Evaluating Dry Manure Storage Options for Water Quality Protection Across King County, WA

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King County Wastewater Treatment WaterWorks Program

King Conservation District

Whatcom Conservation District

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King County

Department of Natural Resources and Parks
Wastewater Treatment Division

Executive Summary

WaterWorks, Discovery Farms® Washington, and the King and Whatcom Conservation Districts conducted a collaborative study from October 2022 to March 2024 to evaluate how on-farm manure storage affects Puget Sound water quality. The research involved two farms, one managing horse manure and the other a mix of primarily sheep and poultry, utilizing concrete bins with and without roofs. To test soil leaching, four 4' X 4' wood enclosed manure cubes were monitored at a county park site, comparing tarp-covered and uncovered piles placed directly on grass. The team tracked weather data and manure temperatures while analyzing soil, manure, and liquid leachate for nutrient and fecal coliform bacteria concentrations.

The findings confirmed that covered manure systems significantly reduce nutrient leaching and runoff while maintaining the higher temperatures necessary for high-quality composting. Storing manure on concrete slabs effectively prevented subsurface infiltration, and the chemical profile of the leachate directly mirrored the composition of the manure source. Ultimately, while concrete and covered storage proved most effective for environmental protection and product quality, simply covering a manure pile on soil with a tarp proved to be a substantial cost-effective improvement, when compared to uncovered piles.

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Discovery Farms® – Concept and Importance

Discovery Farms® is an on-farm research and demonstration program that partners directly with farmers to better understand how agricultural practices influence water quality and natural resource outcomes. The program was pioneered by the Discovery Farms® initiative in Wisconsin, where farmers, conservation professionals, and university researchers collaborated to install monitoring equipment on working farms. Rather than relying solely on small plot trials or modeling, Discovery Farms® measures real-world runoff, nutrient loss, and management impacts under actual production conditions. This approach builds credible, locally relevant data while maintaining producer trust and practical applicability.

A core strength of the Discovery Farms® model is its farmer-led and farmer-engaged framework. Producers volunteer their farms, help guide research questions, and participate in interpreting results. This structure builds transparency and shared ownership of findings. The data collected informs conservation planning, nutrient management recommendations, and public policy discussions, helping bridge the gap between environmental objectives and agricultural viability. Because results are generated under real operating conditions, they often carry more weight with both producers and regulators than controlled research conducted outside commercial systems.

Discovery Farms® programs also serve as education and outreach platforms. Findings are translated into field days, technical reports, and policy conversations that elevate practical conservation solutions. By grounding discussions in measured outcomes rather than assumptions, the model reduces polarization and supports adaptive management. Over time, this has helped demonstrate that environmental protection and agricultural productivity can be mutually reinforcing when supported by sound data and collaborative problem-solving.

Washington's Adaptation of the Model

In Washington, the Discovery Farms® concept was adopted in a more focused and streamlined form. The first effort in the state examined riparian buffer performance, generating locally relevant data on how buffers function under Western Washington conditions. Subsequent work centered on two targeted research projects evaluating dry manure storage and associated water quality implications. Governance was simplified to a single steering committee representative rather than the broader farmer-led oversight model used in Wisconsin. While this approach allowed the program to move forward efficiently and generate useful data on priority issues, it did not establish the same depth of farmer governance structure, long-term monitoring network, or programmatic breadth seen in the original model. Even so, Washington's efforts demonstrate the value of measured, on-farm research and provide a

foundation that could be expanded into a more comprehensive Discovery Farms® network in the future.

Regional Context

Livestock production in King County contributes to the local food economy and rural way of life. Unlike large commercial dairies that typically have engineered waste management systems, many smaller livestock operations rely on simple manure piles or low-cost storage methods that are vulnerable to nutrient loss during the rainy season. Western Washington experiences a prolonged period of rainfall extending from autumn into spring, regularly exceeding 30 inches between October and March. During these months, soils remain saturated and vegetation uptake is minimal, creating conditions where nutrient runoff and leaching pose significant threats to soil and water resources, particularly in salmon-bearing watersheds.

Manure Management Challenges and Opportunities for Small Farms

Composting livestock manure and waste can produce a valuable resource for land managers. When applied correctly, compost can improve soil physical properties such as aggregate stability, water infiltration and water holding capacity, soil biological properties such as microbial diversity and disease suppression, and chemical properties such as nutrient cycling and cation exchange capacity. Compost can also provide an economic benefit to land managers through sales of the product and improving crop and pasture production (Brewer et al. 2013). However, if managed improperly, manure leachate and runoff can contaminate ground and surface water resources posing a risk to humans and other wildlife (Kwon et al. 2017).

Small farms in King County operate with diverse livestock — goats, sheep, alpacas, horses, and poultry — often producing manure volumes that exceed what can be immediately applied or composted. When held in unenclosed piles during fall and winter storms, manure nutrients (nitrogen and phosphorus) can be mobilized by precipitation, transporting contaminants into surface and groundwater.

KCD Technical Assistance and Manure Management

King Conservation District promotes sustainable use of natural resources through responsible stewardship. KCD's Farm Program provides services to King County cooperators through technical assistance, farm planning, education, and outreach. Manure management is one of the most prescribed best management practices (BMPs) by KCD farm planners. Additionally, manure storage is one of the agricultural practices in which KCD's Cost Share Program invests the most public funding.

Based on findings in this study KCD has shifted our Technical Assistant protocols related to Waste Storage Facilities. While KCD still prescribes a variety of treatments to manage manure,

we prioritize the use of a roof and concrete pad due to their effectiveness in producing a superior finished product and protecting water quality. However, these options often present barriers to landowners due to the additional cost, labor and potential permitting issues to install these structures. Studies evaluating the effectiveness of physical coverings of manure piles, such as roofs and tarps, are limited (Patel et al. 2015). This study's evaluation of the effectiveness of commonly prescribed manure treatments with varying costs in protecting water quality will inform planner recommendations of manure treatment options to cooperators and potentially inform changes in cost- share policies and procedures.

