Draft Initial Best Management Practices Database Summary

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Subject: Scope 1, Task 3 – Initial BMP Database Summary

Purpose

The Lower Yakima Valley Groundwater Advisory Committee (GWAC), through Yakima County Public Services, selected HDR Engineering, Inc. (HDR) and Pacific Groundwater Group (PGG) to assist in accomplishing two scopes of work. The first scope (lead by HDR) is a study to identify applicable local, state, and federal regulatory requirements that control and manage nitrates in groundwater, identify Best Management Practices (BMPs), and evaluate the effectiveness of these BMPs. The second scope (lead by PGG) focuses on completing the initial site assessment activities begun by the GWAC and other agencies.

The purpose of the BMP database review (Scope 1, Task 3) is to begin identifying and assessing currently available technologies and management approaches for minimizing nitrate leaching to groundwater from potential sources.

Six potential nitrogen sources are identified for the Lower Yakima Valley Groundwater Management Area (GWMA):

- Irrigated cropland (includes solid and liquid manure cropland application)
- Livestock operations (storage and handling of manure)
- Turfgrass and Other Urban Landscaping
- Municipal and industrial land application of wastewater (including storage and handling)
- Sewer leakage
- Septic systems

The GWAC is evaluating source contribution to nitrate loading to groundwater.HDR proposes a hierarchal classification approach to develop a BMP database:

1. For each potential nitrogen source listed above, develop management objectives for reducing nitrate leaching to groundwater.
2. For each management objective, development management targets relating to general actions for reducing nitrate leaching to groundwater.
3. For each management target, list specific BMPs with associated references.

This hierarchal approach, illustrated in Figure 1, serves as the outline for a BMP database.

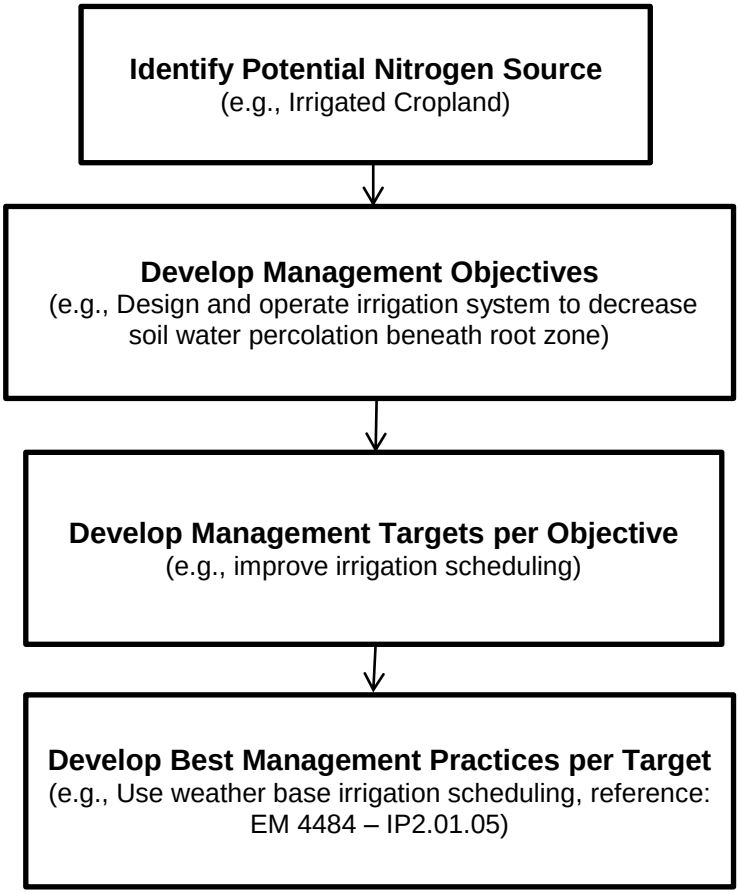

Figure 1. BMP Database Hierarchal Outline

HDR requests that GWAC review the attached tables developed for each potential source, which include management objectives, management targets, and BMPs. Each table also includes BMP references. Following the tables are full reference citations. In addition, HDR has placed each referenced BMP into a PDF file to allow GWAC easy access once the database is fully developed (not yet available).

For each potential nitrogen source, managing nitrate leaching to groundwater may require implementation of multiple BMPs. This hierarchal approach provides for a selection of BMPs that meets a specified management target and management objective. The goal is to select a suite of BMPs that meet specific land users' needs and constraints.

This document serves as a description of the initial BMP database summary. Additional BMPs will be added, and some removed, as the project develops. The next step in the process is to evaluate BMPs for implementation in the GWMA and to assess BMP effectiveness.

Attachments

Attached are six sets of tables, where each table lists the following:

- Source – land activity that potentially contributes nitrate to groundwater
- Objective (OB) – list of objectives for reducing nitrate leaching to groundwater for the source
- Management Target (MT) – general action(s) required to meet the objective
- Best Management Practice (BMP) – specific method, process, or activity that helps meet the management target and the objective for the source.
- Reference –information source for the BMP

Following the six tables is the listing of BMP references with information on author, title, and publication source.

Source 1. Irrigated Cropland (includes solid and manure cropland application)

Which irrigated cropland activities potentially contribute to nitrate (N) leaching to groundwater?

- Irrigation practices
- Crop practices
- N source management (type, quantity, and timing)
- Others (e.g., spills, stockpiling, etc.)

Objectives for Reducing Nitrate Leaching to Groundwater from Irrigated Cropland[1]

1. Design and operate irrigation system to decrease soil water percolation beneath root zone.
2. Manage crop plants to maximize nitrogen use efficiency (NUE)[2].
3. Manage N fertilizer and manure (liquid and solid) to increase crop NUE.
4. Improve storage and handling of fertilizer and manures to decrease off-target discharges.

[1] Information from *Nitrogen Source Reduction to Protect Groundwater Technical Report 3, 2012*. California State Water Resources Control Board was used to aid in the development of BMPs for cropland.

[2] Nitrogen use efficiency (NUE) - percent N applied to cropland (from all sources) that is recovered by the crop and therefore is not lost to the atmosphere (denitrification) or to surface water or groundwater.

