

Montana Feedlot Annualized Runoff Model (MontFARM)

A Tool for Evaluating the Pollution Potential of an Animal
Feeding Operation

**Users Guide
Version 1.2**

November 2011

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Introduction

MontFARM is a spreadsheet tool used to evaluate the pollution potential from animal feeding operations in Montana. With limited number of inputs, MontFARM estimates annual pollutant loadings for Phosphorus, Nitrogen, BOD₅ and Fecal Coliforms. In addition to corral management and land use characteristics, MontFARM requires inputs that describe the type of receiving water and its distance from the corral facility. The annual pollutant discharge is converted to a severity Index on a scale of 0 to 100 used to rate and rank the site. Output generated by MontFARM is an evaluation of the facility's pollution hazard and does not constitute actual discharge.

MontFARM is intended for the assessment of small and medium, open lot, animal feeding operations. MontFARM can be useful in evaluating facility management and BMPs to reduce pollution potential. It can also be used to evaluate a proposed feedlot sites or a feedlot expansions.

MontFARM is not intended to be a design tool. Upon assessing the pollution hazard of a feedlot, design efforts should follow established engineering protocol.

Please send all comments and concerns related to the model or this documentation to karen.hoffman@mt.usda.gov.

Background

An Evaluation System to Rate Feedlot Pollution Potential, formulated in 1982 by the USDA, Agricultural Research Service (ARS) in Morris, Minnesota, has been used extensively in Minnesota to rate and document the pollution potential of feedlots. It was developed to prioritize technical and financial services provided by government agencies that, then and now, have limited resources. The authors performed extensive literary searches and field research for gathering data to develop a scientifically-based model.

In October, 2002, the Bioproducts and Biosystems Engineering Department, University of Minnesota (BBE-UMN), in conjunction with the Minnesota Pollution Control Agency, developed an EXCEL based version of FLEval. This upgrade in software simplified or eliminated some of the hand calculations that were necessary in the DOS version and was much more user friendly. The original tech guide developed by ARS in 1982 was updated to reflect new software change and reach a wider audience.

In 2004, an EPA 319 grant was awarded to evaluate, update, and add to the original algorithms. The primary change with the new model, MinnFARM was to estimate ANNUAL nutrient loadings in contrast to 25-year, 24-hour storm-generated loadings. The user guide was updated accordingly. Some of the information in this guide refers to the original FLEval manual (ARS, 1982). Other information was taken from the Technical Guide originally drafted in 2001 by Justin Jeffery at the Board of Water and Soil Resources and updated in 2002 by David Schmidt, BBE-UMN.

In 2010, BBE-UMN, was contracted by the Montana NRCS to develop MontFARM; a modified version of MinnFARM for use in Montana. David Schmidt, working with Karen Hoffman, Hydrologic and Water Quality Engineer, NRCS, incorporated Montana NRCS's procedure for computing runoff from animal feeding operations. Other changes involved capturing the nutrient load from empty but manure-laden lot areas, adjusting nutrient concentrations for manure age, and populating the weather station and soils database with Montana weather station and soils data.

Historical weather station data drives the precipitation distribution utilized in model computations. Site-specific precipitation conditions are generated when the user selects one of 52 Montana weather station sites included in

MontFARM. All station choices are part of the National Oceanic and Atmospheric Administration (NOAA) weather station network. Each station carries at least 50 years of record. The National Water and Climate Center, NRCS, Portland, Oregon was integral in preparing and analyzing weather station data for the needed statistical parameters required by MontFARM.

Inter-agency technical and implementation teams were assembled during the winter and summer of 2011 to review various aspect of the model. The Technical Team was comprised of Water Quality Specialists representing the United States Geological Survey (Jill Frankforter), Montana Department of Environmental Quality (Robert Ray and Mark Ockey), Montana Department of Natural Resources and Conservation (Karl Christians), Montana State University (Adam Sigler), and Montana NRCS (Cory Wolfe, Pete Husby, Pat Hensleigh, and Karen Hoffman). This team agreed on the End of Treatment and Water of Concern categories and priorities as well as the Index calculation. The Implementation Team, comprised of potential model users (NRCS, DNRC, MSU, and DEQ) was assembled to evaluate the user interface, model stability, and priority index system. Throughout the MontFARM model development, Steve Becker, State Conservation Engineer provided oversight and technical review.

Final modifications to MontFARM incorporated narrative guidance directed towards model applicability and MT-NRCS Practice Standard 635, Vegetated Treatment Area (2009) criteria. These modifications do not effect MontFARM Load or Index computations.

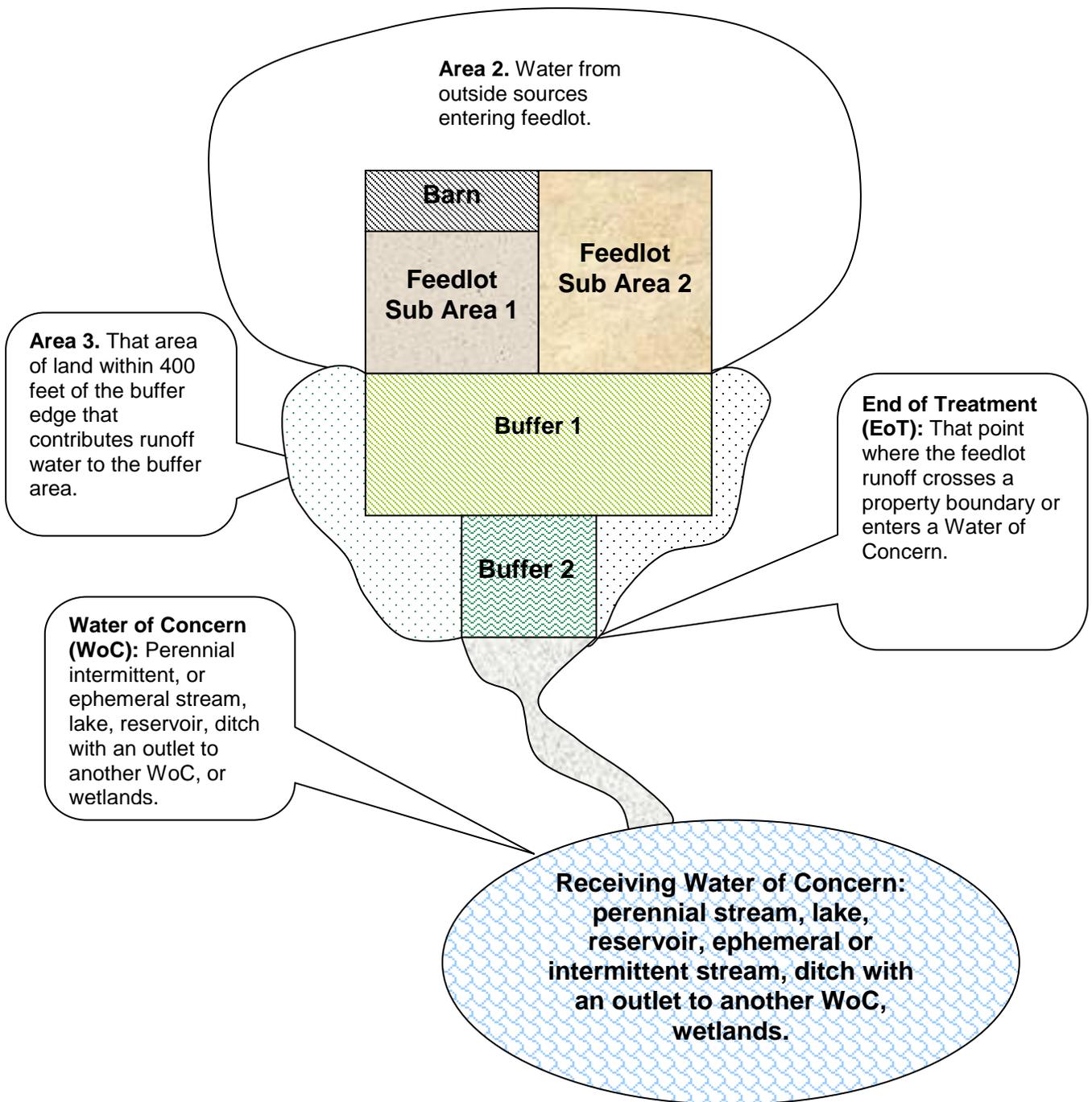


Figure 1. General site sketch showing critical features required in the model.

A Guide to Gathering Field Information

1. Owners and/or operator's name.
2. Begin by drawing a sketch of the feedlot and local watershed showing boundaries, building locations, feedlot areas, roof areas, well locations, and other pertinent features. Note the location and route runoff takes as it leaves the lot(s) and flows to the Water of Concern (WoC).
3. Determine the following information for each sub-lot of the feedlot:
 - a. Type of animals held.
 - b. The number of days, by month, the animals are kept in confinement.
 - c. Daily averages, on a monthly basis, for the number and weight of animals.
 - d. Expansion expected over the next 5 years.
 - e. The size of the lot in square feet or acres.
 - f. The month(s) during which the lots are cleaned.
4. Locate the End of Treatment (EoT) for the runoff water from the feedlot. This is the point where runoff crosses a property boundary or enters a WoC. The EoT represents the point at which the producer no longer has ownership or control of runoff. The EoT is discussed more fully in Definitions and Clarifications.
5. Locate the Water of Concern (WoC). This is the "discharge" point. Water bodies or wetlands indicated on USGS topographic maps will be considered a WoC. Discrete water bodies not indicated on the topographic map may also be considered a WoC depending on the user's judgment. The WoC is discussed further in Definitions and Clarifications. MontFARM choices for WoC are:
 - a. Lake or Reservoir
 - b. Perennial, ephemeral or intermittent stream
 - c. Ditch which conveys flow to another Water of Concern
 - d. Flow-Through Wetland (wetland with creek, stream, lake or other type of surface water connection)
 - e. Depressional wetland
 - f. Other
6. Determine the area of land and/or roofs which contribute clean water to the feedlot area. This area is noted as Area 2 on the site sketch.
7. Determine the area of watershed contributing clean water to the buffer area. This area is noted as Area 3 on the site sketch.
8. Determine the distance from the EoT to the WoC. Note that when the EoT and the WoC are the same location, this distance is zero.
9. Break the watershed into the following areas:
 - a. Feedlot area.
 - i. Sub-lots which have common Area 2, Area 3, and buffer areas should be evaluated with together as multiple sub-lots within a MontFARM analysis.
 - ii. Sub-lots for which runoff flow paths remain separate, throughout the buffer length, should be evaluated individually with separate MontFARM analyses.
 - b. Roof area. Identify those roofs from which rain falls directly on the feedlot.
 - c. Tributary area, Area 2. Identify the boundary of area, including roofs, which contributes clean water to feedlot.
 - d. Buffer area. Identify the flow route and land use changes that occur between the feedlot boundary and the EoT.
 - e. Adjacent area, Area 3. Identify the boundary of area which contributes clean water to the buffer. This water does not cross the lot but enters the buffer.

