


<p>Farm Business Management Reports</p>		<p>EB1948E</p>
	<p>THE ECONOMICS OF DAIRY NUTRIENT MANAGEMENT <i>Worksheets for Designing a Nutrient Management System</i></p>	
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<p>COOPERATIVE EXTENSION WASHINGTON STATE  UNIVERSITY <i>World Class. Face to Face.</i></p>		

Online at: <http://farm-mgmt.wsu.edu/Dairy.html>

The Economics of Dairy Nutrient Management

Worksheets for Designing a Nutrient Management System

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These worksheets are linked spreadsheets. They allow you to adapt the analysis in **EB1947E** individual dairies. They can be downloaded from <http://farm.mngt.wsu.edu/Excel-docs/EB1948E.xls>, saved on your computer, and used with your spreadsheet software. If you prefer, they can be ordered on compact disk from <http://farm.mngt.wsu.edu/dairy.html>.

The worksheets include default values for northwestern Washington for five herds varying in size. The default values are approximate numbers and are not intended to exactly represent any individual dairy.

You may enter information related to your dairy operation on any yellow line. **Bolded lines** make calculations based on default values or the new information you provide. The equations that only create computations are locked to prevent accidental change. If desired, they can be unlocked by doing the following: click on the Tools menu, click on Protection, then click on Unprotect Worksheet.

Abbreviations used in the worksheets are listed on the last page of this document.

Instructions are in bold italics.

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Using the Worksheets

To use the worksheets, you must first make two selections from the drop down menus:

1. *Select a size closest to the herd for which you want to design a nutrient management system.*
2. *Indicate whether you intend to purchase or custom hire an irrigation system for distributing liquid waste to adjoining fields.*

After making these two selections, it is your choice whether to change any of the default values in highlighted cells. You can change one or many items before going to Worksheet IV to review the net cost summary of your nutrient management system. You can also use these worksheets to determine the cost impact of making one or a few changes in your planned system.

The remainder of this narrative provides instruction and explanation as you use the worksheets.

Worksheets I – Manure Production and Storage Requirement

Worksheet I-1 estimates total waste production; the storage capacity required to handle manure, bedding, wastewater, runoff and rainfall; and final volume required to store the waste in a lagoon during the storage period (180 days in this study). *Enter the average number of milking and dry cows and heifers in the dairy on the lines in 1a. Enter average weights on the lines in 1b.* The number of 1,000-pound animal units (au) are calculated from these numbers and recorded on line 1. *Enter the daily volume of manure (DVM) production per animal unit on line 2a. Enter the desired storage period (D) on line 2b.* Using the formula, $TVM=au*DVM*D$, total volume of manure production (TVM) for the storage period is computed on line 2.

Additional storage is required to accommodate bedding, wastewater and runoff. The volume of bedding waste that must be stored depends both on the type of bedding and the housing system. Many types of bedding can be used. Sand and shavings are among the more common types used in northwestern Washington. The default value of 0.15 cubic feet per au per day is for shavings (Falk and Ohlensehlen, 1989). **Enter daily bedding volume per au on line 3a.** Total bedding volume for the storage period is computed on line 3 by multiplying the daily bedding volume by the number of animal units and the storage period.

Solids separation is a necessary procedure if the wastewater stored in the lagoon is later used to flush the barns clean. It is a recommended procedure in all cases to reduce accumulation of solids in the lagoon and to permit alternative disposal methods for the solid waste. Line 4 computes the volume of separated solids removed by the separator. There are approximately 12% solids in raw manure (Caldwell, 2000) and 50% solids in bedding (Gillies, 2001).¹ Assuming 30% separator efficiency for manure solids (Gillies, 2001), the volume of separated solids removed can be computed by the following formula: $\text{separated solids volume} = (\text{manure volume} * 0.3 * 0.12) + (\text{bedding volume} * .5)$. **Enter solids separator efficiency on line 4a.**

The volume of storage required for wastewater is computed in line 5 based on information in lines 5a-5g. **Enter volume of wastewater on lines 5a-5g due to cow preparation; cleaning the bulk tank, pipeline, miscellaneous equipment, and milking facility; and flushing the housing and feeding facilities.** The default values are from Grusenmeyer and Peterson (1995) and estimates from Hillers (1999).