Different manure storage treatments and utilization methods can affect compost quality and elevate runoff concentrations of nitrogen, phosphorus, and pathogens (Webber et al. 2011; Richard 1996). Uncovered manure piles on bare ground can contaminate surface and ground water resources. Covering manure can prevent precipitation from coming into contact with manure and reduce leachate generation (Brewer et al. 2013). Cheng et al. (2015) found that covering piles can reduce nutrient load of leachate nitrogen and phosphorus to ground water, with a tarp being the most effective method at reducing precipitation onto the pile. Covers can also improve the quality and speed at which livestock manure composts. Pare et al. (2000) evaluated the effect of covering compost with geotextile fabric on carbon to nitrogen (C:N) ratio, leachate volume, and phytotoxicity. They concluded that covering piles resulted in compost maturing more rapidly and with better mineral retention than uncovered piles.

Farmers' attitudes towards adopting conservation practices on their land are complex. Adopting conservation practices often comes with economic and labor costs to the farmer. Many farmers care deeply about the stewardship of their land but are faced with competing pressures by communities simultaneously seeking to purchase low-cost products from environmentally friendly managed farms. The decision by a farmer to adopt a new practice can also be influenced by social pressures by other farmers, politics, family succession, the economy, and prior knowledge and experience (Ahnstrom et al. 2008). The Discovery Farms® model promotes the normalization and adoption of BMPs through farmer- to-farmer outreach and learning. Additionally, this study provided a valuable opportunity to engage King County farmers, land managers and other stakeholders in discussions around the different options and benefits of adopting BMPs for manure management.

Project Objectives

The project aimed to measure water, manure and soil quality data for different dry manure storage options, including with and without roofs and concrete and permeable floorings. Specifically, the project set out to:

- Compare solid manure storage structure treatments on two farms including slab with and without cover, as well as two permeable with and without cover treatments located at a King County Park Site (near Issaquah Creek Natural Area).

- Collect samples of stormwater runoff, soil leaching, manure quality, and meteorological parameters to compare the treatments.
- Create outreach materials to increase landowner understanding of dry manure storage options and effectiveness.
- Assess the impacts of manure storage structures on environmental protection of surface and ground waters.

Materials, Methods, and Discussion

Steering Committee

The grant called for a Steering Committee of local farmers to help guide the process and help to interpret the results. Officially only one steering committee was held and attended by five local farmers. The meeting was held in September of 2024 with three major agenda items:

- Overview of project design
- Overview of initial findings
- Discussion

Feedback focused on very practical suggestions to improve the information:

- It may be helpful to condense information into an accessible infographic that people can browse—don't make it too complicated.
- Could try to put information in terms of the ratio you would see on a fertilizer label since people are used to this. There is a lot of information out there; keep it in terms of simple guidelines. Ammonia and nitrate graphs were very easy to understand even for someone with limited knowledge of fertilizer chemistry. Couple these graphs with info on why it is important.
- Keep in mind that not all farmers have a huge pile of manure, some will have smaller so we could recommend turning it. Make sure people know their options, ranging from a manure bin cost share project, to just getting info off web site, or basic best management practices like a tarp.
- Remind people not to overwater because it could bring down temperature—but too dry does not allow enough bacteria growth.

Experimental Design

The project utilized two farm sites with existing concrete slab structures, selected for the landowners' commitment to research protocols and public outreach. Site A managed a diverse livestock population, including alpacas, sheep, goats, chickens, and ducks bedded on pine shavings or pellets. Since site H only had 1 horse, to ensure sufficient volume for the study,

additional horse manure was brought in for each annual trial from nearby farm (Figure 1). Simultaneously, soil leaching was evaluated at a secluded King County Park pasture site using four wooden bins (4' X 4' cubes). To mirror the conditions at the farms, two bins were filled with each manure type. One bin of each type was left uncovered as a control and the other protected with a tarp, allowing for a direct comparison of how coverage impacts nutrient migration into the soil (Figure 1).