10. Determine the vegetative cover within Area 2 and Area 3. Describe the land use, for summer conditions, using the options listed below. If cropland is managed in a rotation, evaluate the effects of the rotation and/or choose the use that exists a majority of the time.
 - a. Row Crop Contour or Straight rotation (e.g., sugarbeets)
 - b. Small Grain Contour or Straight rotation (e.g., crop-fallow or continuous)
 - c. Alfalfa Rotation (e.g., alfalfa-small grain rotation)
 - d. Fallow (nothing planted)
 - e. Permanent Pasture or Grassland (poor, fair, or good condition during summer months)
 - f. Permanent Meadow
 - g. Lawn
 - h. Roads, alleys, and concrete areas
 - i. General Farmstead (50% mix of lawn and gravel driveway)
 - j. Woods
 - k. Roof.
11. Determine the soil types for the Buffer and Areas 2 and 3. Soils maps can be found on the NRCS Web Soil Survey website. Each soil has an assigned Hydrologic Soil Group of A, B, C, or D. This characteristic is a required model input and is listed in the MontFARM Soils drop-down menu. NOTE: Each Soil Survey uses a different naming system to identify soils. Select the correct Soil Survey at the top of the INPUT&OUTPUT worksheet.
12. Break the buffer into different sections based on vegetative cover, soils, or significant changes in slope or width. Gather the following information for each section of buffer area. Assume summer conditions.
 - a. Vegetative cover (same list as given in #10)
 - b. Hydrologic Group (A, B, C, or D)
 - c. Length, in feet. Flow lengths can be measured in the field or, for longer distances, measured off aerial or topographic photos.
 - d. Width, in feet. Buffer width is measured perpendicular to the direction of flow. Its dimension should describe the width of flow when the maximum flow depth is 3 inches. Buffer widths need to be evaluated in the field.
 - e. Slope, in percent. Range finders and clinometers are good tools for evaluating slope. Extreme precision in determining slope is not necessary as MontFARM is not sensitive to this input value.

MontFARM Data Input Sheet

Farm Name _____ Date of Visit _____

Address/phone _____ Evaluator _____

Date of site visit _____

County _____ Soils _____ Weather Station _____

Feedlot Information

Sub-lot 1

Lot size = _____ acres or square feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Days												
Number Animals												
Average Weight												
Pen Cleaning												

Sub-lot 2

Lot size = _____ acres or square feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Days												
Number Animals												
Average Weight												
Pen Cleaning												

Sub-lot 3

Lot size = _____ acres or square feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Days												
Number Animals												
Average Weight												
Pen Cleaning												

Sub-lot 4

Lot size = _____ acres or square feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Days												
Number Animals												
Average Weight												
Pen Cleaning												

MontFARM Data Input Sheet (Page 2)

Runoff Data Input

Area 2 - Area contributing clean water to the feedlot

Roof Area _____ acres or square feet

	Area	Units	Cover type or rotation	Soil Type	Hydro Group
2a		Acres or sq ft			
2b		Acres or sq ft			
2c		Acres or sq ft			
2d		Acres or sq ft			
2e		Acres or sq ft			
2f		Acres or sq ft			

Buffer Area

	Length (ft)	Width (ft)	Slope (%)	Cover Type/Rotation	Soil Type	Hydro Group
Ba						
Bb						
Bc						
Bd						

Area 3 - Area contributing clean water to the buffer

	Area	Units	Cover type or rotation	Soil Type	Hydro Group
3a		Acres or sq ft			
3b		Acres or sq ft			
3c		Acres or sq ft			
3d		Acres or sq ft			
3e		Acres or sq ft			
3f		Acres or sq ft			

Receiving Water Input

- What is the End of Treatment (EoT) for this runoff? _____ Property Boundary or Water of Concern (WoC)_____
- What is the WoC? ____Perennial Stream, Lake, Reservoir, Ephemeral Stream, Intermittent Stream, Ditch with delivery to another WoC, Flow-Through Wetland, Depressional Wetland, or Other_____
- What is the distance from EoT to the WoC? _____ miles or feet
- What is the distance from the corral facility to the WoC? 0 feet? 1 – 35 feet? Greater than 35 feet?

Other Comments? _____

Data Entry

The EXCEL worksheet is similar to the data collection form. All data is entered in the EXCEL workbook tab marked “INPUT&OUTPUT”. There is no particular order for entering the data. Index and load values will compute continuously as input is entered and modified. As a result, load and Index values should not be considered final until all model sections have been considered and keyed appropriately.

Avoid carrying over old data from one analysis to the next by using the CLEAR ALL VALUES button located in the top right hand corner of the MontFARM, INPUT&OUTPUT worksheet. It is advised to keep the original MontFARM file as a template and rename it for every farm.

When clearing individual cell values, use the EXCEL “Clear Contents” command or Delete key in contrast to the Space Bar. EXCEL recognizes the Space Bar keystroke as a character which then affects the MontFARM computations. The “Clear Contents” command can be accessed by using the mouse to Right Click on the cell.

When sub-lots are empty and clean for the entire year, all cells within the sub-lot section should be “cleared”. This includes the sub-lot Feedlot Area cell. Leaving a value in the Feedlot Area cell will affect the calculations even if zero animals are entered on the lot.

Brief Explanation of Data Inputs:

- Farm Information: Enter the farm name and address for future reference along with the date of the evaluation and the name of the evaluator.
- County: Use the drop-down menu to select the county where the feedlot is located.
- Soils: Use the drop-down menu to select the appropriate Soil Survey for the site. The “Soil Survey Map” tab can be used to pull up a map of the Soil Survey names and boundaries. See Figure 2.
- Weather Station: Use the drop-down menu to select the weather station which best represents the site conditions. Typically, this is the nearest station with similar climatic conditions. The “Weather Station Map” tab can be used to view the Weather Station names, location, and average annual rainfall. See Figure 3.
- Sub-lots 1-4: Enter the area of the feedlot subject to direct rainfall. This entry may be in acres or square feet. Sub-lots are typically divided by fences and have different management practices, animal numbers, and/or animal types. Each feedlot can be broken into sub-lots provided they all have the same Area 2, Area 3, and buffer.
- Sub-lots which have different Area 2, Area 3, and/or runoff flow paths need to be analyzed individually, each with their own MontFARM analysis. In cases where the sub-lots are analyzed individually yet have the same WoC, the individual Index values should be summed to obtain an overall facility Index.

- Cleaning Month:** List the typical month during which the sub-lot is cleaned. Put an X in the appropriate box. At least one cleaning per year is required. More than one cleaning per year is allowed.
- Animals:** Enter the type of animal (beef, dairy, horse, sheep) confined on the lot. Only one animal type is allowed on a sub-lot per year. If multiple animals are held at different times throughout the year, convert all animals to the one type using equivalent weights.
- Feedlot Management:** Enter the daily average number of animals and average animal weight held on the lot each month.
- Area 2-Roof:** This entry is the area of roof that contributes runoff directly onto the feedlot. This entry may be in acres or square feet.
- Area 2-Information:** Area 2 includes watershed and roof areas which drain onto the lot. It also includes roof areas which contribute clean water to the lot, but not directly (i.e., it flows overland before entering the lot). The Area 2 entry is in acres or square feet. Up to six contributing areas may be entered. For each Area, enter the land use type, the soil type, and the hydrologic group (A, B, C, or D).
- Buffer Information:** Enter the length (distance in the direction of flow), width (direction perpendicular to flow), average slope (%), land use type, soil type, and hydrologic group for each buffer section. The entire area between the lot and the EoT should be described as either one or sequential buffer sections. A variety of land use types are provided by which to describe the buffer vegetative cover type.
- Area 3 Information:** This area is also known as the adjacent area. It is the area that contributes clean water to the buffer but not the lot. It does not include the feedlot, buffer, or area which contributes clean water to the lot (Area 2). This entry may be in acres or square feet. Up to six areas may be entered. Note that the recommended Area 3 not exceed 400 feet on either side of the buffer. Greater area values can falsely skew your results. Enter the land use type, soil type, and hydrologic group for each Area 3.
- EoT:** End of Treatment (EoT) is assigned where feedlot runoff either crosses the producer's property boundary or enters a Water of Concern (WoC). The EoT represents the location at which the producer no longer has ownership and/or control of the runoff. The EoT can be at the same location as the WoC.
- WoC:** Water of Concern (WoC) is a lake, reservoir, a perennial, ephemeral, or intermittent stream, a ditch which conveys flow to another WoC, a wetland which has connection with creek, stream, lake or other type of surface water, or a depression wetland. It is considered the discharge point or that point where runoff from the lot becomes a concern. Water bodies or wetlands indicated on USGS topographic maps will be considered a WoC. Discrete water bodies or wetlands matching the descriptions above but not shown on

the topographic map should also be considered a WoC providing they meet the following criteria:

- a. Drainages shall demonstrate channel characteristics such as banks and/or bed materials. A grassed swale is not considered a WoC unless designated as perennial, intermittent, or ephemeral stream by the USGS topographic map.
- b. Wetlands shall exhibit the hydrologic, vegetative, and soil characteristics required for wetland designation, as defined by the U.S. Army Corps of Engineers (USACE).
- c. Ditches shall convey flow either directly or through a network of ditches/canals to a stream, lake, or wetland.