Best Management Practices for Irrigated Cropland

OB = objective; MT = management target; BMP = best management practice

Irrigated Cropland Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 1.1 Design and operate irrigation system to decrease soil water percolation beneath root zone	MT 1.1.1 Perform irrigation system evaluation and monitoring	BMP 1.1.1.1 Conduct irrigation system performance evaluation	EM 4885 – IP 2.01.03; PNW 293; EM4828
		BMP 1.1.1.2 Install and use flow meters or other measuring devices to track water volume applied to each field at each irrigation	EM 4885 – IP 2.01.01
		BMP 1.1.1.3 Conduct pump performance tests	EM 4885 – IP 2.01.02
	MT 1.1.2 Improve irrigation scheduling	BMP 1.1.2.1 Use weather based irrigation scheduling	EM 4885 – IP 2.01.05, 2.01.06
		BMP 1.1.2.2 Use plant-based irrigation scheduling	EM 4885 – IP 2.01.05, 2.01.06; EM4821; EB1513
		BMP 1.1.2.3 Measure soil moisture content to guide irrigation timing and amount	EM 4885 – IP 2.01.05, 2.01.06; PNW0475
		BMP 1.1.2.4 Avoid heavy pre-plant or fallow irrigations	
	MT 1.1.3 Improve surface gravity system design and operation	BMP 1.1.3.1 Convert to surge irrigation	EM 4885 – IP 2.02.03; EM4826
		BMP 1.1.3.2 Use high flow rates initially, then cut back to finish off the irrigation	EM 4885 – IP 2.02.10; EM4828
		BMP 1.1.3.3 Reduce irrigation run distances and decrease set times	EM 4885 – IP 2.02.04; EM4828
		BMP 1.1.3.4 Increase flow uniformity among furrows (e.g., compaction furrows)	EM 4885 – IP 2.02.02
		BMP 1.1.3.5 Grade fields as uniformly as possible	EM 4885 – IP 2.02.05, 2.02.05
		BMP 1.1.3.6 Where high uniformity and efficiency are not possible, convert to drip, center pivot, or linear move systems	EM 4885 – IP 2.01.08
	MT 1.1.4 Improve sprinkler system design and operation	BMP 1.1.4.1 Monitor flow and pressure variations throughout system	EM 4885 – IP 2.03.02
		BMP 1.1.4.2 Repair leaks and malfunctioning sprinklers, follow manufacturer recommended replacement intervals	EM 4885 – IP 1.00.05, 2.03.03
		BMP 1.1.4.3 Operate sprinklers during the least windy periods	EM 4885 – IP 2.03.05
		BMP 1.1.4.4 Reduce distance between lateral lines or alternate lateral line location over successive irrigations	EM 4885 – IP 2.03.04, 2.03.06
		BMP 1.1.4.5 When pressure variation is excessive, use flow control or pressure regulating nozzles	EM 4885 – IP 2.03.02
	MT 1.1.5 Improve micro-irrigation system design and operation	BMP 1.1.5.1 Use appropriate lateral hose length to improve uniformity	EM 4885 – IP 2.04.02
		BMP 1.1.5.2 Check for clogging potential and prevent or correct clogging	EM 4885 – IP 2.04.03
	MT 1.1.6 Make other irrigation infrastructure improvements	BMP 1.1.6.1 Installation of subsurface drains	EM 4885 – IP 5.01.01
		BMP 1.1.6.2 Backflow prevention	EM 4885 – IP 6.00.03, EB1722
OB 1.2 Manage crop plants to maximize NUE	MT 1.2.1 Modify crop rotation	BMP 1.2.1.1 Grow cover crops	EM 4885 – IP 5.01.01
		BMP 1.2.1.2 Include deep-rooted or “nitrogen scavenger” crop species in annual crop rotations	PNW513
		BMP 1.2.1.3 Grow more crops per year (double cropping)	Bul 869
		BMP 1.2.1.4 Include perennial crop rotation	PNW513
	MT 1.2.2 Monitor crops	BMP 1.2.2.1 Monitor crop performance for each field including yield, nitrogen content, estimate of nitrogen removed from field versus remaining in field	NRCS Part 651. Ch. 13, Appendix 13B
OB 1.3 Manage N fertilizer and manure to increase crop NUE	MT 1.3.1. Improve rate, timing, and placement of N fertilizers	BMP 1.3.1.1 Adjust nitrogen fertilization rates based on soil nitrate testing	EM 4885 – IP 3.02.01
		BMP 1.3.1.2 Adjust timing of nitrogen fertilization based on plant tissue analysis	EM 4885 – IP 3.02.03
		BMP 1.3.1.3 Apply nitrogen fertilizer in small multiple doses rather than single large dose	EM 4885 – IP 3.02.05
		BMP 1.3.1.4 Measure nitrate content of irrigation water and adjust fertilizer accordingly	EM 4885 – IP 3.02.02
		BMP 1.3.1.5 Use low rates of foliar nitrogen instead of higher rates applied to soil	

Irrigated Cropland Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 1.3 Manage N fertilizer and manure to increase crop NUE	MT 1.3.1. Improve rate, timing, and placement of N fertilizers	BMP 1.3.1.6 Vary nitrogen application rates within large fields according to expected needs (precision agriculture)	Peters and Davenport
		BMP 1.3.1.7 When fertilizing in surface gravity systems, use delayed injection procedures	
		BMP 1.3.1.8 Develop a nitrogen budget that includes crop nitrogen harvest removal, supply of nitrogen from soil, and other inputs	CSU-XCM-173
		BMP 1.3.1.9 Use controlled release fertilizers, nitrification inhibitors, and urease inhibitors	EM 4885 – IP 3.02.06
		BMP 1.3.1.10 Assess the risk of contamination of ground and surface water due to fertilizer leaching or runoff	EM 4885 – IP 3.01.01
		BMP 1.3.1.11 Maintain records of all soil, tissue, and water tests, cropping rotations, yields, and applications (dates, material, method, results)	CSU-XCM-173
		BMP 1.3.1.12 Develop realistic yield goals	EM 4885 – IP 3.02.07
	MT 1.3.2. Improve rate, timing, and placement of animal manure applications	BMP 1.3.2.1 Apply moderate rates of manure and compost, and use materials with high nitrogen content (inorganic fertilizer) to meet the peak nitrogen demand	
		BMP 1.3.2.2 Incorporate solid manure immediately to decrease ammonia volatilization loss	EM 4885 – IP 3.03.05
		BMP 1.3.2.3 When applying liquid manure in surface gravity irrigation systems, use the delayed injection procedure to improve application uniformity	
		BMP 1.3.2.4 Use quick test methods to monitor dairy lagoon water nitrogen content immediately before and during application, and adjust application rate accordingly	
		BMP 1.3.2.5 Develop a nitrogen budget that includes crop nitrogen harvest removal, supply of nitrogen from manure, and other inputs	CSU-XCM-173; USU 2010
		BMP 1.3.2.6 Calibrate solid manure and compost spreaders	EM 4885 – IP 3.03.01; NRCS Part 651. Ch. 13, Appendix 13A
		BMP 1.3.2.7 Ensure uniformity of application with manure	EM 4885 – IP 3.03.07
		BMP 1.3.2.8 Do not apply manure to frozen ground, especially sloping fields	EM 4885 – IP 3.03.08
		BMP 1.3.2.9 Test manure or other waste materials for nutrient content	EM 4885 – IP 3.02.04; NRCS Part 651. Ch. 13, Appendix 13B
		BMP 1.3.2.10 Use synchronized rate nutrient application of lagoon water to reduce or eliminate the need for fertilizer	NDESC 2005 (II)
	MT 1.3.3. Use fertilizer guides to determine and apply appropriate fertilizer amounted.	BMP 1.3.3.1 Follow recommendations of Fertilizer Guide: Home Vegetable Gardens, Irrigated Central Washington	FG0052
		BMP 1.3.3.2 Follow recommendations of Fertilizer Guide: Irrigated Alfalfa Central Washington	FG0003
		BMP 1.3.3.3 Follow recommendations of Fertilizer Guide: Irrigated Asparagus	FG0012
		BMP 1.3.3.4 Follow recommendations of Fertilizer Guide: Irrigated Field Beans for Central Washington	FG0005
		BMP 1.3.3.5 Follow recommendations of Fertilizer Guide: Irrigated Field Corn for Grain or Silage	FG0006
		BMP 1.3.3.6 Follow recommendations of Fertilizer Guide: Irrigated Hops for Central Washington	FG0011
		BMP 1.3.3.7 Follow recommendations of Fertilizer Guide: Irrigated Mint Central Washington	FG0008
		BMP 1.3.3.8 Follow recommendations of Fertilizer Guide: Irrigated Peas for Central Washington	FG0033
		BMP 1.3.3.9 Follow recommendations of Fertilizer Guide: Irrigated Small Grains, Central Washington	FG0009
		BMP 1.3.3.10 Follow recommendations of Fertilizer Guide: Irrigated Sudangrass Pasture or Silage	FG0036
		BMP 1.3.3.11 Follow recommendations of Fertilizer Guide: Irrigated Vineyards for Entire State	FG0013
		BMP 1.3.3.12 Follow recommendations of Fertilizer Guide: Ornamentals, Entire State Except Central Irrigated Washington	FG0049
		BMP 1.3.3.13 Follow recommendations of Fertilizer Guide: Vegetable and Flower Gardens, Except Irrigated Central Washington	FG0050
		BMP 1.3.3.14 Follow recommendations of Fertilizer Guide: Improved Pasture, Hay, Eastern Washington	FG0037
		BMP 1.3.3.15 Follow recommendations of Fertilizer Guide: Grass Seed for Eastern Washington	FG0038