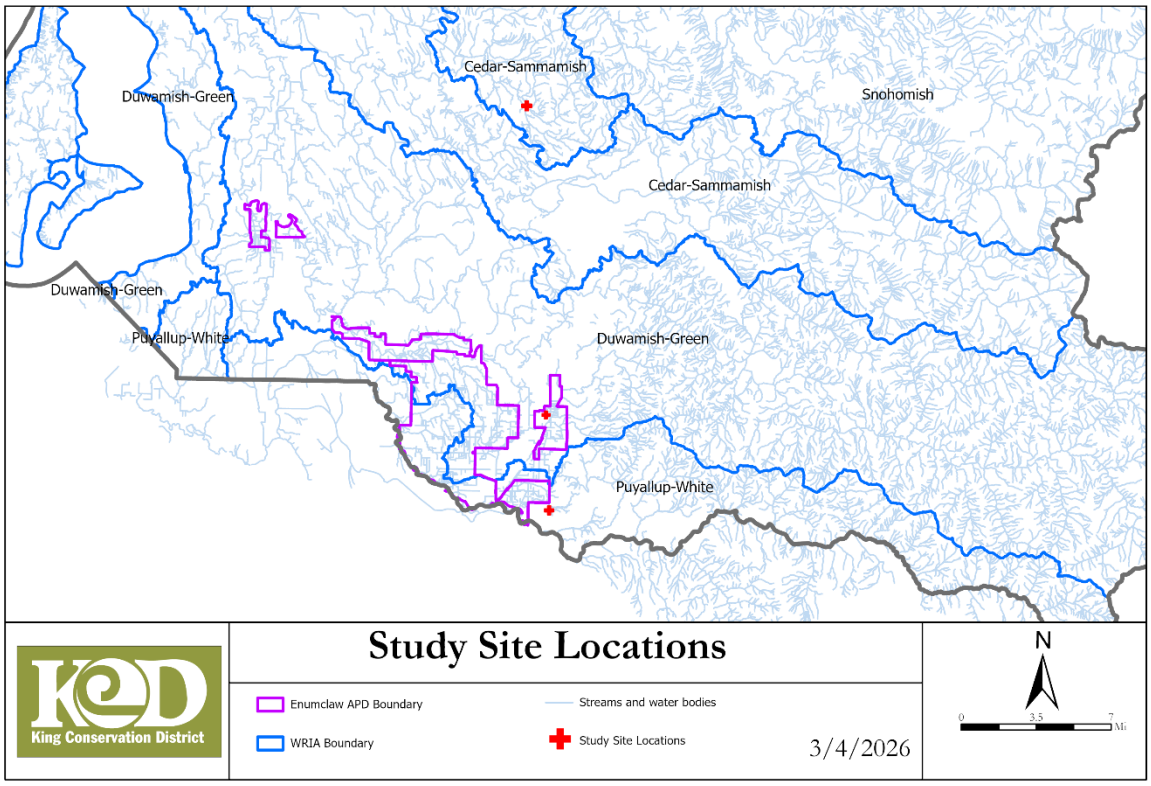

Figure 1. Map of project area in King County, WA and general project site locations.

Samples were collected from these three matched locations that resulted in the characterization and quantification of the relationship between manure storage treatments, water quality outcomes, and practice management. The research cycle for both the concrete slab and permeable soil treatments was launched twice during October of 2022 and 2023, ending in April of 2023 and March 2024 respectively. Fresh manure was sourced at the beginning of each annual cycle and the wooden boxes were placed on new pasture plots.

The study measured environmental data from four different treatments:

- Slab Covered: Manure stored in a three-sided manure bunker with concrete slab floor and cinderblock sidewalls, a braced plywood front, and a roof.

- Slab Uncovered: Manure stored in a three-sided manure bunker with concrete slab floor and cinderblock sidewalls, and a braced plywood front with no roof.

- Dirt Covered: Manure stored in a 4’ X 4’ wooden cube on a mowed pasture and covered with a tarp.

- Dirt Uncovered: Manure stored in a 4’ X 4’ wooden cube on a mowed pasture, without a tarp.

Figure 2. Manure storage treatments. From left to right: slab covered and uncovered, dirt covered and uncovered.

All piles were passively aerated using corrugated drainage pipe. For the concrete slabs, two coiled layers were placed at approximately one-third and two-thirds depth in each bin with single ends exposed for external ventilation. A single coil at half depth was used for the wooden bins. This method of passive ventilation was chosen to minimize variability in active pile management and demonstrate effectiveness of a minimal maintenance approach (Figure 2).

The two treatments with concrete slab flooring (slab covered and slab uncovered) were assessed for runoff from manure piles via collection of stormwater leachate (combination of stormwater precipitation and/or manure leachate from the piles) via 8-inch PVC pipes built into the back of the manure bunker slabs (Figure 3).

Figure 3. Stormwater leachate collection and monitoring setup. Left: The front of the bunker with two collection pipes shown per lab treatment. Right: The back of the bunker with PVC collection pipes, weir, and sample box with ISCO shown.

Sample Collection

Meteorological parameters including ambient temperature (°C) and precipitation (in) were collected with weather stations (METER Group ATMOS-41) located near the study sites.

Manure piles from all treatments were sampled by collecting a subsample of 10 randomly selected grab samples which had been mixed in a bucket by hand. Manure samples were sent to the laboratory for analysis of ammonium (mg/kg), nitrate (mg/kg), total nitrogen (mg/kg) potassium (mg/kg), phosphorous (mg/kg), and fecal coliform (mpn/g DW). Manure pile temperature was assessed manually the first year using a 36-inch compost thermometer when collecting storm event samples. During the second year of the project, real-time temperature was monitored using Meter Group TEROS 21 soil water potential sensors.

Runoff from the uncovered bunker was routed from the PVC through a flow monitoring V-notch insert and samples were collected by an ISCO auto-sampler. Due to the low volume of runoff from the covered bunker, all leachate was collected directly in a plastic storage bin with a lid. Samples from manure storage areas were collected when a runoff event occurred in conjunction with precipitation events expected to exceed half an inch within a 24-hour period. Water samples were sent to a laboratory for analysis of nitrate + nitrite (mg/L), total nitrogen (TKN, mg/L), total phosphorous (mg/L), and fecal coliform (CFU/100 ml).

The two treatments on dirt surfaces (dirt covered and dirt uncovered) were assessed for leachate losses below the piles via monthly 12 and 24-inch profile soil sampling. Soil samples were collected from under the manure piles via a 45-degree diagonal borehole from the outside of the box. Residual holes were plugged with kaolinite clay and flagged, to prevent preferential leaching pathways or cross sampling. Samples were sent to the laboratory for analysis of ammonium (mg/kg), nitrate (mg/kg), potassium (mg/kg), phosphorous (Bray, mg/kg), and fecal coliform (mpn/g DW). See Appendix A for additional details.

Results

Relatively dry winters during 2022-24 resulted in fewer than anticipated storm events and thus fewer sample collection opportunities. A total of 56 stormwater / leachate samples were collected, including 14 covered and 19 uncovered at Site H and 8 covered and 15 uncovered at Site A. Sixty-Four (64) manure samples (8 from each bin), and 47 soil samples (23 from Site A and 24 from Site H) were also collected. In order to increase the robustness of the primary analysis, all samples from both manure types for both years were combined and compared monthly. Both manure types performed similarly overall, therefore only notable differences are presented below.