Distance from
EoT to WoC:

This value is pertinent when the WoC is located beyond the EoT. This is the case when the property boundary is encountered prior to the WoC. In cases where the EoT is defined by the WoC, this value should be 0.0.

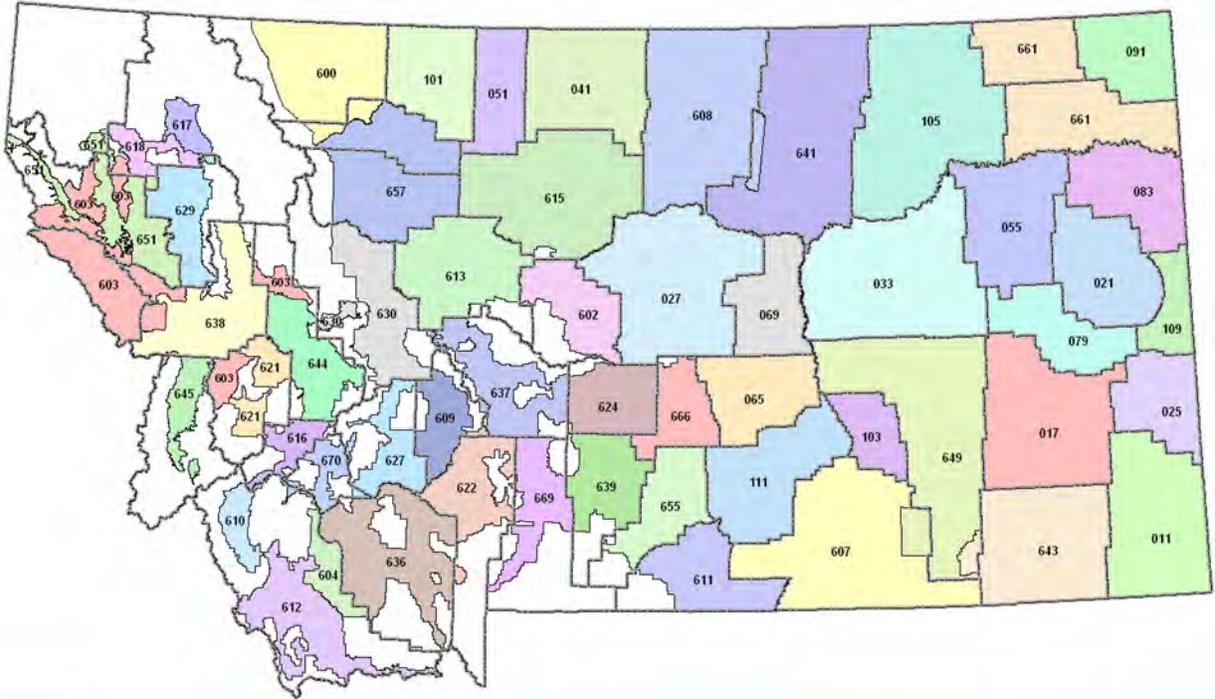
Distance from
Corral to the WoC:

The entry for this question is prompted by three choices: 0 feet, 1 – 35 feet, and greater than 35 feet. The selected choice does not affect the Load or Index calculations. It merely prompts a narrative guiding the user on interpreting the Index. Narratives are currently directed toward model applicability and MT-NRCS Practice Standard 635, Vegetated Treatment Areas (2009) criteria, established for Small facilities.

Definition of Worksheets

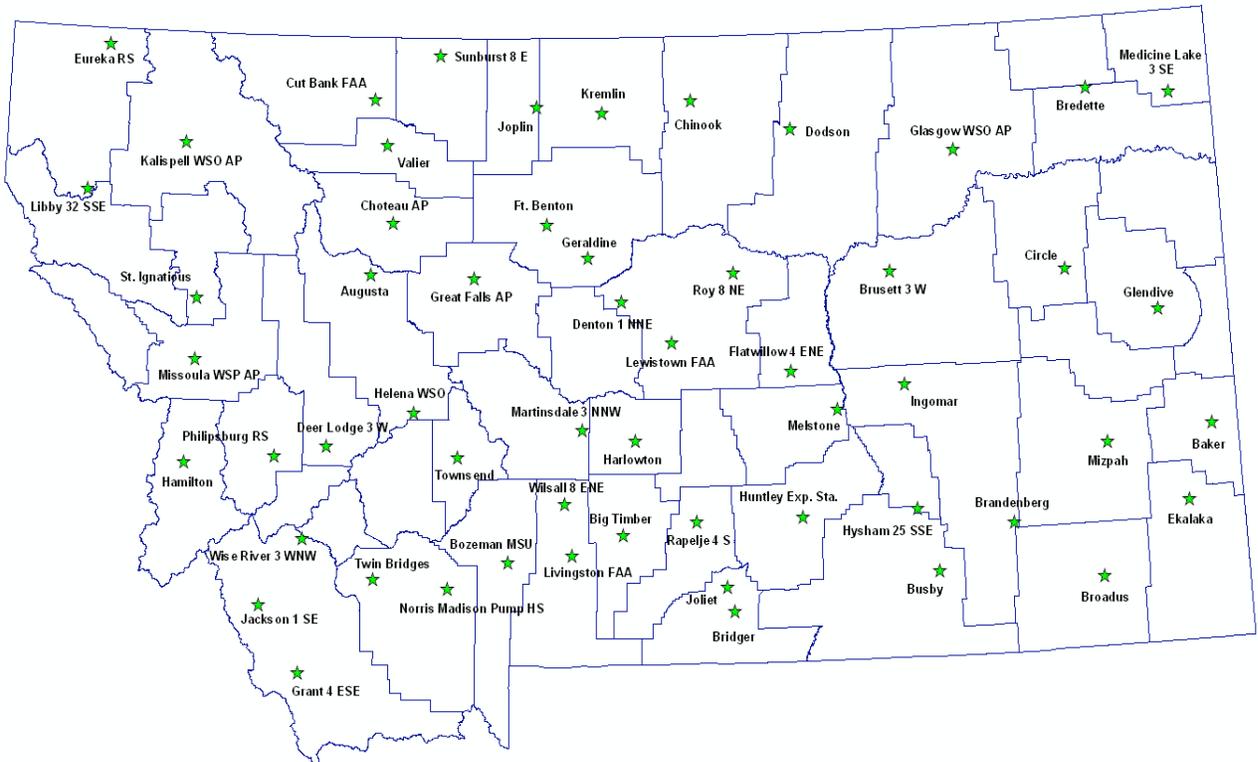
- Introduction tab:** A worksheet containing a brief discussion of the model, worksheet definitions, and key notes in order to avoid model operational errors.
- INPUT&OUTPUT tab:** All inputs are made on this page. This includes feedlot information and buffer information along with information on the EoT and WoC. Some cells include a red triangle which indicates a comment or clarification for that particular input. Sliding your cursor over the triangle will make the comment appear.
- The second page of this worksheet summarizes the output or results of the model run. Outputs include summary data for the farm, the seasonal and annual loadings for all the pollutants at the WoC, the Index, and INDEX Notes displaying guidance relative to NRCS Standards and Specifications.
- Standard Values tab:** This worksheet provides a summary of the default values used in the current version of the model.
- Soil Survey Map tab:** This tab provides a map of Montana and delineates the name and boundary of the Soil Surveys included in MontFARM (see Figure 2).
- Weather Station Map:** The tab provides a map of Montana and delineates the name, location, and average annual rainfall amount for each Weather Station included in MontFARM (see Figure 3).
- Revisions tab:** This worksheet describes all of the revisions made to the model since the release Version 1.2 and the impact these changes have on the model results.

Soil Survey Map



011	Carter	612	Horse Prairie South Valley
017	Custer	613	Cascade
021	Dawson	615	Choteau
025	Fallon	616	Deer Lodge
027	Fergus	617	Upper Flathead
033	Garfield	618	Flathead Lincoln
041	Hill	621	Granite
051	Liberty	622	Gallatin
055	McCone	624	Wheatland
065	Musselshell	627	Jefferson Silverbow
069	Petroleum	629	Lake
079	Prairie	630	Lewis and Clark
083	Richland	636	Madison
091	Sheridan	637	Meagher
101	Toole	638	Missoula
103	Treasure	639	Sweetgrass
105	Valley	641	Phillips
109	Wibaux	643	Powder River
111	Yellowstone	644	Powell
600	Glacier Pondera	645	Bitterroot Valley
602	Judith	649	Rosebud Big Horn
603	Lolo National Forest	651	Sanders Lincoln Flathead
604	Dillon	655	Stillwater
607	Big Horn County	657	Choteau Conrad
608	Blaine Phillips	661	Roosevelt Daniels
609	Broadwater	666	Golden Valley
610	Big Hole	669	Park
611	Carbon	670	Silverbow Jefferson Beaverhead

Figure 2. Soils Map used in MontFARM.