Irrigated Cropland Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 1.3 Manage N fertilizer and manure to increase crop NUE	MT 1.3.3. Use fertilizer guides to determine and apply appropriate fertilizer amounted.	BMP 1.3.3.16 Follow recommendations of Fertilizer Guide: Barley for Eastern Washington	FG0029
		BMP 1.3.3.17 Follow recommendations of Fertilizer Guide: Soil Samples/Orchards	FG0028C
		BMP 1.3.3.18 Follow recommendations of Fertilizer Guide: Instructions for Tree Fruit Leaf Nutrient Analysis	FG0028E
		BMP 1.3.3.19 Follow recommendations of Fertilizer Guide: Peas and Lentils for Eastern Washington	FG0025
		BMP 1.3.3.20 Follow recommendations of Fertilizer Guide: Lawns, Playfields and Other Turf, East and Central Washington	FG0024
OB 1.4 Improve storage and handling of fertilizer and manures to decrease off-target discharges	MT 1.4.1 Avoid fertilizer material and manure spills during transport, storage, and application	BMP 1.3.4.1 Do not overfill trailers or tanks. Cap or cover loads.	EM 4885 – IP 4.01.06
		BMP 1.3.4.2 When transferring fertilizer, take care not to allow materials to accumulate on the soil	
		BMP 1.3.4.3 Maintain all fertilizer storage facilities and protect them from the weather	
		BMP 1.3.4.4 Clean up fertilizer spills promptly	
		BMP 1.3.4.5 Shut off fertilizer applicators during turns and use check valves	
		BMP 1.3.4.6 Maintain proper calibration of fertilizer application equipment	EM 4885 – IP 3.03.01
		BMP 1.3.4.7 Create a buffer around wellheads from fertilizer and manure storage, handling, and application	EM 4885 – IP 6.00.02
		BMP 1.3.4.8 Distribute rinse water from fertilizer application equipment throughout field	
		BMP 1.3.4.9 Avoid manure spills/discharges during transport, storage, and application	
		BMP 1.3.4.10 Prevent back siphonage/flow of chemicals or nutrients down a well after injection	EM 4885 – IP 6.00.03, EB1722
		BMP 1.3.4.11 Identify and properly seal all abandoned and improperly constructed wells	EM 4885 – IP 6.00.04

Source 2. Livestock Operations (storage and handling of solid and liquid manure)

2.1 Background

A basic description of dairy and other livestock operations is presented below in order to develop management objectives, targets, and practices. The application of manure (both solid and liquid) to cropland is covered under "Source 1. Irrigated Cropland."

2.2 Dairy Waste Management Systems

Dairies operate either as a freestall operation, as a drylot operation, or as a combination of both.

Freestall. In a freestall dairy operation, adult cows are housed in covered freestalls and have access to exercise yards (open areas with no roofs), often referred to as corrals or open lots. Freestalls are buildings with long rows of individual stalls. They are bordered on the front side by a feed bunk and on the back side by a concrete-paved flush and travel lane (often referred to as flush-lane or flush-alley), used for both manure collection and as access pathway for the animals to their stalls. The stalls themselves are unpaved and generally bedded with dry manure solids or other dry materials that are periodically refreshed to keep the freestalls clean and comfortable for the cows. Feed is distributed into feed bunks along the front of the freestalls. Typically, milking cows are walked to a centrally-located milking barn (milking center) two to three times a day. The entire complex of freestall, flush-lane, and feed bunk is roof-covered to protect from sun and rain.

Animal manure (from liquid and solid excretions) accumulates primarily in the flush-lane that passes behind an individual animal's bedded freestall. The flush-lane is often comprised of a slatted floor, where animal hooves work the manure through the slats into the lane (also referred to as an alley) below, and the manure is collected by flushing or scraping the lane. Flush-lanes are flushed with recycled water from the liquid manure storage lagoon two to five times daily. Flush water is collected, passes through a mechanical solid separation system, and the liquid portion (with suspended solids) is stored in a manure storage lagoon for treatment. Some dairies may use a mechanical scraper under the slatted floor as an alternative to flushing or a combination of the two systems.

A number of different collection and solid separation systems are available. Systems differ in their effectiveness at separating coarse solids and fine solids from the liquid fraction. Separated solids (solid manure) are generally stored in stockpiles or windrows for drying and storage. Dried, separated solids are reused for bedding in freestalls and corrals, as soil amendment in crop fields, or hauled off-property as soil amendment.

Liquid manure is stored in manure storage lagoons ("lagoons") and recycled for flushing. Liquid manure is ultimately blended with irrigation water and used as fertilizer in crop fields associated with the dairy.

Drylot. Drylots (corrals) are earthen-surface exercise yards without flooring or plant cover, and usually without any roofing. Drylot dairies generally lack flush-lanes for the collection of manure, except in the milking barn area and its associated travel lanes. Animal excrement collects in the corral area and is regularly scraped. Scraped solids are dried, sometimes composted to various degrees, and then reused as bedding in the freestalls and corrals, used as soil amendment in fields, or sold off-dairy as soil amendment.

Dairies also collect surface runoff from animal housing areas. Stormwater runoff from roof tops is often collected separately and diverted to stormwater drains. Any runoff that has come in contact with animal waste must be collected in the liquid manure storage pond or lagoon.