Meteorological

Rainfall data was collected at the two sites by separate meteorological stations installed on the respective properties. The AgWeatherNet Enumclaw station data (Enmclw.N) was used to measure precipitation at the two slab treatment locations, while the AgWeatherNet Issaquah (Issaquah Rain) was installed to measure precipitation at the permeable treatment location. Total cumulative rainfall recorded at the Enumclaw and Issaquah stations during year 1 (October 2022 – April 2023) were 27.23 inches and 37.69 inches respectively.

During year 2 (October 2023 – March 2024) the Enumclaw station recorded 33.09 inches and the Issaquah station recorded 38.37 inches. The rainfall accumulated during the monitoring period (Oct 2022 – March 2024) was compared to the 30-year average data (1991-2020) from the NOAA weather station located in Buckley, WA (USC00450945) (Figure 4). The Buckley station is located approximately 3 miles southwest of the Enumclaw slab sites.

The first monitoring season was significantly dryer than average, with the Enumclaw station recording 10 inches less rain, or 73% of normal during the first monitoring season. The second monitoring season was wetter, with the Enumclaw station recording cumulative precipitation within 0.1 inches of the 30-year average.

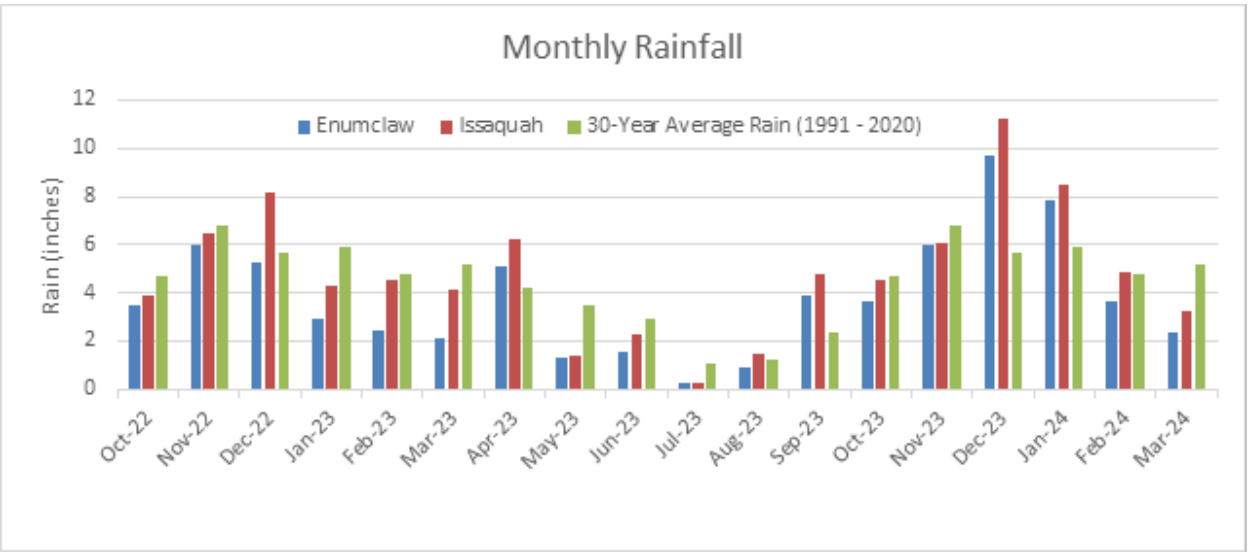

Figure 4. Monthly rainfall (inches) as recorded at the AgWeatherNet *Enmclw.N* and *Issaquah Rain* weather stations, compared to 30-year averages from NOAA weather station located in Buckley, WA (USC00450945).

Manure Pile Temperature

While the covered bin at Site A retained higher temperature (2022-2023), the uncovered bin at Site H achieved higher temperatures during the first year (Figure 5). We believe that this may have been due to insufficient initial moisture in the covered bin at Site H.

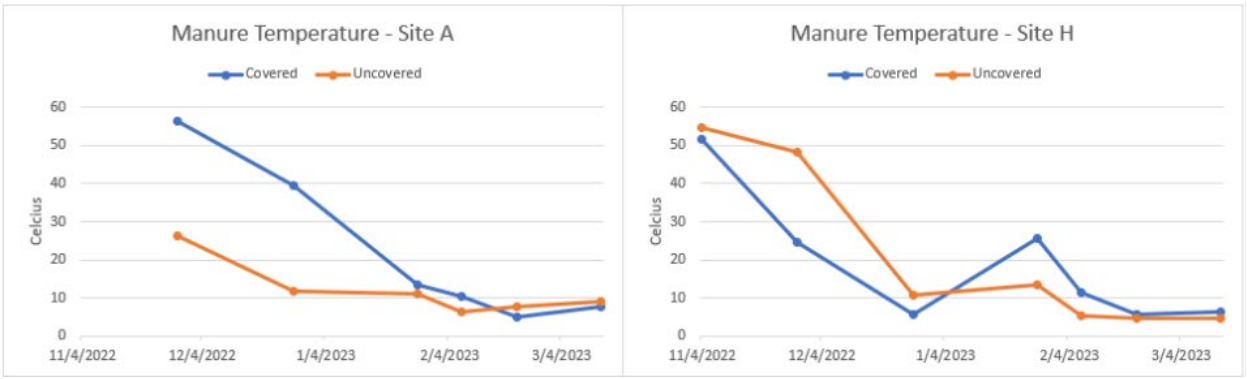

Figure 5. Manual temperature measurements (°C) of the manure piles from November 2022 – March 2023.