Slab runoff volume (line 6) is computed by multiplying slab area by rainfall less evaporation during the storage period. **Enter slab area per cow on line 6b.**

Frequently, lagoons are designed to include outside runoff from watersheds. ***For such, enter the runoff volume from a 25-year, 24-hour storm on line 7.*** Total waste volume is then calculated for the storage period on line 8 by summing manure production, bedding, wastewater volume, and runoff volume and subtracting separated solids volume.

The size of the lagoon required to store dairy waste is computed on line 9a. ***Enter the lagoon's bottom length (BL), depth (d), and side-slope ratio (Z) on lines 9c-9e.*** The bottom width (BW) is calculated on line 9b by the formula set forth in the *Agricultural Waste Management Field Handbook* (NRCS, 1999):

$$V = \frac{4 \times Z^2 \times d^3}{3} + (Z \times BL \times d^2) + (Z \times BW \times d^2) + (BW \times BL \times d).$$

Enter lagoon depth required for accumulated solids, expected precipitation less evaporation during the winter storage period (only if different from that calculated from information entered on Worksheet I-3), precipitation from a major storm, emergency outflow, and freeboard on lines 10a-10e. Based on this additional information, the required lagoon depth is calculated on line 10. Total lagoon volume after depth adjustment is calculated on line 11.

Slab area required to store separated solids is computed on line 12 based on ***average solids depth, which is entered on line 12a.*** An average depth of 6 feet is the default for the solid waste.

Worksheet I-2 estimates storage requirements and dimensions for liquid tank systems. ***Enter information on lines 1a-1b, 2a-2b, 3a, and 4a-4g in the same manner as in Worksheet I-1.*** Total waste volume is calculated on line 5 using this information in a way similar to that computed for the lagoon system. An exception is that the liquid tank does not include adjustments for separated solids or runoff volume. The size of the liquid tank required to

¹ Note: all cited references are included in the bulletin.

store dairy waste is computed using the formulas noted on lines 6, 6f, and 6g. ***Enter the depth of the liquid tank on line 6a, depth of accumulated solids on line 6b, expected precipitation less evaporation and a 25-year, 24-hour storm (if the tank is not covered) on lines 6c and 6d, and freeboard on line 6e.***

If the tank is rectangular, enter its width on line 7a. Various combinations of length and width (line 7a) or diameter (line 7b) can be used to provide the surface area required.

Worksheet I-3 is used to compute annual waste production for both systems. ***Enter annual rainfall and pond evaporation rate during the winter months on lines 2 and 3.*** The calculation procedure used in this worksheet is similar to Worksheets I-1 and I-2 except that it applies to an entire year rather than a single storage period.

Worksheets II – Cost Computation

Worksheets II-1 and II-2 can help farmers estimate total investment costs as well as annual fixed costs for lagoon and liquid tank systems. In order to estimate the investment required to construct a lagoon or liquid tank, ***enter construction cost per unit (acre foot for lagoon, million gallons for liquid tank) in the investment column on line 1.*** Lagoon construction in northwestern Washington costs approximately \$9,600 per acre-foot for the first three acre-feet and \$7,500 per acre-foot for additional storage volume (Gillies, 2001). This estimate includes the cost of appurtenances such as fencing, access ramps, dike seeding, and imported fill material for the embankment or the earthen liner. Typical construction costs for a liquid tank are about \$120,000 per million gallons of storage capacity (Dyk, 2000). The cost of either system can be somewhat higher if a private engineering firm is consulted. However, many farmers rely on help from local Natural Resources Conservation Service staff rather than hiring an engineering firm. The total construction cost is computed on line 2.

Enter costs of other essential and optional items in the investment column on lines 3-10 of the appropriate worksheet. For the lagoon system, a tractor is typically used to operate the agitator and can be used for other farm operations on smaller dairies (line 4). Other equipment generally needed include a storage tank for gutter flushing, recycling pump and pipe, an agitator or mixing propeller, a separator, a big gun sprinkler, irrigation pump and pipe. For the liquid tank system, equipment typically includes a scraper, tractor, tank wagon, agitator or mixing propeller, agitating and loading pump, open impeller, irrigation reel, and manure spreader or injector.