2.3 Beef Cattle Waste Management Systems

Beef cattle feedlots function similarly to dairy drylots or uncovered animal holding areas, although the animal stocking rate may be higher for beef cattle. Beef cattle can be confined on unpaved, partially-paved, or totally paved lots. Large feedlot operations (confined animal feeding operations [CAFOs]) are similar to dairies in that any runoff that has come in contact with animal waste must be collected and managed.

2.4 Sources of Nitrogen from Live Stock Operations

What are potential source areas for nitrate in livestock operations?

- Manure generated in uncovered animal holding areas (corrals and drylot areas)
- Manure generated in freestall and milking barn operations
- Liquid manure storage lagoons
- Solid manure storage area
- Feed stock (primarily forage)
- Liquid and solid manure applied to crop fields (addressed under “Source 1. Irrigated Cropland”)
- Human waste discharged to septic leach fields (addressed under “Source 6. Septic Systems”)

Objectives for Reducing Nitrate Leaching to Groundwater from Livestock Operations (land application of liquid and solid manure is covered under “Source 1. Irrigated Cropland)”:

1. Manage solid and liquid manure in uncovered animal holding areas (e.g., corrals an drylots) to minimize the direct and indirect leaching of nitrate to groundwater.
2. Manage manure in freestall and milking barn operations (and other enclosed structures holding livestock), to maximize capture of solid and liquid waste, while minimizing water usage.
3. Design and operate liquid manure storage lagoons, settling basins, and holding ponds to minimize the leaching of nitrate to groundwater.
4. Design and operate solid manure storage areas to minimize leaching of nitrate to groundwater.
5. Manage livestock herds to minimize leaching of nitrate to groundwater.

Best Management Practices for Livestock Operations

OB = objective; MT = management target; BMP = best management practice

Livestock Operation Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 2.1. Manage manure and liquid waste in uncovered animal holding areas (e.g. corrals and drylots) to minimize the direct and indirect leaching of nitrate to groundwater	MT 2.1.1. Perform livestock site assessment (new or established facility). Applicable to all objectives under livestock operations.	BMP 2.1.1.1 Conduct a livestock site characteristics evaluation (checklist) (meant to be an aid in planning and design, improvements, and operation and maintenance of a livestock facility)	USU – 2010 (dairy); NRCS Part 651 Ch. 8 and Ch. 10, Table 10-4; EB1746-W7; EB1746-F8
	MT 2.1.2. Improve surface management of uncovered animal holding area	BMP 2.1.2.1 Collect manure from uncovered holding areas as frequently as possible to achieve optimum animal health, comply with regulations, and to reduce exposure of manure to precipitation and runoff prior to treatment	USU – 2010; EB1746-F7
		BMP 2.1.2.2 Maintain a firm, dry surface with loose manure layer less than 1 inch deep and 25 to 35 percent pen moisture content	USU - 2010
		BMP 2.2.2.3 Clean corrals and drylots to provide a smooth surface with 3 to 5 percent slope and maintain the integrity of the hardpan below the holding area surface	USU – 2010; NRCS Part 651, Ch. 9, 651.96b(2)
		BMP 2.2.2.4 Collect runoff from holding areas	USU – 2010; NRCS Part 651, Ch. 10, 651.1001(b); EB1746-F8
		BMP 2.2.2.5 Divert clean stormwater runoff away from uncovered animal holding areas	USU – 2010; NRCS Part 651 Ch. 10 651.1001(a),(b); EB1746-F8
		BMP 2.2.2.6 Remove all manure from abandoned uncovered animal holding areas	NRCS Part 651, Ch. 9, 651.96(b)
		BMP 2.2.2.7 Create a buffer around wellheads from manure storage and handling areas	EM 4885 – IP 6.00.02; EB1746-F7
		BMP 2.2.2.8 Identify and properly seal all abandoned and improperly constructed wells (applicable for all source BMPs)	EM 4885 – IP 6.00.04
OB 2.2 Manage animal waste in freestall and milking barn operations to minimize indirect leaching of nitrate to groundwater	MT 2.2.1 Improve exterior building water management	BMP 2.2.1.1 Divert roof runoff from entering uncovered animal holding areas and from entering wastewater system	NRCS Part 651, Ch. 10, 651.1001(a)
	MT 2.2.2 Optimize water use for freestall and milking center manure management	BMP 2.2.2.1 Scrape (manual or automated) alleys, open areas, and/or gutters system to conserve flush water	NRCS Part 651 Ch. 10, 651.1002(a)(1)
		BMP 2.2.2.2 Meet NRCS design criteria for flush-lane (alleys) and gutters	NRCA Part 651 Ch. 10, 651.1002(a)(2)
OB 2.3 Design and operate liquid manure storage lagoons, settling basins, and holding ponds to minimize the leaching of nitrate to groundwater	MT 2.3.1 Improve solids separation from manure liquid stream in dairy operations to reduce solids loading into lagoons	BMP 2.3.1.1 Use settling basin (see MT 2.3.3 for basin design and management considerations)	USU – 2010; NRCS Part 651 Ch. 10, 651.1005(a)(2)
		BMP 2.3.1.2 Use mechanical methods	USU – 2010; NRCS Part 651 Ch. 10, 651.1005(a)(2)
		BMP 2.3.1.3 Use weeping wall basins	NDESC 2005
	MT 2.3.2 Improve lagoon nitrogen treatment design and operations	BMP 2.3.2.1 Conduct lagoon treatment performance and adequacy assessment	USU – 2010; NRCS Code 359; NRCS Part 651 Ch. 10, 651.1005 (a)(b)
		BMP 2.3.2.2 Use mechanical aeration for aerobic lagoon treatment	USU -2010; NRCS Part 651 Ch. 10, 651.1005(b)(3)
		BMP 2.3.2.3 Use anaerobic digestion	NRCS Code 359; NDESC 2005; NRCS Part 651 Ch. 10, 651.1005(b)(2)
		BMP 2.3.2.4 Use Oxidation Ditch	NRCS Part 651 Ch. 10, 651.1005(b)(5)
	MT 2.3.3 Improve lagoon, settling basin, and holding pond design and management	BMP 3.3.3.1 Evaluate criteria for siting, investigation, and design of liquid manure storage facilities (both new and for existing facilities)	NRCS Part 651 Ch. 10, Table 10-4
		BMP 2.3.3.2 Use impermeable or low permeable liner (synthetic or clay) material (see NRCS Part 651 Ch. 10, Table 10-4 to assess liner criteria)	NRCS Code 359; NRCS Part 651 Ch. 10, 651.1004(b)
		BMP 2.3.3.3 Ensure lagoons, basins, and holding ponds have capacity to handle stormwater runoff (e.g. 25-year, 24-hour storm event) in addition to normal wastewater	NRCS Code 359; NRCS Part 651 Ch. 10, 651.1004
		BMP 2.3.3.4 Inspect storage structures, pumps and piping, toe and foundation drains, tanks, and treatment	NRCS Part 651, Ch. 13, 651.1302

Livestock Operation Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
		equipment regularly. Use a checklist and keep records of inspections	