To better monitor the composting process, we installed real-time thermometers in each slab site manure pile during the second season. Manure temperature levels in the covered bin at Site A were not as expected during the first month. Manure testing results confirmed that this was because the moisture content was insufficient to initiate rapid biological activity. Water was then added to the piles at Site A to reach optimal levels. It is interesting to note that due the lack of initial moisture levels rain events during the first month increased subsequent temperatures in the uncovered pile (Figure 6).

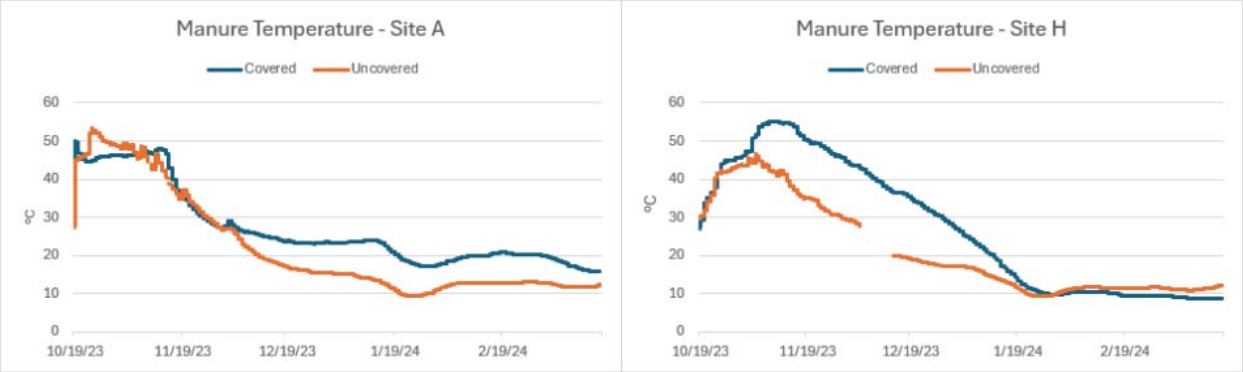

Figure 6. Average temperature (°C) of the manure piles from October 2023 – February 2024.

Manure Sampling

Manure samples were collected from the four treatments (dirt covered, dirt uncovered, slab covered, slab uncovered) each monitoring season. All data from both sites and both years for slab and dirt treatments were averaged together when comparing covered and uncovered bins. Since the overall trends observed for each manure type individually were similar, this was done to minimize variability due to our small sample size.

As the manure composted, fecal coliform levels decreased in both covered and uncovered bins due to heat buildup in the pile, while a clear difference in soluble nutrient concentrations was observed between covered and uncovered treatments. Ammonium levels decreased in both treatments as microbial nitrification converted it to nitrate. However, while nitrate concentrations increased over time in the covered bins, they remained low in the uncovered bins from increased precipitation induced leaching through the pile. Similarly, potassium levels remained higher in the covered bins than the uncovered bins (Figure 7).

The interplay between ammonium and nitrate concentrations during the composting process also resulted in total nitrogen concentrations remaining higher in covered bins. Even though phosphorus is more particulate bound and therefore less susceptible to leaching, the covered bins showed the same overall pattern to a lesser extent. (Figure 7).

Figure 7. Combined monthly average manure concentrations of ammonium (mg/kg), nitrate (mg/kg), potassium (mg/kg), total nitrogen (mg/kg), phosphorus (mg/kg), and fecal coliform (mpn/g DW) for covered and uncovered treatments.

Leachate

Leachate data collected from covered and uncovered slabs for both years were combined. Concentrations were higher overall for the uncovered slab sites compared to the covered slab sites. While fecal coliform concentrations coming off the pile were logarithmically reduced with both treatments, leachate concentrations of phosphorus and nitrate from the uncovered slabs were elevated compared to the covered slabs (Figure 9).