Weather Stations for MontFARM Modeling

County	Station	Elev.	Average Annual Precip (in)	Average Annual Snowfall (in)	County	Station	Elev.	Average Annual Precip (in)	Average Annual Snowfall (in)
Lewis & Clark	Augusta	4070	13.8	7.7	Lewis & Clark	Helena WSO	3830	11.3	43.6
Fallon	Baker	2930	14.4	26.1	Yellowstone	Huntley Exp. Sta.	2990	14.3	42.2
Sweet Grass	Big Timber	4100	16.3	30.7	Big Horn	Hysham 25 SSE	3100	14.4	56.3
Gallatin	Bozeman MSU	4860	19.3	91.6	Rosebud	Ingomar	2780	12.3	36.4
Rosebud	Brandenberg	2770	14.2	43.3	Beaverhead	Jackson 1 SE	6480	11.8	27.9
Roosevelt	Bredette	2690	13.0	30.9	Carbon	Joliet	3700	15.9	56.0
Carbon	Bridger	3583	11.5	38.0	Liberty	Joplin	3300	10.0	13.2
Powder River	Broadus	3030	13.6	45.4	Flathead	Kaispell WSO AP	2970	17.2	62.4
Garfield	Brusett 3 W	3270	13.2	43.2	Hill	Kremlin	2860	12.2	27.7
Big Horn	Busby	3430	14.5	55.7	Fergus	Lewistown FAA	4130	17.9	66.2
Blaine	Chinook	2340	13.3	29.9	Lincoln	Libby 32 SSE	3600	24.3	96.1
Teton	Choteau AP	3950	10.5	40.0	Park	Livingston FAA	4650	15.7	60.5
McCone	Circle	2440	13.3	24.4	Meagher	Martinsdale 3 NNW	4800	13.6	56.5
Glacier	Cut Bank FAA	3840	12.5	32.5	Sheridan	Medicine Lake 3 SE	1950	13.0	25.0
Powell	Deer Lodge 3 W	4850	10.7	35.4	Musselshell	Melstone	2920	15.1	48.6
Fergus	Denton 1 NNE	3620	15.0	39.2	Missoula	Missoula WSP AP	3200	13.8	43.6
Phillips	Dodson	2280	11.8	18.4	Custer	Mizpah	2480	13.4	29.4
Carter	Ekalaka	3430	17.2	20.7	Madison	Norris Madison Pump HS	4750	17.6	53.5
Lincoln	Eureka RS	2530	14.8	42.6	Granite	Philipsburg RS	5270	15.0	30.0
Petroleum	Flatwillow 4 ENE	3140	13.3	31.5	Stillwater	Rapelje 4 S	4130	15.2	69.0
Chouteau	Ft. Benton	2640	13.7	49.7	Fergus	Roy 8 NE	3450	14.2	42.9
Chouteau	Geraldine	3130	16.0	55.6	Lake	St. Ignatius	2900	16.5	41.6
Valley	Glasgow WSO AP	2280	11.2	30.8	Toole	Sunburst 8 E	3610	13.1	24.2
Dawson	Glendive	2080	13.7	24.4	Broadwater	Townsend	3840	10.7	22.9
Beaverhead	Grant 4 ESE	5820	10.3	43.2	Madison	Twin Bridges	4620	9.9	2.8
Cascade	Gt. Falls AP	3660	14.9	58.9	Pondera	Valier	3810	12.2	16.7
Ravalli	Hamilton	3530	13.6	8.7	Park	Wisall 8 ENE	5840	21.0	102.0
Wheatland	Harlowton	4140	14.1	37.7	Beaverhead	Wise River 3 WNW	5740	11.2	13.0

* Data taken from WETS station data. Refer to www.mt.nrcs.usda.gov/snow/climate.

Figure 3. Weather stations and map used in MontFARM.

Expanded Definitions and Clarifications

Farm and Date Information

The first inputs asked for in the model are the farm name and address along with the date of the evaluation and the name of the evaluator. This information is useful for future reference and is listed on the Summary Output at the bottom of the worksheet.

Feedlots and Sub-Lots

Feedlots are defined as the areas where animals are confined and perennial vegetation cannot exist due to animal use. A single feedlot in MontFARM can be broke into several sub-lots but they all must have the same up-slope contributing watershed area, buffer area, and End of Treatment (EoT) location. Lots with differing Area 2, Area 3, buffer, or EoT areas/locations should be analyzed individually. INDEX values from each individual run can be added to obtain a rating for the entire facility.

Feedlots can be broken into sub-lots based on differing management practices, animal types, animal numbers, or weights. Each sub-lot can have only a single animal type. If differing animal types are held within the same lot at same or differing times of year, animal types should be combined by converting to one type using equivalent animal weights and numbers. For example one, 1,100 pound horse equals 1.1, 1,000 pound beef animal.

Note that for each sub-lot, the animal numbers, weights, and days on the lot can change on a monthly basis. This is especially relevant where animals are held for only a portion of the year.

Sub-Lot Characteristics

Lot Area

The area of the sub-lot can be input in either acres or square feet (ft²). This area is defined as the confined area where manure accumulates and is exposed to rainfall and subsequent runoff. Open lots in Montana typically have a soil base. An area with substantial permanent or perennial vegetation (a pasture area) is not considered a feedlot or sub-lot. Some farms may have large, fenced, vegetated areas with, for example, designated feeding areas which result in well-defined areas of heavy use. In such cases, the soil area, assuming it has noticeable manure deposition, can be defined as the sub-lot. Animal lanes or alleys are typically not considered a sub-lot or part of a sub-lot. Although there may be no vegetation in these areas, the amount of manure distributed is likely minimal as compared to feedlots or feeding areas. These areas would typically be accounted for in Area 2 or Area 3.

Type of Animal, Animal Numbers, Animal Weight, Days on Lot, Cleaning

Within each sub-lot, the user can choose one of four options for animal type and describe, by month, the daily average animal numbers, average animal weight, and number of days on the lot. Animal numbers, weights, and days on the lot affect the runoff generated as well as the concentration of nutrients within the runoff. Computations based on these values are ultimately averaged across winter, spring, summer, and fall months to compute seasonal average runoff and load amounts.

Type of Animal

Use the drop down menus to select the type of animal on each sub-lot. Current available animal types are Beef, Dairy, Horse, and Sheep. Varying the type of animal will affect the amount of manure produced, its absorptive capacity, the animal unit density, and the background nutrient concentration of the lot runoff. If the term “None” is used, the model will not recognize any of the subsequent entries of animal number, animal weight, or time on lot.

Runoff nutrient values are adjusted based on animal type. The adjustment to runoff nutrient concentration is assumed to be equal to the ratio of the animal’s manure nutrient concentration to that of beef. For example, if the nutrient value of sheep manure is 75% of that for beef manure, nutrient concentration of the runoff from a sheep lot will be 75% of that from a beef lot.

Number of Animals

Often the animal numbers on a particular sub-lot change as animals are moved on and off the lot. Input values should represent the average number of animals confined on a daily basis during the given month. If animals are converted to 1,000 pound animal units, this value should reflect the average number of 1,000 pound animals held on a daily basis.

Varying the number of animals on the lot results in a corresponding change in the amount of manure produced. More manure on the lot means greater absorptive capacity. Greater absorptive capacity means less precipitation is available to runoff. This is discussed further under the RUNOFF Section.

Average Animal Weight

For each month animals are held in confinement, the model requires a corresponding average animal weight. Input values should represent the average animal weight considering all animals held in that sub-lot within that month. If animal weights on a given sub-lot vary widely (by more than 25%) within a given month, the number of animals should be converted to number of 1,000 pound animal units and the average weight entered would be 1,000 pounds.

Varying the average animal weight on the lot results in a corresponding change in the amount of manure produced. Similar to animal numbers, more manure on the lot means greater absorptive capacity. Greater absorptive capacity means more precipitation is held and less is available to runoff.

Days on the Lot

Time on the lot is described in terms of 24-hour days. Partial days should be counted as full days assuming the animals are fed and produce a majority of their manure while in confinement. If this assumption is not true, partial days can be described in decimal format, as a percentage of a 24-hour day, and accumulated through the month for an input value.

Cleaning

Cleaning occurs when the manure is removed from the lot. It is assumed that manure is removed down to mineral soils. MontFARM requires the user to “clean” the lot at least once per year. Cleaning is encouraged as it removes the nutrient source and promotes a healthier environment for the animals confined. Under conditions of a cleaned and empty lot, nutrient concentrations are set to the minimum value of 2 percent of the assumed maximum values. The computed nutrient load is nearly zero.

Manure on the lot affects the computed load values in different and opposing directions. While serving as a nutrient source for pollutant load, it also reduces the amount of runoff generated. The absorptive capacity of manure acts as a sponge and results, to a limit, in increased storage of precipitation and less runoff leaving the lot.

Cleaning removes the “sponge” effect of manure and results in a significant increase in runoff. MontFARM incorporates the effects of cleaning by resetting the Curve Number (CN), discussed later, to a value which generates higher runoff volumes. This value is 90 for winter and spring seasons when background conditions are assumed to be moist. It is 78 for summer and fall seasons when background conditions are assumed to be dry.

The minimum Animal Unit Density, discussed later, on any lot is 2 even when the lot has been cleaned and there are no animals present. MontFARM recognizes there is some pollutant loading even from a cleaned lot. At times, depending on the balance between runoff volume and nutrient concentrations, the runoff from a cleaned lot may generate higher loading values than runoff from a lot with a heavy loading of manure and large absorptive capacity.

Runoff

Runoff generated from the feedlot is computed based on the NRCS Curve Number Methodology (see NRCS, National Engineering Handbook, Part 630, Chapter 10). This methodology computes runoff as a function of the watershed area, precipitation amount, and initial abstraction or the ability of the ground and vegetation to store water prior to generating runoff.