Livestock Operation Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 2.3 Design and operate liquid manure storage lagoons, settling basins, and holding ponds to minimize the leaching of nitrate to groundwater	MT 2.3.3 Improve lagoon, settling basin, and holding pond design and management	BMP 2.3.3.5 Keep cows away from storage structure banks	
		BMP 2.3.3.6 Maintain at least 2 feet of freeboard in storage structures at all times and consider an additional structure(s) for diverting runoff and to allow for cleaning of solids from structures	NRCS Part 651, Ch. 13, 651.1302
		BMP 2.3.3.7 Use aboveground waste storage tank for storing liquid manure	NRCS Part 651 Ch. 10, 651.1004(b)
OB 2.4 Design and operate solid manure storage areas to minimize leaching of nitrate to groundwater.	MT 2.4.1. Improve surface management in manure solids holding areas	BMP 2.4.1.1 Assess manure stockpile location and relocate if necessary	NRCS Part 651 Ch. 8
		BMP 2.4.1.2 Control and collect runoff from stockpile areas	NRCS Part 651 Ch. 10, 651.1004(a); EB1746-F8
		BMP 2.4.1.3 Divert clean stormwater runoff away from stockpile areas	NRCS Part 651 Ch. 10, 651.1004(a);EB1746-F8
		BMP 2.4.1.4 Use grassed filter strips below stockpiles	USU-2010
		BMP 2.4.1.5 Measure nitrate in soils down gradient of manure stockpiles to assess nitrate buildup in soils	USU-2010
	MT 2.4.2 Improve manure storage facility design	BMP 2.4.2.1 Properly size solid manure storage areas to account for number and size of animals and number of days in storage	NRCS 313; NRCS Part 651, Ch. 10, 651.1004(a)
		BMP 2.4.2.2 Use roof solid manure storage	NRCS Part 651, Ch. 10, 651.1004(a)
	MT 2.4.3. Improve manure treatment	BMP 2.4.3.1 Use manure composting	NCRS Part 651, Ch. 10, 651.1005(b)(6)
OB 2.5 Manage livestock herd to minimize leaching of nitrate to groundwater	MT 2.5.1 Adjust feed formulation to reduce nitrogen excretion without reducing animal performance	BMP 2.5.1.1 Adjust feeding method to reduce crude protein levels by supplementing with amino acids to reduce N excretion	USU – 2010; NDESC 2005
	MT 2.5.2 Base herd size on land base requirements for manure	BMP 2.5.2.1 Calculate herd size for fixed acreage based on manure management	USU -2010; NRCS Part 651, Ch. 4, 651.0403
	MT 2.5.3 Find alternative outlets for manure land application based on land base requirements for set herd size	BMP 2.5.3.1 Calculate cropland needs for fixed herd size based on manure management	USU -2010; NRCS Part 651, Ch. 4, 651.0403
	MT 2.5.4 Improve livestock pasture management	BMP 2.5.4.1 Manage livestock in pastures based on stocking rates and manage pasture so cattle graze evenly over field	NRCS Part 651, Ch. 9, 651.96; WSU-CE 1992

Source 3. Turfgrass and Other Urban Landscaping

Urban landscaping refers to areas within the Lower Yakima Valley that have turfgrass (e.g., residential lawns, golf courses, parks, athletic fields, school grounds) and non-turfgrass landscaped areas (e.g., ornamental plants). Turfgrass in the valley usually requires nitrogen fertilizer and irrigation. Thus, there is a potential for over application, resulting in nitrate leaching to groundwater.

What controls nitrate leaching to groundwater from turfgrass and other urban landscaping?

- Irrigation practices
- Fertilizer nitrogen management (type, quantity, and timing)
- Vegetation selection and management

Objectives for reducing nitrate Leaching to groundwater from turfgrass and other urban landscaping

1. Design and operate irrigation system to decrease soil water percolation beneath root zone.
2. Make effective use of fertilizer and fertilizer alternatives to maximize plant nitrogen uptake.
3. Select turfgrass and landscape plants that efficiency use nitrate and water.

Best Management Practices for Urban Landscaping

OB = objective; MT = management target; BMP = best management practice

Urban Landscaping Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 3.1 Design and operate landscape irrigation system to decrease soil water percolation beneath root zone	MT3.1.1 Improve irrigation scheduling	BMP 3.1.1.1 Use soil moisture content and soil type to guide irrigation timing and amount	SPU Lawn Care for the PNW; EB 0482;
		BMP 3.1.1.2 Use "weather-smart" irrigation controller to determine frequency and amount of turfgrass and landscaping irrigation	ET Manager™ RainBird (example only: http://www.rainbird.com/landscape/products/controllers/ETmanager.htm)
	MT3.1.2 Improve irrigation system design	BMP 3.1.2.1 Design turfgrass sprinkler system to provide even application of water and design sprinkler sets based on water demand (e.g., have separate set for turfgrass areas in shade versus fully exposed areas, as timing of sets would be different)	EB 0482
		BMP 3.1.2.2 Use drip irrigation for landscape scrubs and individual plants	Peters (WSU)
OB 3.2 Make effective use of fertilizer and fertilizer alternatives to maximize plant uptake	MT 3.2.1. Improve rate, timing, and placement of nitrogen fertilizer and fertilizer alternatives	BMP 3.2.1.1 Conduct soil testing of lawn (ask about through local WSU Extension) to determine nutrient requirements and deficiencies	PNW646, EB1971E
		BMP 3.2.1.2 Use slow release fertilizers such as urea formaldehyde (UF), sulfur coated urea (SCU), or isobutylidine diurea (IBDU) to allow lawns to absorb nutrients more efficiently	EB0482
		BMP 3.2.1.3 Apply fertilizer in multiple applications throughout year instead of a single application with a larger application occurring in September	EB0482
		BMP 3.2.1.4 Apply fertilizer to landscape trees and shrubs at agronomic rates and at recommended times of the year	EB1034
		BMP 3.2.1.5 Make and use compost or buy compost as an alternative to using commercial synthetic fertilizers	EB1971E
		BMP 3.2.1.6 Apply plant or lawn fertilizers only when plants show a need – not for the sole purpose of following a schedule	Ecology #0004048
		BMP 3.2.1.7 Apply just enough nitrogen to lawns to promote dense turf and prevent yellowing to yield a healthier lawn	SPU Lawn Care for the PNW
		BMP 3.2.1.8 Set realistic expectations for lawn and plant appearance, and for the benefits of using fertilizer	SPU Lawn Care for the PNW
		BMP 3.2.1.9 Do not apply fertilizer when heavy rains are predicted that could wash away fertilizer	Ecology #0004048
		BMP 3.2.1.10 Follow directions on fertilizer label when applying	EB0482
		BMP 3.2.1.11 Use cover crops in gardens in the winter to fix nitrogen and till into garden during the spring for use as green manure	EB1971E
		BMP 3.2.1.12 Use a mulching lawn mower to lower the required amount of fertilizer needed to apply to lawn	
OB 3.3 Select Turfgrass and landscape plants that efficiency use nitrate and water	MT 3.3.1 Select plant types that are specific for Lower Yakima Valley	BMP 3.3.1.1 Use drought tolerant cool-season turfgrasses designed for eastern Washington.	EP0482
		BMP 3.3.1.2 Use xeriscaping for landscaping to reduce water and fertilizer demand.	WSU –http://public.wsu.edu/~lohr/wcl/

Source 4. Municipal and Industrial Land Application of Wastewater (including storage and handling)

The land application of industrial and municipal wastewater to cropland is allowed through a State Waste Discharge Permit as required by Chapter 90.48 Revised Code of Washington (RCW) and Chapter 173-216 Washington Administrative Code (WAC). Design criteria for the permitted facilities includes the application of wastewater at agronomic rates and also the requirement to meet the Water Quality Standards for Ground Waters of the State of Washington (Chapter 173-200 WAC).