For solid waste storage with the lagoon system ***enter the cost per cubic yard for installation of a slab on line 11a and the depth of the slab on line 11b.*** The total cost of constructing the solid waste storage slab based on this information is computed on line 11.

Enter the interest rate, useful life, salvage value, repair and maintenance charge, tax rate, and insurance charge (in percent for all but useful life) in the respective column for each item. We use an annual interest rate of 8% as the default. The annual interest is charged on an average of initial investment and salvage value. When calculating depreciation charges, we use the straight-line method. The default salvage value for equipment is 10%. Default values for useful life are 30 years for the storage slab, 20 years for the waste storage facility, and 10 years for equipment. Except for the separator, annual repair and maintenance costs associated with the waste handling system are expected to average 1.5% of the investment (Hansen, 1993). Taxes vary both with the tax rate and the value added to the property. Typical assessments and tax rates are used as defaults – 0.8% for the storage facility and 1.25% for other equipment (Hansen, 1993). All facilities and equipment in the system, except the storage facility, fencing, and storage slab are insurable. We use a common 0.5% insurance rate as the default. Based on our default values, annualized fixed costs range from 9.63% of the investment in the storage slab to

16.25% in equipment. The user can change the set of investment items and can also modify the annual interest rate (either the loan interest rate or the rate of return received for alternative investments), useful life, salvage value, annual repair and maintenance rate, tax rate, and/or insurance rate for individual items.

Total investment is computed from this information on Worksheet II-1, line 12, for the lagoon system and Worksheet II-2, line 11, for the liquid tank system.

Worksheets II-3 and II-4 help farmers estimate annual operating costs for lagoon and liquid tank systems, respectively. Annual recycle pumping cost, solids separation cost, and application cost are the main costs for a lagoon system (Worksheet II-3). ***Enter the size of the pump and daily pumping time on lines 2a and 2b. Enter the energy cost per kilowatt hour in the equation on line 2c.*** The default value of \$0.07 per kilowatt-hour is the average price paid by dairy farmers (Puget Sound Energy's *Electricity Rates Handbook*, 2001). The annual cost for recycle pumping is computed on line 2 and follows the procedure of Bennett et al. (1999).

Enter the annual operating cost of separating solids on line 3. Both power and labor expenses of separating solids should be included.

To compute the application cost for a lagoon system, annual pumping time is estimated first. Pumping time for a lagoon system with a hired custom irrigation system is calculated by the annual waste stored in the lagoon (I-3, line 10) divided by the amount pumped per hour (II-3, line 4b). Application costs are then computed as agitation cost plus the hourly custom pumping charge multiplied by pumping time. ***Enter the amount pumped per hour, custom pumping charge per hour, and agitation cost (both labor and power) on lines 4b-4d.***

The annual application cost for a lagoon system with an owned irrigation system is calculated as agitation cost plus the sum of the hourly wage rate and power costs

multiplied by pumping time. *Enter the amount pumped per hour, labor and power costs per hour, and agitation cost (if not already entered on line 4d) on lines 9b-9e.*

Enter the annual cost of applying separated solids on line 10 and any other operating expenses on line 11.

The total operating cost of the lagoon waste management system with the selected irrigation system is repeated on line 14.

Operating costs for a liquid tank system are composed mainly of application costs due to labor and tractor time (Worksheet II-4). *Enter labor cost (including fringe benefits) per hour on line 2 if it wasn't entered in Worksheet II-3. Enter tractor cost per hour on line 3. Tank wagon capacity is entered on line 4a and average trip time (in minutes) on line 5a. Enter any other operating costs on line 6.* Application hours for a liquid tank system depend on the number of tank wagon trips (line 4), tank wagon capacity (line 4a) and average time required per trip (line 5a). The default average time per trip for the tank wagon is 30 minutes. Total operating cost and operating cost per cow are computed on lines 7 and 8.