MontFARM incorporates Montana NRCS’s modified CN methodology to account for the absorptive capacity of manure for feedlot situations (see Appendix B, Hydrologic Analysis of Open Lot Runoff). Computations factor the initial abstraction based on the amount of moisture manure can absorb during a precipitation event. This amount is dependent on the background moisture content of the manure on the lot. When animals are using the lot, manure laying on the lot is assumed to be 60% moisture characterizing relatively moist conditions. When the lot is empty, manure on the lot is assumed have a moisture content of 37% reflecting drier conditions. The moisture content to which manure will rehydrate is assumed to be 81% (Agricultural Waste Management Field Handbook, AWMFH, Figure 11-1). This value represents the moisture content of beef manure as it transitions from a semi-solid to a slurry condition.

Antecedent Runoff Condition (ARC) is a tool used to adjust the CN and resulting runoff volume as a result of climatic conditions. Antecedent Runoff Condition I, indicates dry conditions. Antecedent runoff Condition II reflects moderately moist conditions while Antecedent Runoff Condition III reflects wet conditions. Typically, feedlot conditions are wetter in the spring during which the highest values of monthly rainfall occur (Figure 4). Wet conditions can also exist during the winter months when temperatures rise to above freezing and melting occurs. These seasons are assumed to be ARC II. Summer and fall seasons are assumed to be ARC I. While summer months can have significant amounts of rain, high evaporation rates and empty lots commonly result in dry conditions. Rainfall amounts during the fall are typically quite low also resulting in dry background conditions. For further discussion of Antecedent Runoff Condition see National Engineering Handbook (NEH), Part 630, Chapter 10, Estimation of Direct Runoff from Storm Rainfall.

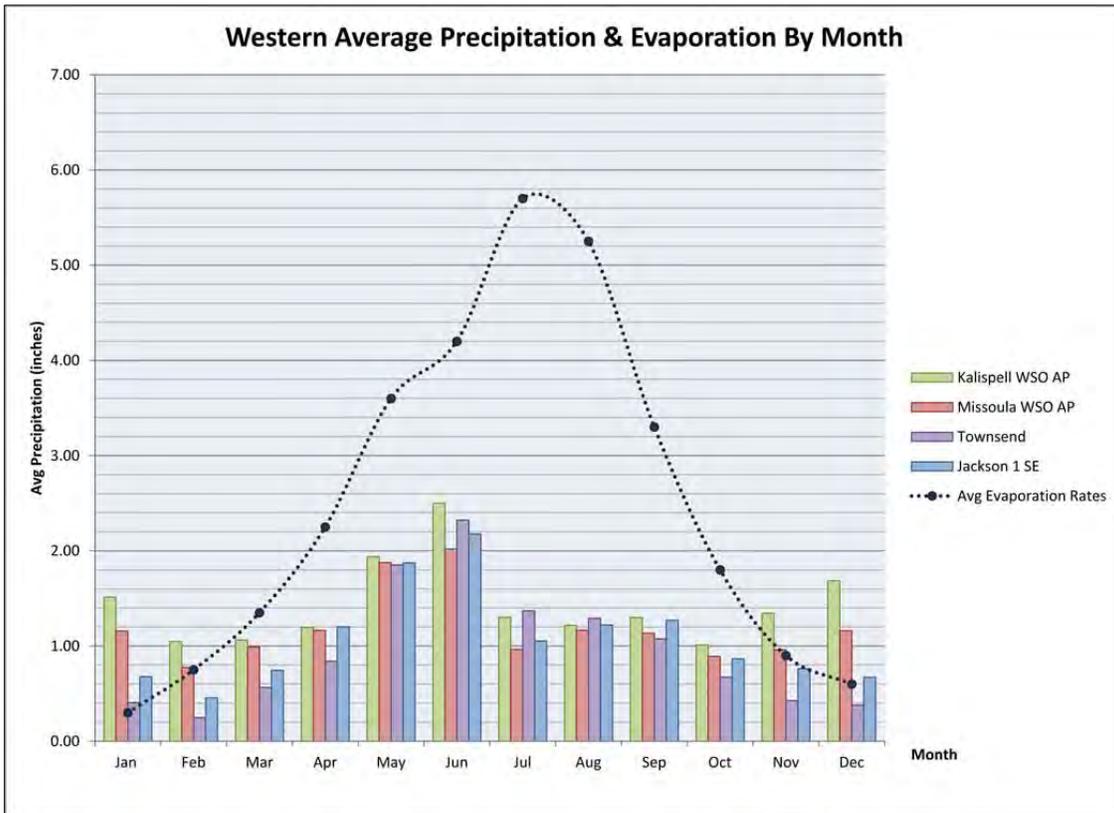
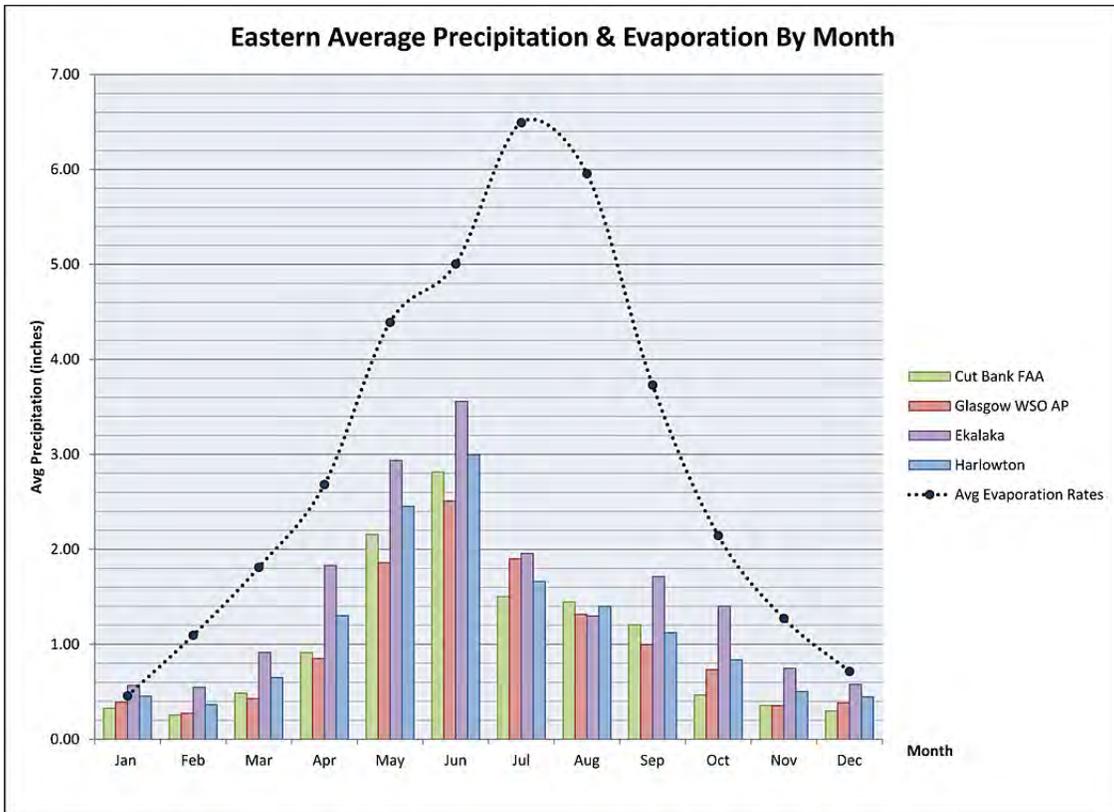


Figure 4. Average monthly precipitation and evaporation amounts for selected locations in Montana. Values are averaged from National Weather Service Data over a period of record of 48 years.

In all cases, MontFARM limits manure pack absorption to the top 3 inches of the pack (see discussion in Appendix B). As a result, CN values are limited to minimum values of 80 during the winter and spring seasons if animals are in the lot. The minimum value in the summer and fall with animals in the lot is 63. When the lots are empty, CN values are allowed to decrease to values of 62 for winter and spring and 42 for summer and fall.

Animal Unit Density (AUD)

The Animal Unit Density (AUD) is a function of the animal species, animal weight, animal time on the lot, and size of the lot. This is an internal calculation that estimates the average manure coverage based on the number of 1,000 pound animals per acre. Its value affects the nutrient concentration assigned to the runoff generated from the lot. If the AUD is equal to any value greater than 100, it is assumed that the lot is 100% covered with manure. In this case, and assuming animals are on the lot, the nutrient concentration of the generated runoff will be at its maximum and increasing the AUD above 100 will have no effect. For instance, if the AUD is equal to 150 and additional cleaning of the lot brings the AUD to 110, there will be no change in the pollutant potential. When AUD is less than 100, the nutrient concentration is factored by the AUD percentage. For example, an AUD of 50 indicates that the specific lot area and management will contribute 50% fewer pollutants as the same size lot with an AUD of 100 or greater.

The AUD value of 100 is based on a study (ASAE paper No 78-2032) that concluded that one 1,000 pound beef animal covered approximately 43.6 square feet per day with manure. Using this figure, 100 beef animals at 1,000 pound weight would cover a 1-acre lot with manure in only 10 days. Therefore, an AUD value of 100 (100, 1,000 pound animals per acre) is assumed to represent a lot with full manure coverage.

AUD on empty lots

Months during which animals are not held in confinement still contribute to the pollution potential assuming the manure pack is still in place. MontFARM uses AUD to estimate the concentration of nutrients for lots with varying combinations of cleaned, manure-laden, empty and stocked conditions. The AUD value for manure-laden but empty lot conditions is computed at 20% of the previous month's AUD. This reduction recognizes the decrease in nutrient content which occurs as manure ages. Table 11-5, Chapter 11, AWMFH, indicates beef manure, stored in an open lot in a hot arid region, retains 50% of its original nitrogen and 75% of its original phosphorus. Research by Mankin (2006) found that nitrogen concentration in runoff from empty lots was one-sixth (17%) that of runoff from stocked feedlots. Phosphorus values were one-seventh (14%) that of stocked lots.