What controls nitrate leaching to groundwater at a wastewater land application site?

- Irrigation practice
- Crop practice
- N source management (type, quantity, and timing)
- Wastewater storage facilities

Objectives for Reducing Nitrate Leaching to Groundwater from Municipal and Industrial Wastewater Land Application Sites

1. Design and operate irrigation system to decrease soil water percolation beneath root zone.
2. Manage crop plants to maximize NUE[1].
3. Manage wastewater and other sources of N to increase crop NUE.
4. Improve handling, storage, and overall management of wastewater to minimize leaching of nitrate to groundwater.

[1] Nitrogen use efficiency (NUE) - percent N applied to cropland (from all sources) that is recovered by the crop and therefore is not lost to the atmosphere (denitrification) or to surface water or groundwater.

Best Management Practices for Municipal and Industrial Land Treatment and Application of Wastewater (including storage and handling)

OB = objective; MT = management target; BMP = best management practice

Municipal and Industrial Land Treatment and Application of Wastewater Objectives for Reducing Nitrate Loading to Groundwater	Management Target	Best Management Practices	References
OB 4.1 Design and operate irrigation system to decrease soil water percolation beneath root zone	MT 4.1.1. Follow MT 1.1.1 through MT 1.1.6 for Source 1. Irrigated Cropland	BMPs 1.1.1.1 through BMP 1.1.6.2 for Source 1. Irrigated Cropland	See references for Source 1. Irrigated Cropland
OB 4.2 Manage crop plants to maximize NUE	MT 4.2.1. Follow MT 1.2.1 and MT 1.2.2 for Source 1. Irrigated Cropland	BMPs 1.2.1.1 through BMP 1.2.2.1 for Source 1. Irrigated Cropland	See references for Source 1. Irrigated Cropland
OB 4.3 Manage wastewater and other sources of N to increase crop NUE	MT 4.3.1. Improve rate, timing, and placement of wastewater effluent and other nitrogen source applications	BMP 4.3.1.1. Conduct a monitoring program to record facility operation and management practices, monitor effluent variations, monitor treatment effectiveness, evaluate soil and crop treatment effectiveness, and to determine compliance with water quality standards	Ecology #93-36
		BMP 4.3.1.2. Estimate the agronomic rate for a crop and include all sources of nitrogen available during the growing season.	Ecology #04-10-081; PNW 513
		BMP 4.3.1.3. Adjust treatment/application rate based on soil nitrate testing	EM 4885 – IP 3.02.01
		BMP 4.3.2.4. Adjust treatment/application timing based on plant tissue analysis	EM 4885 – IP 3.02.03
		BMP 4.3.1.5. Measure nitrate content of effluent and adjust treatment/application accordingly	EM 4885 – IP 3.02.02
		BMP 4.3.1.6. Cease operation of facility during heavy or prolonged rainfall to prevent ground saturation and runoff	Ecology #04-10-081
		BMP 4.3.1.7. Avoid application of effluent to frozen ground	Ecology #04-10-081
		BMP 4.3.1.8. Follow seasonal application by only applying effluent during the growing season	Ecology #04-10-081
OB 4.4 Improve handling, storage, and overall management of wastewater to minimize leaching of nitrate to groundwater	MT 4.4.1. Site land treatment/application facilities using criteria protective of surface water and groundwater	BMP 4.4.1.1. Provide buffers and setback from any wells near application site	DOH Design Criteria for Municipal WW Land Treatment Systems, Ecology #97-23
		BMP 4.4.1.2. Site facility so applied effluent does not pond or flow into any streams, rivers, lakes, or other water bodies	DOH Design Criteria for Municipal WW Land Treatment Systems, Ecology #97-23
		BMP 4.4.1.3. Provide an appropriate buffer between the facility and any surface water drainage systems	Ecology #93-36, Ecology #97-23
	MT 4.4.2 Follow operational requirements for wastewater land application	BMP 4.4.2.1. Create a farm management plan which addresses irrigation, cropping, harvesting, worker access, and equipment methods	DOH Design Criteria for Municipal WW Land Treatment Systems
		BMP 4.4.2.2. Refrain from allowing livestock to graze in application area to prevent excess nutrient loading and soil compaction	Ecology #93-36
	MT 4.4.3. Construct and operate wastewater storage facilities to prevent groundwater contamination	BMP 4.4.3.1. Design storage facilities to be able to adequately store the volume of wastewater during time frames when land treatment/application is not possible (such as during the winter or non-growing seasons). Include a hydraulic balance analysis considering precipitation, evapotranspiration, and estimated influent volumes.	Ecology #98-37
		BMP 4.4,3.2 Locate and construct storage facilities in a manner where wastes do not overflow or leach into groundwater	Ecology #98-37
		BMP 4.4.3.3. Equip storage facilities with a free-board gauge so that it can be determined when it is necessary to empty or stop filling impoundment to prevent overflow	Ecology #98-37
		BMP 4.4.3.4. Conduct seepage evaluation of storage facilities	Ecology #98-37

Source 5. Sewer Leakage

What controls sewer water leaching from sewers systems?

- Exfiltration of wastewater from damaged, outdated, and/or poorly fitted pipes and collection system components (e.g., manholes).

Objectives for Reducing Wastewater Leaching to Groundwater from Leaking Sewers

- Maintain municipal sewers in a good working order to prevent seepage of sewer water to groundwater.

