be designed to lead into the storage area. ○ A 20-foot width should be adequate for small farm and garden tractors. ○ If concrete or crushed rock is used for ramping, install angle grooves across the ramp to help drain rainwater. • Treated Wood[88] ▪ Use criteria from NRCS CPS Roof and Covers (Code 367) for treated wood and fasteners. • Vegetated Filter Strips ○ Construct a vegetated filter strip to prevent leaching of runoff water. The filter should be established in a vigorous, thick stand of grasses adapted to the soil conditions at the site. Animals should be kept off, and it should be mowed or cut for hay at least twice a year to remove nutrients and encourage growth. On a flatter slope, the strip should be a minimum of 30 feet wide, wider if slope is steeper.[89] ○ Trenching can be used to capture or divert manure pile leachate. • Construction Specifications[90] ○ Follow the USDA NRCS Practices Scenarios for specific construction building scenarios to understand what materials, sizes, construction considerations, and associated costs are for storing solid manure. See the Cost section below for a list of the scenarios. • Storage Method ○ Bin: Small farms with few animals can store manure in plastic garbage cans with lids, wood or metal bins, or carts. Farms that are utilizing manure for land **application can store manure and stall waste in the manure spreader.[91]** • **Compost Pad: Moderate** to high cost, produces low odor, crumbly topsoil product that can be marketable. Composting is a managed process, resulting in accelerated decomposition of organic materials. Composting is a recommended management practice manure management and, when done properly, will result in the destruction of internal parasites and weed seeds. The composted product can be spread on pastures according to a nutrient

[88] NRCS CPS Roofs and Covers (Code 367) (https://efotg.sc.egov.usda.gov/api/CPSFile/33774/367_WA_CPS_Roofs_and_Covers_2022)
[89] Rutgers, Storing Manure on Small Horse and Livestock Farms, 2014 (https://njaes.rutgers.edu/fs1192/)
[90] NRCS Practice Scenarios, 2023 (https://www.nrcs.usda.gov/sites/default/files/2022-11/Washington-Scenarios-23-payment-rates.pdf)
[91] Rutgers, Storing Manure on Small Horse and Livestock Farms, 2014 (https://njaes.rutgers.edu/fs1192/)

Considerations	Details
	management plan that accounts for crop uptake of nutrients. Avoid overspreading. ○ Composting requires proper levels of moisture and oxygen, and the appropriate feedstock mixture to ensure proper microbial activity. Aeration or turning the composting material ensures that all parts of the manure pile reach elevated temperatures for a certain time period (see Rutgers Composting Bulletin E307[92] for more information). Compost will be less odorous than fresh horse manure and may have value as a soil amendment or fertilizer. ○ Turning the pile is usually done with a small tractor equipped with a front bucket loader. There are many ways to set up the composting site. It could just be several long windrows, 4 to 6 feet high, on compacted ground or compacted gravel, or concrete. Or there may be several small dry stack-type bays connected together side by side, the manure is moved from one bay to the next, mixing and aerating while the manure composts in the process. Manure and bedding, when properly mixed, can be transformed into compost in as little as six weeks. • Examples of a Compost Manure Storage Facility[93]  **Figure 2. Example A Manure Storage Facility.**

[92] https://njaes.rutgers.edu/pubs/publication.php?pid=e307
[93] Snohomish Conservation District. Interview. May 15,2023.

Considerations	Details

	
	Figure 3. Example B Manure Storage Facility.
	
	• **Dry Stacking:** Moderate cost and most common and practical choice for small livestock operation.
	  ▪ Structures have three walls and ideally a slightly sloped, poured concrete floor to contain manure and prevent water accumulation.
	  ▪ Include an adjacent vegetative filter strip.
	  ▪ The walls of a dry stack facility should be sturdy to hold pressure from the manure and should be a minimum of four feet high with a maximum stacking height allowed of 8 feet.
	• The walls can be poured concrete, cinder block, horizontal timbers, or vertical timbers. Secure anchoring below the frost line is crucial."[94] A front-end loader should be used for moving the manure.

Maintenance	• Develop an operation and maintenance plan
	  ○ Ensure the plan is consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. See USDA Code 213 for a detailed operation and maintenance consideration guide of an agricultural waste storage facility made by constructing an embankment, excavating a pit or dugout, or by fabricating a structure.[95]
	  ○ See USDA Code 318 for a detailed guide of operation and maintenance considerations for short-term storage of animal waste and by-products, in which temporary, nonstructural measures are used to store solid or semisolid waste on a short-term basis between collection and utilization.[96]
	  ○ Manure can be stacked into piles and handled with equipment like front end loaders and box scrapers.