Worksheet III – Value of Dairy Waste for Plant Production

Worksheet III estimates annual total nutrients (N, P, K) in the excreted manure, nutrients contained in the wastewater, total nutrients produced in fertilizer form, nutrient values of fertilizer equivalents after adjusting for nutrients lost during storage and application, and acres on which manure can be applied without environmental risk. The fertilizer value of nutrients in dairy waste is estimated based on information provided in Worksheet I. Total nutrients in the excreted manure are calculated on line 3 as $au * \text{daily nutrient production per au (lb/day/au)} * 365 \text{ (days)}$. Using NRCS (1999) data, daily production of N, P and K in the excreted manure is estimated to vary for milking cows, dry cows, and heifers. For milking cows, the figures are 0.45, 0.07, and 0.26 lb/au/day,

respectively. For dry cows, the corresponding figures are 0.36, 0.05, and 0.23. For heifers, they are 0.31, 0.04, and 0.24. Daily production of N, P and K in the wastewater is 1.67, 0.83 and 2.50 lbs/1,000 gallons, respectively. Nutrients contained in wastewater are computed on line 4 as number of cows * daily wastewater production (1,000 gal/day/cow) * daily nutrient production (lb nutrient/1,000 gal) * 365 (days). Total nutrients produced from dairy manure and wastewater are summarized on line 5 and converted to elemental fertilizer form (N, P₂O₅, K₂O) on line 6.

The economic value of manure fertilizer is calculated from its available N, P and K at commercial fertilizer prices. ***Enter prices of N, P₂O₅ and K₂O fertilizer on lines 7a to 7c.*** Because fertilizer prices change with economic conditions, expected prices should be used for needed nutrients. If K₂O is not needed on the cropland, a value of zero should be used for potash. The default values of \$0.27, \$0.31, and \$0.14 for N, P, and K, respectively, are recent characteristic prices from the Washington Agricultural Statistics Service (2000).

Enter the percent of each manure nutrient removed in separated solids and not distributed on your land on lines 8a to 8c. Approximate values are included in the worksheet (NRCS, 1999).

Nutrient losses from dairy waste during storage and application vary widely and depend on climate and management, including methods used for collection, storage, treatment, and application. ***If available, you may use local information to enter nutrient losses due to storage on lines 9a to 9c for the lagoon system and 15a to 15c for the liquid tank system, volatilization on lines 10 and 16, and denitrification on lines 11 and 17.*** In the absence of local data, NRCS estimates are used. For the lagoon system, approximate nutrient losses during storage are 35% of N, 10% of P, and 10% of K (lines 9a to 9c). For the covered liquid tank system, the corresponding losses during storage are 15%, 10%, and 10%, respectively (lines 15a to 15c). Lines 12 and 18 report the nutrients left after

adjusting for losses during storage, through volatilization, and through denitrification for the lagoon and liquid tank systems, respectively. Default values for additional nitrogen lost are 15% through volatilization and 30% through denitrification (NRCS, 1999).

The fertilizer value of manure nutrients from the lagoon and liquid tank systems is computed on lines 13 and 19.

The minimum number of acres on which manure can be applied without environmental risk is computed for the lagoon and liquid tank systems on lines 14a-b and 20a-b.² On these lines, two crops are listed – corn silage and orchardgrass hay. Target yields of these crops appear first, and the required acres to safely dispose of the waste are computed following NRCS guidelines (1999). The largest of the three acreage computations for the selected crop is required to safely dispose of the dairy waste.

The quantity of nutrients needed for different crops and different yields are not automatically computed on this worksheet. *If you want to change crop or yield, consult your local office of the USDA Natural Resources Conservation Service to determine minimum acreage required for application rather than simply entering new information on lines 14a-b or 20a-b.* Important additional information may be available from the local WSU Cooperative Extension office, the DAFOSYM dairy forage system model that is available from Pennsylvania State University (Web site: pswmru.arsup.psu.edu), and from several programs available to farmers from the private sector.

Worksheet IV – Benefits and Costs of Alternative Waste Management Systems

Worksheet IV summarizes the investment, annual costs, value of waste, and net annual costs associated with each waste management system. Total investment and annual fixed

² The minimum acreage estimates account for nutrient mineralization and nutrient losses during application, denitrification, and leaching. Leaching losses occur because nitrogen in the nitrate form is soluble and can pass through the root zone with percolating water. Nitrogen can also be lost from the root zone through denitrification. This occurs when nitrogen in the nitrate form is subject to anaerobic activity.

cost for the lagoon systems come from Worksheet II-1, and annual operating cost comes from Worksheet II-3. Total annual cost on line 5 is computed by adding annual fixed cost (line 3) and annual operating cost (line 4). Subtracting the value of wastes (line 7) from total annual costs, line 8 gives net annual cost required to manage dairy wastes by a lagoon system with the selected irrigation option. Similar information is developed on subsequent lines for a liquid tank system. The net annual cost required to manage dairy wastes by a liquid tank system is reported on line 17. Net annual cost per cow for these systems is computed on lines 9 and 18.