MontFARM recognizes there is some pollutant loading even from a cleaned lot. For this reason, AUD is not allowed to decrease below a value of 2 for any feedlot condition including cleaned lots which are empty. At times, depending on the balance between runoff volume and nutrient concentration, higher volumes of runoff from a cleaned lot with a low AUD can generate larger loading amounts than reduced runoff volumes from a manure-laden lot with a large AUD.

Area 2

During rainfall events runoff water will be generated from all land areas and roofs. Those areas that are upslope of the feedlot and whose runoff water passes through some portion of the lot are

defined in the model as “Area 2”. The model allows the user to define up to six different contributing areas along with an additional input for total roof area. This single “roof area” is the roof area that contributes rainfall directly on the feedlot. Roof areas upslope of the lot can be listed as one of the Area 2 inputs. Different Area 2s, defined by different vegetative cover or soil hydrologic group (see definitions below) can be input on a per acre basis or per square foot basis. MontFARM assumes that any water running across the lot from these areas moves additional nutrients off the lot in the runoff water. As such, decreasing Area 2 through diversions or other means will reduce the annual nutrient loading.

Cover Type, Soils, and Hydrologic Group

The model uses the NRCS Curve Number (CN) method to estimate runoff amounts from the feedlot, Area 2, Area 3, and buffer. This runoff estimation method requires the input of the area, vegetative cover, and soil hydrologic group. See Appendix A for more definition on these topics.

Cover Type

In general, increasing the amount of vegetation decreases the amount of runoff. Model choices are “Row Crop” rotations (e.g., sugarbeets/corn), “Alfalfa” rotations (e.g., alfalfa/small grain) “Pasture/Grassland”, “Lawn”, “Roads, Alleys, Concrete”, “Farmstead” (a mix of driveways and lawn), “Roof”, or “Woodland” areas. Vegetated cover selections should reflect conditions that exist during the summer growing season. The model will adjust this cover, and respective estimates of runoff, automatically for fall, winter, and spring seasons.

Soil Type

The model requests input for “Soil Type” for Area 2, Area 3 and buffer areas. Although the actual soil type name or number is not used for model calculations, it is important to document this information for future reference. “Soil type” is a drop-down menu with entries specific to the soil survey selected at the top of the INPUT page. Each entry includes the Soil Hydrologic Group which is an important factor for model computations and is discussed in the next paragraph.

Hydrologic Group

As noted, the amount of runoff from a particular area is a function of the vegetative cover but is also a function of soil properties. These properties are defined as the Hydrologic Soil Group (HSG) with choices A, B, C, and D. A soil classified as HSG A has the highest ability to absorb moisture (sandier soils). A soil classified as HSG D has the lowest ability to absorb moisture (heavy clays). As such, selecting “Hydro Group A” for a specific area will result in less runoff than the selection of “Hydro Group B”. The classification for each soil’s Hydrologic Soil Group is found in front of the soils name in the Soils drop-down menus. Soil Hydrologic Group values must be entered for all Area 2, Area 3, and Buffer entries.

Buffers and Buffer Delineation

Buffers are defined by the area downstream of the feedlot prior to the End of Treatment (EoT). Typically, this area is thought of as flat and vegetated. Rather, a buffer is defined as ANY area between the end of the feedlot and the EoT and can include areas which would have carried channelized flow during rainfall events. Buffer dimensions are easily determined through standard distance measurements using a measuring wheel, pacing, cloth tape, GPS, or in the case of longer distances, aerial photos.

A maximum of four sequential buffers can be delineated in the model. Criteria for designating buffer sequence boundaries include vegetation changes, slope changes, soil type changes, and changes in buffer width. The level of detail in the computational model does not warrant micro-analyzing the changes in buffer characteristics. Typically, the boundaries between sequential buffer areas are defined by dramatic visual changes in vegetation such as moving from permanent meadow to cropland. The assigned vegetative cover (land use) should reflect the cover that is present **during the growing season**.

The slope of the buffer impacts the speed at which the runoff flows which in turn impacts the depth of flow computed for a given precipitation event. As a result, slope impacts the amount of pollutants that are trapped or filtered by the vegetation. If there are no changes in vegetation, but changes in slope occur, a new buffer could be defined. Alternatively, where there are no dramatic changes in vegetation, use the average slope and indicate only one buffer. Slope can be measured with a hand level, range finder, clinometer, laser level, or similar technique.

Buffer treatment occurs through infiltration and filtration. Width and length dimensions define the buffer area over which these processes occur. Buffer width also affects the buffers ability to filter flow. Buffer width factors into the computed flow depth for a given precipitation event. The narrower the width, the deeper the flow depth will be. The ability of the buffer to filter nutrients decreases as the depth of flow increases to a computed maximum value. This maximum value is typically 6 to 8 inches and a function of the vegetative cover conditions. Runoff flow depths computed at values greater than the maximum result in zero reduction due to filtration and have no effect on the computed nutrient load.

The input value for buffer width is defined as the width of flow when the maximum depth of flow is 3 inches. This measurement is made perpendicular to the flow direction. In measuring this dimension, minor, superficial changes in elevation should be neglected such as hoof imprints and small soil ridges. Figure 5 provides a visual of this measurement. The input value for buffer length is defined as the length of the flow path.

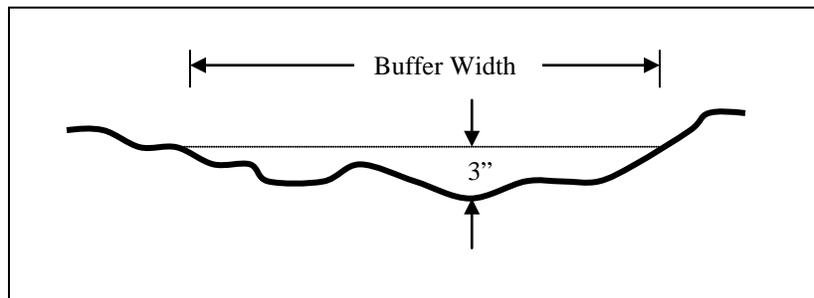


Figure 5. Buffer width determination

Many buffers are rectangular so the flow direction, length and width are easy to determine and the delineation of additional buffers is straightforward. However, there are sites where the buffer area is triangular or some other geometric shape with a variety of slopes and contours (see Figure 6). Modeling these buffers is more challenging. In general, try to imagine the flow paths for both small and large runoff events and use average lengths, widths and slopes. Averaging lengths, width, and slopes is preferred to dividing the area into several smaller buffers.

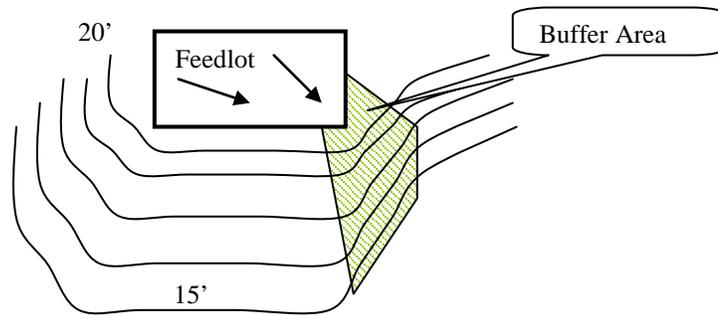


Figure 6. Irregular-Shaped Buffer Area.

Often there is a question of where the buffer begins. For example, the manure and lack of vegetation may extend beyond the edge of the confinement area due to steep lot slopes which cause solids to flow beyond the lot boundary. Another example is where there are no physical boundaries between the defined “feeding” area and buffer such as within pastures or animal lanes. In these cases, the buffer should begin at the down-slope edge of the manure or where vegetation begins.

Area 3 (Adjacent Area)

Area 3 is defined as the area adjacent to the buffer which contributes clean water to the buffer between the edge of the feedlot and the End of Treatment (EoT) location. The buffer is not part of Area 3.

Because Area 3 adds to the total runoff volume but little to nothing to the pollutant load, additional Area 3 will decrease the concentrations of the pollutants at the EoT. Added runoff volume also reduces the efficiency of the buffer area because of increased depth of flow and reduced filtration treatment.

Realistically, the timing of the feedlot runoff and the timing of the Area 3 runoff will not coincide with each other – especially with large Area 3’s. As such, Area 3 should be limited to 400 feet on either side of the buffer. The model computes an estimated maximum Area 3 based on this criteria. This value is shown on the INPUT&OUTPUT worksheet in the Area 3 input box. Although the model does not limit the size of Area 3, the estimated maximum value for Area 3 should be adhered to unless a justification can be made otherwise.

Receiving Water Information

The MontFARM model calculates the annual loading at the end of the buffer area for Total Phosphorus (TP), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD₅), Total Nitrogen (TN) and Fecal Coliform (FC) bacteria for a given feedlot. This information is provided on the results summary on the bottom of the INPUT&OUTPUT worksheet. In addition to these estimates, the model assesses the relative pollution potential for the site. This relative pollution potential incorporates the annual pollutant loading along with the characteristics of the receiving water and its potential to convey pollutants to larger water networks. The following questions are used to assess this pollution potential ranking.

What is the End of Treatment (EoT)

The EoT is that point where runoff from the feedlot and buffer area crosses a property boundary or enters a Water of Concern (WoC). It represents that point where the producer loses ownership and/or control of the runoff. When runoff from the buffer enters directly into a WoC; the EoT is the WoC and should be noted as such. Use the drop-down menu to describe the EoT.