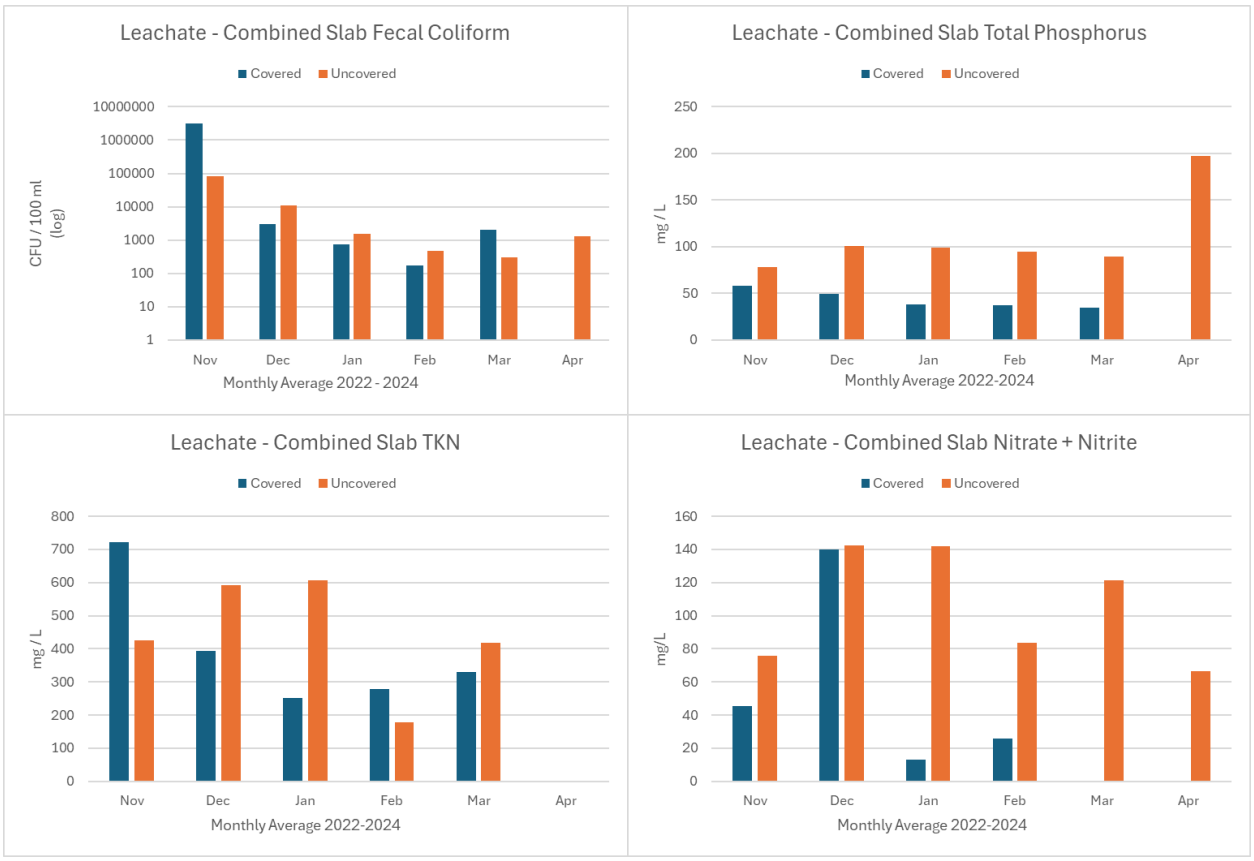

Figure 9. Combined monthly average leachate concentrations of fecal coliform (CFU/100ml), nitrate + nitrite (mg/L), TKN (mg/L) and total phosphorus (mg/L) for covered and uncovered treatments.

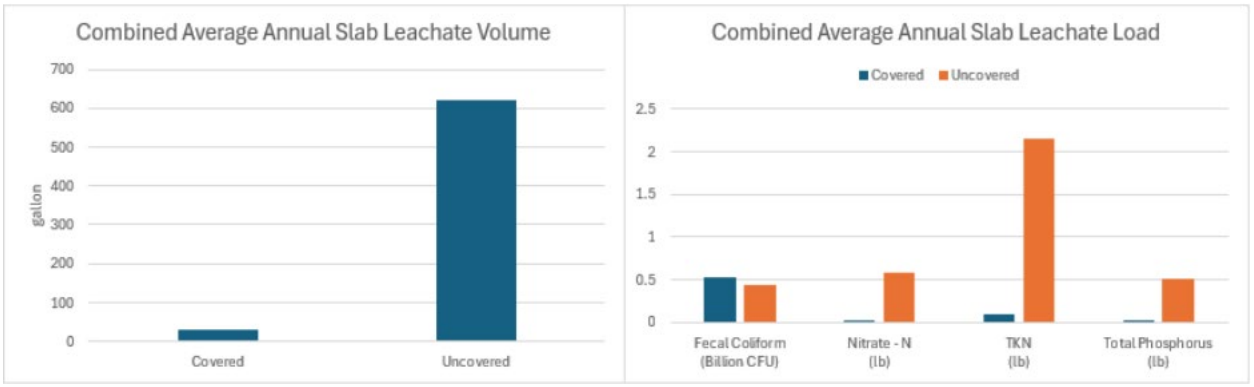

Figure 10. Combined average annual slab leachate volume, and fecal coliform (billion CFU), nitrate-N (lb), TKN (lb) and total phosphorus (lb) load for covered and uncovered treatments.

In addition, a large difference in the total volume of leachate from each site was observed. The average estimated total annual runoff from the uncovered manure piles on slabs at Site A and Site H during all sampled events (2022 – 2024) was 622 gallons. Only 31 gallons of leachate on average was collected annually from the covered slab bins at each location. This led to large differences in overall loading of the constituents monitored between the covered and uncovered sites (Figure 10).

Soil

Leachate penetrated more deeply into the soil over time in the uncovered piles compared to the covered piles, presumable due to precipitation induced transportation.

Figure 11. Combined monthly average soil concentrations of ammonium (mg/kg), nitrate (mg/kg), potassium (mg/kg), phosphorus (mg/kg), and fecal coliform (mpn/g DW) for covered and uncovered treatments.

Due to their high solubility, nitrate, ammonium, and potassium concentrations showed the largest impact at both the 0-12” and 12-24” depths. Fecal coliform levels increased during the first month in the 0-12” horizon, but then decreased by January. We hypothesize that low soil temperatures during the winter may have caused the bacteria present to enter dormancy, or a viable but non-culturable state (VBNC), leading to lower readings.

Manure Type Comparison

While both manure types behaved similar overall, Site A (mixed animal) contained higher initial levels of ammonium compared to Site H (horse).

Figure 12. Site specific manure comparison of ammonium and nitrate manure concentrations with subsequent bin soil concentrations.

Although both manures showed the same evidence of metabolic transition from ammonium to nitrate over time, the higher initial concentrations present in the Site A manure led to increased soil penetration at both the 0-12" and 12-24" horizons. It is important to note that even with higher ammonium and resultant nitrate concentrations, the covered bins effectively minimized leaching into the soil compared to the uncovered bins.

Manure Management

While some records on the manure pile management were captured, detailed measurements of manure quality and use were not part of the project objectives. However, managers from both project sites provided anecdotal observations of the differences in the manure quality between the four treatments.

In general, both sites noticed that the manure piles in the cover treatments had a drier, more decomposed product as compared to the uncovered piles which were described as more of a "slop" texture. Manure from the covered treatments was characterized as easier to use, had a better-quality feel, and had less offensive odor. All of these observations point to a better "composting" process in the covered manure piles.