Best Management Practices for Sewer Leakage

OB = objective; MT = management target; BMP = best management practice

Sewer Leakage Objectives for Reducing Wastewater Loading to Groundwater[1]	Management Target	Best Management Practices	References
OB 5.1 Maintain municipal sewers in a good working order to prevent seepage of sewer water to groundwater	MT 5.1.1. Perform routine inspections to locate sewer leaks and problem areas	BMP 5.1.1.1 Create a maintenance and inspection plan of sewers with a priority focused on older systems (concrete pipes and vitrified clay pipes are considered most problematic)	EPA 832-F-99-031
		BMP 5.1.1.2 Use dye testing to verify illicit connections and determine connectivity between sewer and other systems	Ecology #98-37
		BMP 5.1.1.3 Use smoke testing to locate illicit connections, pipe defects, and other problems in sanitary sewer	Ecology #98-37
		BMP 5.1.1.4 Perform closed circuit television (CCTV) or camera inspection to locate problems in sanitary sewer	EPA 832-F-99-031
		BMP 5.1.1.5 Perform lamping type inspection to locate problems in sanitary sewer near sewer access points	EPA 832-F-99-031
		BMP 5.1.1.6 Use air pressure testing to determine if sewer sections are compromised	Ecology #98-37
	MT 5.1.2. Rehabilitate outdated or inadequate sewer lines	BMP 5.1.2.1. Replacement of compromised sanitary sewer line with new pipe	EPA 832-F-99-031
		BMP 5.1.2.2. Sealing of leaking joints in sanitary sewer line	EPA 832-F-99-031
		BMP 5.1.2.3. Slip line leaking pipe for rehabilitation of sanitary sewer line	Ecology #98-37
		BMP 5.1.2.4. Use cured-in-place-pipe (CIPP) technology for pipe rehabilitation of sanitary sewer line	Ecology #98-37
		BMP 5.1.2.5. Use fold-and-form technology for pipe rehabilitation of sanitary sewer line	Ecology #98-37
		BMP 5.1.2.6. Perform manhole rehabilitation for manholes identified as a location of potential exfiltration	Ecology #98-37

[1] For sewer water, nitrate is expected to be present at low or non-detectable levels. However, once sewer water enters groundwater, the wastewater undergoes mineralization and nitrification resulting in the formation of nitrate.

Source 6. Septic Systems

The following agencies are responsible for regulating on-site domestic (human-derived) wastewater treatment systems in the Lower Yakima Groundwater Management Area:

- Yakima Health District – Authority and approval over individual and small (up to 3,499 gallons/day) on-site sewage systems.
- Washington State Department of Health (WDOH) – Authority and approval over on-site sewage systems designed to handle domestic strength sewage at design flows from 3,500 to 100,000 gallons/day (may include mechanical treatment). Staff also reviews and approves all septic tanks, pump chambers, and other tanks used as part of small and large systems in Washington State.

Objectives for Reducing Nitrate Leaching to Groundwater from On-Site Domestic Waste Treatment Systems

1. Operate, maintain, and repair on-site treatment system to meet performance requirements.
2. Reduce nitrogen loading to soil drainfields.

Best Management Practices for Septic Systems

OB = objective; MT = management target; BMP = best management practice

Reducing Nitrate Leaching to Groundwater from On-Site Domestic Waste Treatment Systems	Management Target	Best Management Practices	References
OB 6.1 Operate, maintain, and repair on-site treatment system to meet performance requirements	MT 6.1.1. Routinely conduct inspections and maintenance on septic system	BMP 6.1.1.1 Have a qualified professional conduct an annual inspection of the septic tank to assess sludge and scum levels, baffles and tees, and drainfield and downslope area	EB1671; WAC 46-272A-0270
		BMP 6.1.1.2 Pump out septic tank when needed	EB1671; WAC 46-272A-0270
		BMP 6.1.1.3. Practice good housekeeping by reducing water use, avoiding flushing of toxic chemicals and hard to digest waste, and protecting the system from physical damage	EB1671; WAC 46-272A-0270
	MT 6.1.2. Repair septic system failures	BMP 6.1.2.1. Repair or replace the on-site septic system with conforming system or component or a system meeting regulatory requirements	WAC 246-272A-0280
OB 6.2 Reduce nitrogen loading to soil drainfields	MT 6.2.1. Improve on-site treatment of nitrogen	BMP 6.2.1.1. Install and operate an on-site nitrogen reduction system to reduce nitrogen concentration entering drainfield	DOH 337-024; WAC 246-272C
	MT 6.2.2. Use alternatives to on-site septic system	BMP 6.2.2.1. Connect to available public wastewater treatment system sewer line and eliminate on-site septic system	
		BMP 6.2.2.2. Compost Toilets	DOH 337-024
		BM P 6.6.2.3 Design, install, and use greywater system for subsurface irrigation	DOH 337-063

Attachment A

Best Management Practice (BMP) References

Source 1. Irrigated Cropland BMP References

EM4885
BUL 869
NRCS Part 651
CSU-XCM-173
NDESC 2005 (II)
FG0052
FG0003
FG0012
FG0005
FG0006
FG0011
FG0008
FG0033
FG0009
FG0036
FG0013
FG0049
FG0050
FG0037
FG0038
FG0029
FG0028C
FG0028E
FG0025
FG0024
EB1722
EB1513
PNW513
Peters and Davenport
EM4821
PNW0475
PNW293
EM4826
EM4828

Source 2. Livestock Operation BMP References

USU – 2010
NRCS Part 651
EM4885
NDESC 2005
NRCS Code 359
NRCS Code 313
EB0820 (WSU-CE 1992)
EB1746-W7

EB1746-F7
EB1746-W8
EB1746-F8

Source 3. Urban Landscaping BMP References

SPU Lawn Care for the PNW
EB0482
ET ManagerTM RainBird
PNW646
EB1971E
EB1034
Ecology #0004048
WSU –http://public.wsu.edu/~lohr/wcl/
Peters

Source 4. Municipal and Industrial Land Treatment and Application of Wastewater BMP References

Ecology #93-36
Ecology #04-10-081
EM 4885
DOH Design Criteria for Municipal WW Land Treatment Systems
Ecology #97-23
Ecology #98-37

Source 5. Sewage Leakage BMP References

Ecology #98-37
EPA 832-F-99-031

Source 6. Septic System BMP References

EB1671
WAC 46-272A (DOH Publication #333-117)
DOH #337-024
WAC 246-272C (DOH Publication #337-065)
DOH #337-063

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CSU-XCM-173	Waskom M, R. (1994). *Best Management Practices for Irrigation Management (Publication XCM-173).* Fort Collins: Colorado State University Cooperative Extension.