Water of Concern (WoC)

The WoC is considered the discharge point or that point where runoff from the lot becomes a concern. Water bodies or wetlands indicated on USGS topographic maps will be considered a WoC. Discrete water bodies or wetlands matching the descriptions above but not shown on the topographic map should also be considered a WoC providing they meet the following criteria:

- a. Drainages shall demonstrate channel characteristics such as banks and/or bed materials. A grassed swale is not considered a WoC unless it is designated a perennial, intermittent, or ephemeral stream by the USGS topographic map.
- b. Wetlands shall exhibit the hydrologic, vegetative, and soil characteristics required for wetland designation, as defined by the U.S. Army Corps of Engineers (USACE).
- c. Ditches shall convey flow either directly or through a network of ditches/canals to a stream, lake, or wetland.

Distance between EoT and WoC

This value is pertinent when the EoT is defined by the property boundary. In this case, the distance to the WoC extends beyond the EoT and the pollutant load at the EoT receives additional treatment before discharging to a WoC. While the primary Index value is computed at the EoT (discussed later), the model computes an additional Index value at the WoC. The Index at the WoC incorporates a percent reduction in pollutant strength as a function of the distance between the EoT and WoC. This relationship was developed using assumed values for runoff velocity (see NEH, Part 630, Figure 15-4) and research presented by Young (1982) relating reduction of pollutant loads to contact time for grassed waterways. MontFARM assumes an overland velocity of 1.5 feet per second and computes contact time based on the distance value entered. This distance can be measured or can be estimated from maps. In cases where the EoT is defined by the WoC, the distance value should be 0.0 feet.

Distance from Corral to the WoC

The model requires the user to select either 0 feet, 1 to 35 feet, or greater than 35 feet for defining the flow path distance between the corral and WoC. This question is prompted by Montana NRCS Practice Standard 635, Vegetated Treatment Area (2009), which requires, for SMALL AFO facilities, a minimum distance of 35 feet between the lot and WoC. The selected choice for this question merely prompts a narrative guiding the user on interpreting the Index relative to this criteria.

A value of 0 feet should be selected when animals have direct contact with the WoC. Direct contact occurs when the animals can stand either partially or fully in the WoC. Examples of direct contact include the WoC flowing through the lot itself, along its edge or across a corner, or the animals having access to a water gap utilized for drinking water. Direct contact does not include animals crossing the WoC when being moved from one pen or pasture to another.

MontFARM is not an appropriate tool to use when animals have direct contact with the WoC as computed load and Index values are not accurate. MontFARM does not have the ability to account for manure that is discharged directly from the animals into the water or nutrients that are stirred up as a result of animal activity. With or without the use of MontFARM, sites where direct contact occurs are inherently HIGH in terms of their potential for pollutant loading to the WoC.

Other Comments

The comments space on the model INPUT page allows the evaluator to keep track of any other observations on the site that may be useful in the documentation process.

Model Output

Model results or outputs are shown at the bottom of the INPUT&OUTPUT worksheet. Combining the feedlot inputs and model results is useful for reporting and recordkeeping. When the INPUT&OUTPUT worksheet is printed, the results are on printed on the second page.

Site Summary

The site summary provides a recap of the information input into the model including the range of animal stocking densities and the ratio of feedlot area and Area 2 area to buffer area. Stocking densities are useful in checking the management scenario described by producer and also provide a measure which can be helpful when interpreting the computed Index value. The ratio of feedlot area and Area 2 area to buffer area can also be useful. Montana NRCS Standard 635, Vegetated Treatment Area establishes, for SMALL facilities, a maximum value of 6.0 for this ratio.

Receiving Water Summary

This is a summary of what was defined as the EoT and WoC, the distance between the two, and the computed Index value at the WoC. The Index value at the WoC will be different from the primary Index when the WoC is located beyond the property boundary. In this case, the Index at the Property Boundary is the value to utilize with regards to NRCS interpretations. It represents the potential for the pollutant loading to leave the producer's property and effect a neighboring property. The Index at the WoC provides a measure, for the producer's information, of the potential for the pollutant loading to reach an actual WoC.

Seasonal Runoff Summary

Both seasonal and annual runoff volumes (acre-inches) are reported. These values are reported for locations at the feedlot edge and at the buffer edge or EoT.

Pollutant loading for Chemical Oxygen Demand (COD), Total Phosphorus (TP), Total Nitrogen (TN), Fecal Coliforms (FC), and Biological Oxygen Demand (BOD₅) is reported in a table format. Seasonal and annual calculations for these loadings are based on the number and probability of loading from several different sized storm events throughout a year.

INDEX Notes

INDEX Notes are posted to provide the user guidance in interpretation of MontFARM results. Notes are scripted relative to application of the model and criteria provided in the Montana NRCS Standard 635, Vegetated Treatment Area. Additional notes based on input from other agencies can be incorporated upon contacting the Montana NRCS State Conservation Engineer.

Index System

The Index is a calculated value that considers the pollution potential of the feedlot at the location of the designated EoT. This location may be the WoC or the property boundary. Index computations use the annual BOD₅, TP and TN loading calculated at the EoT, BOD₅, TP, and TN loading from a worst case scenario, and a priority factor depending on the type of WoC. Index values range between 1 and 100 with higher Index values indicating higher pollution potential.

In March 2011, NRCS gathered a team of water quality specialists representing the USGS, Montana DEQ Nonpoint Source Section, Montana DNRC, Montana State University, and Montana NRCS. This team is known as the MontFARM Technical Team and was assigned the task, amongst others, to determine categories and priorities of Montana's various receiving waters. This group was also tasked with formulating the Index computation approach along with appropriate factors for Montana.

Index values are computed at both the WoC and EoT locations. The Index value at the EoT is the value used to reflect the pollution potential of the facility. This location was selected because, generally speaking, any flow leaving a person's property can be considered state waters. Furthermore, a producer cannot claim, with long-term assurance, the treatment capacity that may exist beyond their property boundary. When the WoC defines the EoT location, the Index at the EoT will be the same as the Index at the WoC.

Priority Factor

The different categories for WoC were determined to be: perennial streams, lakes and reservoirs, intermittent and ephemeral streams, ditches which deliver flow to another WoC, depressional wetlands, and wetlands which have surface water connection to a stream and/or lake. Index values are stratified based on the priority of the Water of Concern. Priority factors are based on the typical characteristics of the receiving water and their ability to convey water to larger downstream networks. This approach is similar in concept to Montana DEQ's consideration for the receiving waters' assimilation capacity when determining the allowable load limits for Wastewater Treatment Plant discharge permits (Suplee, 2008).

The following is a description of how each WoC was prioritized in MontFARM.

High Priority Water of Concern types (Priority factor = 1.0):

- **Perennial Streams** - Perennial streams flow year round and always deliver the nutrient load to downstream waters.
- **Lakes and Reservoirs** - Water bodies such as lakes and reservoirs are sensitive to nutrient inputs due to the likelihood of an increased rate of eutrophication.

Medium Priority Water of Concern types (Priority factor = 0.8):

- **Ditches which deliver flow to a WoC** - Ditches are not pristine waters and often are a compilation of a variety of tailwater discharges originating from general rural overland areas to farmsteads and agricultural fields. Ditches which lead "nowhere" and ultimately deliver 100% of its flow to agricultural fields are NOT considered a WoC.

- **Intermittent Streams** - Intermittent streams are “A stream or stream segment that is below the local water table for at least some part of the year, and obtains its flow from both surface run-off and ground water discharge.” (Supple, 2008) These stream types do not provide a continuous flow route by which to deliver nutrient loads to a perennial stream.
- **Ephemeral Streams** - Ephemeral streams are “A stream or stream segment which flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice and whose channel bottom is always above the local water table.” (Supple, 2008) These stream types typically flow only during spring snowmelt events. While the flow path may be continuous to downstream perennial waters, temperatures are generally cool and impact from a nutrient load would be reduced.
- **Depressional Wetlands** - Depressional wetlands do not drain or outlet on a regular basis to adjacent drainages. In Montana, depressional wetlands are often Prairie Potholes. Depressional wetlands can be sensitive to nutrient influxes. From a surface water perspective, they seldom, if ever, discharge nutrients to downstream receiving waters.
- **Flow-Through Wetland** - Wetlands in this category have a surface water connection with a creek, stream, lake or other type of surface water. This type of wetland can deliver nutrients to downstream receiving waters but also has a natural ability to assimilate and reduce the impact of nutrient loads.

Low Priority Water of Concern types (Priority factor = 0.6): There were no specifically defined Water of Concern types designated as low priority. The MontFARM Technical Team determined that all of the above listed categories represent State Waters and therefore, should not be considered “low” in priority.

- **Other** - The “other” option is left in place for the user to implement in the event they encounter a category that does not fit the categories defined above. When used, a justifiable reason should be documented as per why the receiving water is considered different from the options present above. Justification should also address the applicability of a “low” priority rating. An example may be an expansive wetland heavily vegetated with cattails. This condition indicates a water body which has a high assimilative capacity for additional nutrient loading.

Baseline Pollutant Load

The core of the Index algorithm is a comparison of the site’s model pollutant load to a “worst case”, baseline condition. In order to reflect the full range of loading conditions, the baseline is set to represent a maximum load scenario. Any load condition equal to or above the baseline would Index a value of 100.

The site conditions for baseline or maximum load are assumed to be a 4.6 acre feedlot stocked with 800 weanlings in mid-October weighing 550 pounds. The animals are held through April with an average daily weight gain of 2.5 pounds. Clean water additions include 0.46 acres (10% of the lot area) of roaded area and 1.2 acres (25% of the lot area) of pasture grass in fair condition. Both of these contributing areas are assumed to be Hydrologic Soil Group B. The flow converges on the lot before discharging to the WoC which is a perennial stream. Buffer

dimensions are a 50-foot length and 30-foot width with a 2 percent slope. The above baseline scenario, located in Fergus County, models load values of BOD₅, TP, and TN at 131 pounds, 11 pounds, and 33 pounds, respectively, at the EoT.