Education and Outreach Outcomes

The Discovery Farms® Dry Manure Storage project engaged producers and partners through both in-person and virtual education efforts designed to translate research into practical action. A farm tour held on June 22, 2024 at Blue Mist Farm in Enumclaw brought together 25 registered participants (15 in attendance) to see manure storage systems firsthand, discuss water quality monitoring results, explore heavy use area improvements and riparian plantings. Six King Conservation District staff supported the event, providing technical context and individualized guidance. A follow-up Zoom webinar focused on presenting scientific findings and management implications, drawing 66 registrants with 26 attendees and supported by four staff. While only one formal steering committee meeting was convened due to farmers' time constraints, two host producers remained actively engaged throughout the research process, providing ongoing input and practical insight. Collectively, these outreach efforts strengthened producer's understanding of nutrient runoff risks, increased awareness of covered manure storage solutions, and reinforced the value of science-based best management practices supported by technical assistance.

Findings and recommendations will be added to the KCD website. These materials, including factsheets and instructional videos, will be shared with King County farmers through social media, KCD's monthly newsletter, and at upcoming farm tours and events.

Project Challenges and Lessons Learned

Overall, the project revealed several important challenges that shaped both implementation and future program direction. Producer time constraints significantly limited sustained participation in the steering committee process, underscoring the reality that small-scale farmers often balance off-farm employment and seasonal labor demands. Weather variability, particularly the intensity and timing of storm events—also affected sampling opportunities and reinforced the need for flexible, event-based monitoring protocols. A

relatively dry 2022-23 winter and spring resulted in fewer than anticipated stormwater runoff events and thus sample collection events. Soil and manure samples taken during the 2023-2024 season were also lost during shipping. Therefore, the data collected during both trials were combined to increase the sample size, minimize the impact of individual sample variability, and create a more robust dataset for analysis.

Earlier phases of the work demonstrated that highly engineered systems, while effective, may be cost-prohibitive or impractical for widespread adoption, and that experimental designs must balance scientific rigor with on-farm feasibility. One key lesson learned was the importance of designing manure storage solutions that are both technically sound and economically accessible. Another was the value of continuous engagement with host producers, whose practical feedback improved study design and ensured results were grounded in real-world conditions. Ultimately, the project reinforced that adaptive management—refining BMPs based on field experience and data—is essential to achieving durable water quality outcomes in working agricultural landscapes.

Conclusion

Despite a relatively small data set, the project results support the conclusion that the covering of dry manure piles has positive environmental benefits. Results show that covering manure piles greatly reduces nutrient loss due to precipitation, while maintaining better conditions for composting. Composting on an impervious surface prevents the leaching of manure nutrients and fecal coliform bacteria into the soil. However, if manure piles are placed directly on the ground, simply covering the pile with a tarp will reduce the amount of leachate entering the soil. While storing manure in a concrete manure bin with a roof is recommended, it may be cost prohibitive for some farmers. This study has shown that other low-cost alternatives focused on keeping precipitation out of the pile can still dramatically improve composting efficiency, nutrient retention, and environmental protection.

As a result of this project, King Conservation District has already received requests for assistance with manure storage planning and cost-share assistance. The provision of data along with conservation management practice recommendations, such as covered manure storage, is invaluable to both knowledge of environmental protection and landowner confidence in applying the practice. This project is providing unique and needed data on dry manure storage strategies to improve landowner adoption and ultimately water quality in the Puget Sound region.

By combining rigorous field research with hands-on technical assistance and planning services, the District supports producers in meeting both environmental and operational goals, contributing to healthier watersheds, improved soil health, and more resilient agricultural systems throughout King County.

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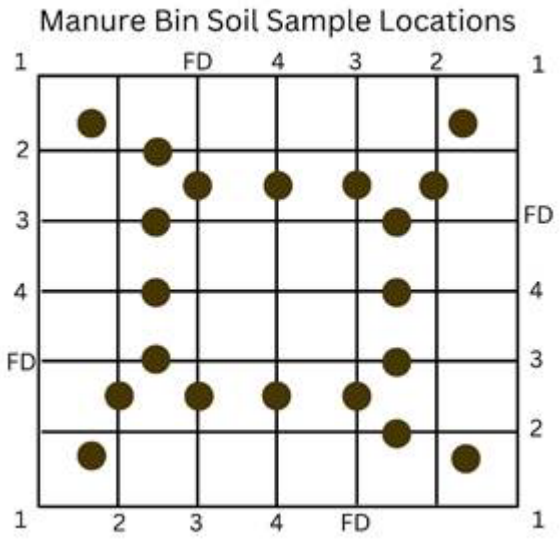
Appendix A

Manure Bin Soil Sampling Protocol

This protocol is designed for sampling composite soil samples at multiple depths beneath 4'X4' manure storage bins over the course of 3 months; without moving the manure after initial placement.



1 = First sample from each bin taken either just before or when the bins are filled. Taken diagonally from each corner toward the center of the bin.

2,3,4 = Samples taken each month.

FD = Field duplicate. Additional quality control sample taken from 1 bin each month from the 3.5"–12" depth profile only. If fecal coliform is analyzed in any soil sample that month, it must also be analyzed in the FD.

***It is important that the bins are not moved at all once soil sampling has begun.**

Figure 1. Manure Bin Sample Locations

These sample locations have been specifically designed to meet the volume requirements for all lab analysis each month while maintaining at least 5 inches between boreholes in 3-dimensional space. Once soil sampling has begun, it is important that the bins are not moved, or borehole intersection may occur.

All sample locations should be measured and marked on the outside of the bins before soil sampling begins. Facing the bin, start at the left corner. The first samples are taken here at a diagonal, directly toward the center of the bin.

Use a large permanent marker to draw a single vertical arrow pointing at the ground along the bottom of the bin every 8" from the left corner until there are 4 arrows on the external side wall. When done, there should be a 16" gap to the right corner with no arrows. Samples 2,3,4 and FD should be labeled above each arrow for reference; matching Figure 1 (above).