[94] NRCS Dry Stack Manure Storage Structure For Horse And Beef Cattle O&M Plan (https://efotg.sc.egov.usda.gov/references/Delete/2014-5-24/NRCS_DSWSS_313.pdf)

[95] NRCS Practice Conservation Standard, Waste Storage Facility, Code 313, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33782/313_WA_CPS_Waste_Storage_Facility_2022)

[96] NRCS Conservation Practice Standard, Short Term Storage of Animal Waste and By-Products, Code 318, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28719/318_WA_CPS_Short_Term_Storage_of_Animal_Waste_and_By-Products_2021)

Considerations	Details
	○ Determine your maximum length of time anticipated between emptying events for your Stockpile period. • Air quality and fly control ○ Maintain appropriate manure moisture content for solid manure stockpile facilities to lower potential toxic emissions and improve air quality.[97] ○ Keep the manure as dry as possible, except when composting. When composting, keep the manure pile as wet as a wrung-out sponge.[98] ○ Insecticides, pesticides, or fly larval can be purchased and added to the manure pile as a fly control. Remove manure from the farm regularly during fly breeding season. ○ Stall waste is usually dry. However, manure from paddock cleanup may contribute to the formation of leachate. If stall bedding is not sufficient to absorb liquid from added manure, consider adding additional straw or similar material. ○ Leaking waterers, wash water from flushing stalls, cleaning milking equipment, etc. may contribute to the moisture content of manure if not captured. • Maintenance ○ Keep roof water discharge areas and drains clear of debris and silt. ○ Ensure there are no holes with leakage. ○ It is important to perform periodic maintenance on equipment.[99] ○ It is important to perform periodic maintenance on equipment. ○ When using tractors, ensure the tires and scooping does not create ruts in the ground that would cause the area to be difficult to access.[100]
Costs	• See USDA NRCS WA State 2023 Practice Scenarios for a list of very detailed construction scenarios and their associated costs. It is recognized that costs will vary by location and individual scenarios and costs will change over time. • General Considerations: ○ Since unmaintained waste storage facilities and accumulated manure may have high risks to water quality, consider the cost to close and decommission the facility. ○ Consider costs to remove of the planned stored manure volume and as well as the maximum operating volume. ○ Consider maintenance and operation costs.

[97] NRCS Conservation Practice Standard, Short Term Storage of Animal Waste and By-Products, Code 318, 2021 (https://efotg.sc.egov.usda.gov/api/CPSFile/28719/318_WA_CPS_Short_Term_Storage_of_Animal_Waste_and_By-Products_2021)
[98] Rutgers, Storing Manure on Small Horse and Livestock Farms, 2014 (https://njaes.rutgers.edu/fs1192/)
[99] NRCS Practice Conservation Standard, Waste Storage Facility, Code 313, 2022 (https://efotg.sc.egov.usda.gov/api/CPSFile/33782/313_WA_CPS_Waste_Storage_Facility_2022)
[100] Skagit County Conservation District. Interview. May 12, 2023.

Considerations	Details
	○ Consider cost of maintaining proper bedding if bedded pack barns are used. • Compost Pad base/wall scenario costs (Practice 317, Scenarios #5-9) range from $5.91/square foot to $83.56/square foot. Costs vary based on facility size, wall material (none, wood, concrete, precast concrete blocks), distance from the concrete plant, and equipment installation, • A composted bedded pack (Practice 313, Scenario 26) is $17.82/square foot. This includes equipment installation, labor, materials, and mobilization of a structure with concrete floor and walls. This does not include bedding cost. • Drystack base/wall scenario costs (Practice 313 Scenarios #15-20) range from $4.17/cubic foot to $9.73/cubic foot, depending on factors including size, materials (wood, concrete, or precast concrete block), wall quantity, labor, equipment installation, and distance from the concrete plant. • Roofing Scenario Costs ○ Roofing scenarios costs (Practice 367 Scenarios #1-8) range from $13.10/unit to $35.23 per foot. These costs vary depending on the roof material (e.g., flexible membrane, steel sheet, timber), the square footage, the supporting foundation and siding (metal or timber framed), whether the roof is sloped, labor, and equipment installation.