Worksheets V – Costs and Benefits of Composting Systems

Worksheets V-1 and V-2 compute additional investment and annual costs for a composting system. Depending on the method used to compost, additional annual fixed and operating costs vary greatly. Data in Worksheets V-1 through V-3 for a 250-cow herd assume the capital-saving passive-windrow method is used. Default values in the worksheets for larger herds are for the turned-windrow method.

In Worksheet V-1, ***enter the additional equipment and facilities needed to produce compost in the investment column on lines 1 through 5.*** For a small dairy applying the final product to the land rather than selling it, a screen is not needed. For a dairy with excess tractor and loader capacity and extra storage space, it may be possible to compost with no additional investment. ***Enter the interest rate, useful life, salvage value, repair and maintenance charge, tax rate, and insurance charge (in percent for all but useful life) in the respective column for each item.*** Total additional investment and annual fixed cost are computed on lines 6 and 7.

Line 1 in Worksheet V-2 provides the volume of compostable manure and bedding, which comes from Worksheet I-3, line 6. The lagoon operating cost on line 2 comes from Worksheet II-3, line 14 for the selected irrigation system. Line 3 is used to compute annual

operating cost of composting. **Enter the hours required for composting and the hourly operating cost on lines 3a-3b.** Default values are based on weekly turning of the compost and information in Table 10.2 from the *On-Farm Composting Handbook* (Rynk, 1992). **Enter other operating costs on line 4.** The total annual operating cost of the composting system is computed on line 5.

Worksheet V-3 is used to summarize the profit when dairy waste is composted. Line 1 is the volume of compost produced assuming a 50% shrinkage of manure volume during composting (Caldwell, 2000). **Enter the percent of compost sold on line 2 and its F.O.B. sale price on line 4.** Compost revenue is calculated on line 5. The default values assume that 100% of the compost is sold and all compost is sold at the same price. In Washington, final compost is frequently marketed for \$12-\$15 per cubic yard. The default F.O.B. prices in the worksheet are \$12 per cubic yard for the passive windrow system and \$14 per cubic yard for the turned windrow system. Compost not sold is assumed to be distributed on the farmer's land (line 7) with a value equal to 2/3 the price of sold compost (line 8). The fertilizer value of nutrients from liquid waste applied to the land is added to compute the total annual revenue of the waste management and composting system (line 10). Total annual cost of waste management and composting is computed on line 11. Line 12 gives the profit (positive or negative) of the waste management and composting system. **If tipping or processing fees are received from composting non-farm waste materials, add them to the result on line 12.**

For additional help in designing your nutrient management system, contact your local Natural Resources Conservation Service office.

References

All references cited in the appendix and worksheets are included in the Extension bulletin.

Symbols Used in the Worksheets

au: Number of 1,000-pound animal units

BW: Bottom width of the lagoon, ft

BL: Bottom length of the lagoon, ft

cf: Cubic feet

cy: Cubic yards

d: Depth of dairy waste, ft

D: Storage period, days

DVB: Daily bedding volume per au, cf/au/day

DVM: Daily volume of manure production per au, cf/au/day

ED: Effective depth of the liquid tank, ft

ft: Feet

lb: Pound

N: Number of animals

ORV: Outside runoff volume for storage period, cf

SA: Surface area of the liquid tank, ft²

sf: Square feet

SRV: Slab runoff volume for storage period, cf

SSR: Separated solids removed, cf

TVB: Total bedding volume for storage period, cf

TVM: Total manure production for storage period, cf

TWW: Total wastewater volume for storage period, cf

W: Animal weight, lbs

WV: Total waste volume for storage period, cf

Z: Side slope ratio, horizontal/vertical 4

Use pesticides with care. Apply them only to plants, animals, or sites listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is violation of law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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