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DOH #337-063	Washington State Department of Health. (2012). *Guidance for Performance, Application, Design, and Operation & Maintenance: Tier Two and Three Greywater Subsurface Irrigation Systems Chapter 246-274 WAC (DOH Publication #337-063).* Olympia: Department of Health.
DOH Design Criteria for Municipal WW Land Treatment Systems	Washington State Department of Health. (1994). *Design Criteria for Municipal Wastewater Land Treatment Systems for Public Health Protection.* Olympia: Department of Health.
EB0482	Stahnke, G. K., Brauen, S. E., Byther, R. S., Antonelli, A. L., & Chastagner, G. (2005). *Home Lawns (Publication EB0482).* Pullman: Washington State University Extension.
EB0820	Brauen, S. (1992). *Pasture Management for Small Landowners in Western Washington (Publication EB0820).* Pullman: Washington State University Cooperative Extension.
EB1034	Maleike, R., & Pinyuh, G. (1996). *Fertilizing Landscape Trees and Shrubs (Publication EB1034).* Pullman: Washington State University Cooperative Extension.
EB1513	James, L.G, J.M. Erpenbeck, D.L. Bassett, and J.E. Middleton. *Irrigation Requirements for Washington. Estimates and Methodology* (Publication EB1513). Pullman: Washington State University Extension.
EB1671	Washington State University Cooperative Extension. (2002). *Properly Managing Your Septic Tank System (Publication EB1671).* Pullman: Washington State University Cooperative Extension.
EB1722	Stevens, R. G., Sullivan, D. M., & Cogger, C. G. (1993). *How Fertilizers and Plant Nutrients Affect Groundwater Quality (Publication EB1722).* Pullman: Washington State University Cooperative Extension.
EB1746-F7	Washington State University Cooperative Extension. (1993). *Assessing the Risk of Groundwater Contamination by Improving Animal Manure Storage Fact Sheet 7 (EB1746-F7).* Pullman: Washington State University.
EB1746-W7	Washington State University Cooperative Extension. (1993). *Assessing the Risk of Groundwater Contamination from Animal Manure Storage Worksheet 7 (EB1746-W7).* Pullman: Washington State University.
EB1746-F8	Washington State University Cooperative Extension. (1993). *Assessing the Risk of Groundwater Contamination from Improving Animal Lot Management Fact Sheet 8(EB1746-F8).* Pullman: Washington State University.
EB1746-W8	Washington State University Cooperative Extension. (1993). *Assessing the Risk of Groundwater Contamination from Animal Lot Management Worksheet 8 (EB1746-W8).* Pullman: Washington State University.
EB1971E	Cogger, C. (2005). *Home Gardener's Guide to Soils and Fertilizers (Publication EB1971E).* Pullman: Washington State University Extension.
Ecology #93-36	Washington State Department of Ecology. (1993). *Guidelines for Preparation of Engineering Reports for Industrial Wastewater Land Application Systems (Publication #93-36).* Olympia: Department of Ecology.
Ecology #97-23	Washington State Department of Ecology. (1997). *Water Reclamation and Reuse Standards (Publication #97-23).* Olympia: Department of Ecology.
Ecology #98-37	Washington State Department of Ecology. (2008). *Criteria for Sewage Works Design (Publication #98-37 WQ).* Olympia: Department of Ecology.

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Ecology #04-10-081	Washington State Department of Ecology. (2004). *Guidance on Land Treatment of Nutrients in Wastewater, with Emphasis on Nitrogen (Publication #04-10-081).* Olympia: Department of Ecology.
EM4821	Ley, T. W. (2003). *Visual Crop Moisture Stress Symptoms (Publication EM4821).* Pullman: Washington State University Cooperative Extension.
EM4828	Ley, T. W., & Leib, B. (2003). *Surface Irrigation Systems (Publication EM4828).* Pullman: Washington State University Cooperative Extension.
EM4885	Canessa, P., & Hermanson, R. (1995). *Irrigation Management Practices to Protect Ground Water and Surface Water Quality State of Washington (Publication EM 4885).* Pullman: Washington State University Cooperative Extention.
EPA 832-F-99-031	United States Environmental Protection Agency. (1999). *Collection Systems O&M Fact Sheet: Sewer Cleaning and Inspection (Publication EPA 832-F-99-031).* Washington D.C.: Environmental Protection Agency.
ET ManagerTM RainBird	Rain Bird. (2013, August 28). *ET Manager*. Retrieved from Rain Bird: Sprinkler Systems, Commercial Irrigation, Residential Irrigation, Lawn Sprinklers, Drip Irrigation, Golf Course Irrigation and Agricultural Irrigation: http://www.rainbird.com/landscape/products/controllers/ETmanager.htm
FG0003	Washington State University Cooperative Extension. (1980). *Fertilizer Guide: Irrigated Alfalfa Central Washington (FG0003).* Pullman: Washington State University.
FG0005	Washington State University Cooperative Extension. (1980). *Fertilizer Guide: Irrigated Field Beans for Central Washington (FG0005).* Pullman: Washington State University.
FG0006	Washington State University Cooperative Extension. (1979). *Fertilizer Guide: Irrigated Field Corn for Grain or Silage (FG0006).* Pullman: Washington State University.
FG0008	Washington State University Cooperative Extension. (1980). *Fertilizer Guide: Irrigated Mint Central Washington (FG0008).* Pullman: Washington State University.
FG0009	Washington State University Cooperative Extension. (1977). *Fertilizer Guide: Irrigated Small Grains, Central Washington (FG0009).* Pullman: Washington State University.
FG0011	Washington State University Cooperative Extension. (1977). *Fertilizer Guide: Irrigated Hops for Central Washington (FG0011).* Pullman: Washington State University.
FG0012	Washington State University Cooperative Extension. (1982). *Fertilizer Guide: Irrigated Asparagus (FG0012).* Pullman: Washington State University.
FG0013	Washington State University Cooperative Extension. (1983). *Fertilizer Guide: Irrigated Vineyards for Entire State (FG0013).* Pullman: Washington State University.
FG0024	Washington State University Cooperative Extension. (1982). *Fertilizer Guide: Lawns, Playfields and Other Turf, East and Central Washington (FG0024).* Pullman: Washington State University.
FG0025	Washington State University Cooperative Extension. (1980). *Fertilizer Guide: Peas and Lentils for Eastern Washington (FG0025).* Pullman: Washington State University.

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FG0036	Washington State University Cooperative Extension. (1978). *Fertilizer Guide: Irrigated Sudangrass Pasture or Silage (FG0036).* Pullman: Washington State University.
FG0037	Washington State University Cooperative Extension. (1980). *Fertilizer Guide: Improved Pasture, Hay, Eastern Washington (FG0037).* Pullman: Washington State University.
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FG0049	Washington State University Cooperative Extension. (1983). *Fertilizer Guide: Ornamentals, Entire State Except Central Irrigated Washington (FG0049).* Pullman: Washington State University.
FG0050	Washington State University Cooperative Extension. (1982). *Fertilizer Guide: Vegetable and Flower Gardens, Except Irrigated Central Washington (FG0050).* Pullman: Washington State University.
FG0052	Washington State University Cooperative Extension. (1982). *Fertilizer Guide: Home Vegetable Gardens, Irrigated Central Washington (FG0052).* Pullman: Washington State University.
NDESC 2005	National Dairy Environmental Stewardship Council. (2005). *Cost-effective and Environmentally Beneficial Dairy Manure Management Practices.* San Francisco: Sustainable Conservation.
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PNW646	Collins, D., Miles, C., Cogger, C., & Koenig, R. (2013). *Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers (Publication PNW646).* Pullman: Washington State University Extension.
SPU Lawn Care for the PNW	McDonald, D. (1999). *Ecologically Sound Lawn Care for the Pacific Northwest.* Seattle: Seattle Public Utilities.
USU - 2010	Davis, J. G., Koenig, R. T., & Flynn, R. P. (2010). *Manure Best Management Practices: A Practical Guide for Dairies in Colorado, Utah and New Mexico.* Logan, Utah: Utah State University Cooperative Extension.
WAC 46-272A	Washington State Department of Health. (2007). *Rules and Regulations of the State Board of Health: On-site Sewage Systems Chapter 246-272A WAC (Publication #333-117).* Olympia: Department of Health.
WAC 246-272C	Washington State Department of Health. (2012). *Rules and Regulations of the State Board of Health: On-site Sewage System Tanks Regulations Chapter 246-272C WAC (Publication #337-065).* Olympia: Department of Health.
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