Do the same on every side of every bin. These arrows correspond to the placement and direction of the boreholes, and should be matched to the front of the first flange when sampling.

Soil Sample Rig Construction

The base of the sampling rig is a 1”X12”X18” pine wood board (Figure 2). 2” holes are drilled through the board with 45° angle flanges placed over them. The first hole is placed horizontally in the center of the board, and positioned so that once the flange is attached, it is at the edge of the board. The distance from the center of the first flange hole to the center of the second flange hole is 12”. Two additional ¾” holes are drilled on either side of the second flange for the rebar stakes.

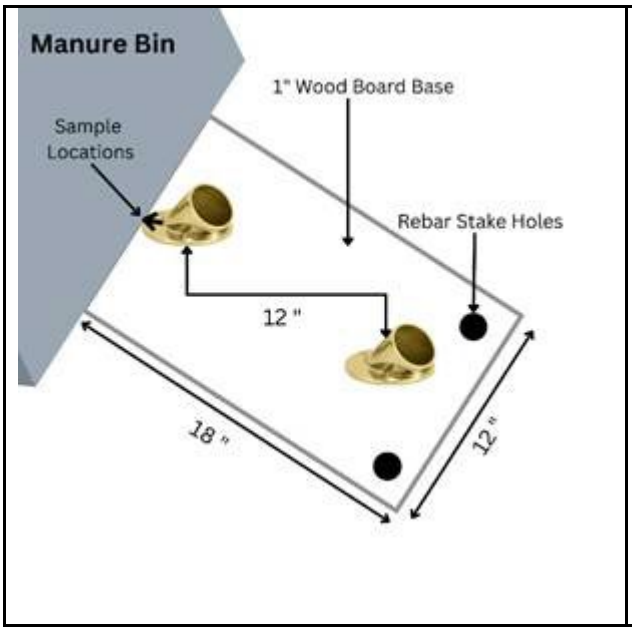


Figure 2. Diagram of 45° angle soil sampling rig.

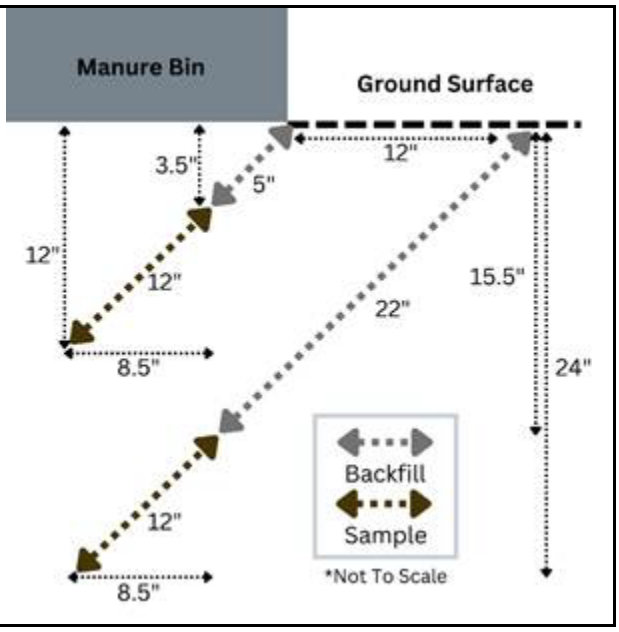


Figure 3. Soil sampling depth profile cross section.

Sample Collection

Place the soil sampling rig flush against the manure bin so that the first flange lines up with the pre-measured sampling locations marked on the side of the bin. Once placed against the bin, drive rebar stakes into the holes on the opposite side to sufficient depth to hold it in place. Samples are then taken at a 45° angles by placing the soil sampling probe through the flanges into the ground beneath.

The first flange is used to collect a 3.5” – 12” depth profile (Figure 3). The first 5” are removed and saved for backfill, then the next 12” sampled is retained for the composite sample.

The second flange is used to collect a 15.5” – 24” depth profile (Figure 3). It positions the second borehole 12” “behind” the first borehole, so that the sample collected in the second borehole is directly below the first. The first 22” of material is saved for backfill. The following 12” is collected as the soil sample.

Keep the rig in place during the collection of both depth profiles, separating each profile sample into a labeled clean bucket. Once both samples have been collected, remove the rig and backfill the deepest 12” of each borehole with bentonite, using a funnel and pipe to minimize gaps, and then the saved soil from each borehole.

Place a red marker flag in the ground at the location of each borehole once backfilled.

Composite Soil Sampling

For each depth profile sampled, four (4) samples will be collected, one from each side of the manure bin at the marked locations. The samples will be thoroughly mixed together in a clean bucket, then placed in a gallon Ziplock bag, appropriately labeled and submitted as a composite sample to the lab overnight in a chilled (4°C) temperature-controlled container.

Sample Volume

Before backfilling the 4th borehole, measure the total composite sample volume. The sample probe used (JMC 12-inch large diameter sampling tube) produces a specified core size of 1.25” in diameter and 9” long. Total composite volume of the four samples collected at each depth profile should be 44 cubic inches (just over the 3 cups required for laboratory analysis). If insufficient material is obtained, collect additional soil from the 4th sample hole until sufficient composite sample volume is collected.

Sampler Depth Calibration

The soil sampler can be calibrated and marked to facilitate easier and more consistent sampling.

This is done by incrementally measuring the first flange bore hole until a 5” depth below ground is reached and then marking the soil sampler at the point that matches the top of the flange with colored electrical tape. Do this again using a different colored tape at the 17” below ground depth. This way, the depth of future boreholes will be known by the position of the probe relative to the colored tape at the top of the flange.

For the second flange borehole, again mark the sampler with different colored electrical tape at the 22” and 34” depths.