Distance factor

Nutrient loads are modeled for the site up to the EoT location. Beyond this point the producer loses ownership and/or control of the runoff. While the loads are defined at this point, MontFARM recognizes that additional loss and/or assimilation which occurs as the nutrient load continues its path towards the WoC. When computing the Index at the WoC, the model incorporates a Distance Factor which computes the percent reduction in pollutant strength as a function of flow distance beyond the EoT. This calculation utilizes a relationship developed for grassed waterways by Young (1982) which predicts the reduction in pollutant strength as a function of contact time. MontFARM assumes an overland velocity of 1.5 feet per second (see NEH, Part 630, Figure 15-4) and computes contact time based on the value entered for “distance from the EoT to the WoC.” Figure 7 shows how a typical Index values change as the distance between the EoT and the WoC increases. Note that after 3,000 feet there are no further reductions in the Index value.

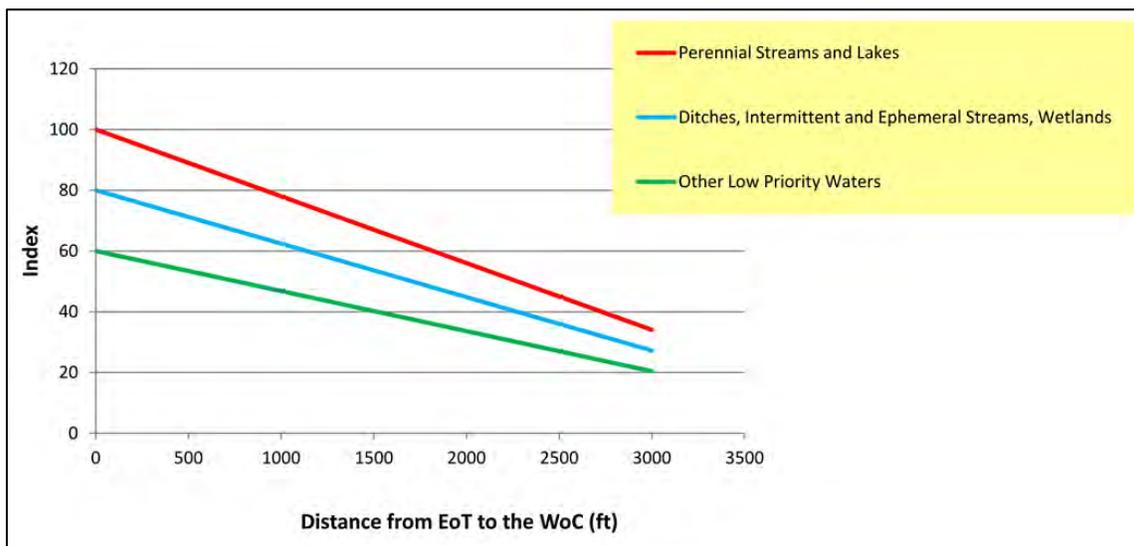


Figure 7. INDEX value as a function of distance for a simulated site.

Ecoregion Factor

The Index algorithm has the POTENTIAL to include adjustments for Montana Ecoregions. Ecoregions have been developed throughout the United States through a multi-agency effort to spatially identify areas of general ecosystem similarity. Ecoregions denote similarities in the type, quality, and quantity of environmental resources. Seven Ecoregions exist across the State of Montana. Montana DEQ has proposed numeric water quality criteria based on these Ecoregions. The values of the criteria indicate, for the purpose of use in MontFARM, the seven regions can reasonably be condensed into two regions (see Figure 8): Eastern Prairie and Western Mountain Ecoregions. Interestingly, Ecoregions in the Eastern Prairie section of the State exhibit water quality concentration criteria values roughly 10 times that of the Western Mountain Ecoregions.

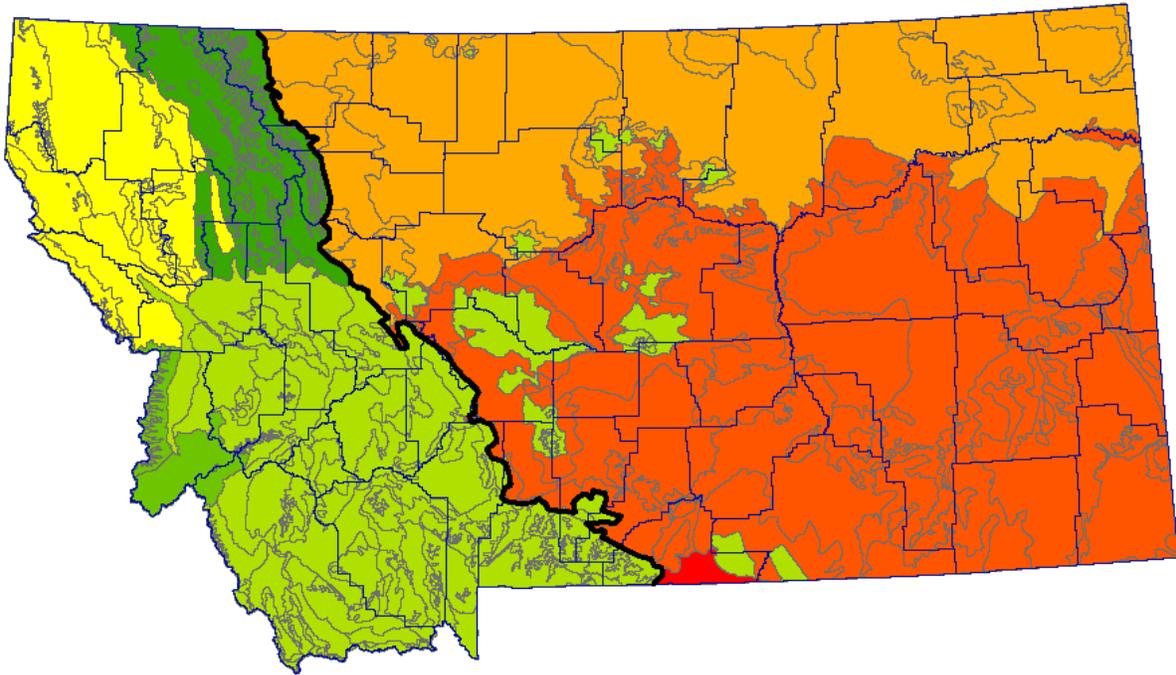


Figure 8. Proposed East and West Ecoregions.

MontFARM incorporates the option to implement an Ecoregion factor. With this factor, the model recognizes the difference between background water quality conditions in the western and eastern parts of the State. **THIS FEATURE IS CURRENTLY TURNED OFF IN THE MODEL.** If utilized, each Soil Survey in the MontFARM database is assigned either an East or West Ecoregion with a corresponding Ecoregion factor of 0.8 or 1.0, respectively. As a result, provided all other input equal, the Index value for a site located in the East Ecoregion would be 80% of that in a West Ecoregion. This means the East site would have a lower potential for pollution which seems reasonable given the water quality of receiving water is of significantly (roughly a factor of 10) less quality.

Appendix A. Vegetative Cover Determinations

Assessing the vegetative cover or land use is easy if the land is in a standard crop rotation. However, it becomes more difficult for continuously vegetative areas where the quality of the vegetation is on a continuum and changes throughout the year. There is only limited formal guidance on this assessment from the NRCS. This information is provided below and was taken from the NRCS, National Engineering Handbook (NEH).

Excerpts from

(210-VI-NEH, June 2002)

United States Department of Agriculture

Natural Resources Conservation Service

National Engineering Handbook, Part 630, Hydrology

CHAPTER 7. HYDROLOGIC SOIL GROUPS

Group A: (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.

These soils have a high rate of water transmission.

Group B: Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C: Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes down-ward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

Group D: (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils **have** a very slow rate of water transmission.

Chapter 8 Land Use and Treatment Classes

630.0801 Classification of land use and treatment

In the Natural Resources Conservation Service (NRCS) method of runoff estimation, the effects of the surface conditions of a watershed are evaluated by means of land use and treatment classes. *Land use* is the watershed cover and includes every kind of vegetation, litter and mulch, fallow, and bare soil as well as non-agricultural uses, such as water surface (lakes, swamps) and impervious surfaces (roads, roofs). *Land treatment* applies mainly to agricultural land uses and includes mechanical practices, such as contouring or terracing, and management practices, such as grazing control or rotation of crops. The *classes* consist of use and treatment combinations that actually occur on watersheds.

Land use and treatment classes are readily obtained either by observation or by measurement of plant and litter density and extent on sample areas.

630.0802 Classes

The land uses and treatments described here are listed in NEH, Part 630, Chapter 9, Table 9–1. This table also shows the runoff curve numbers (CN) for hydrologic soil cover complexes for which the hydrologic conditions are listed.

(a) Cultivated land:

Fallow listed in Table 9–1 is the agricultural land use and treatment with the highest potential for runoff because the land is kept as bare as possible to conserve moisture for use by a succeeding crop. The loss by runoff is offset by the gain because of reduced transpiration. Other kinds of fallow, such as stubble mulch, are not listed, but they can be evaluated by comparing their field condition with those for classes that are listed.

Row crop is any field crop (maize, sorghum, soybeans, sugarbeets, tomatoes, tulips) planted in rows far enough apart that most of the soil surface is exposed to rainfall impact throughout the growing season. At planting time the crop is equivalent to fallow and may be again after harvest. In most evaluations the average condition when runoff occurs is assumed. Row crops are planted either in straight rows or on the contour, and they are in either a poor or a good rotation. These land treatments are described later in this chapter.

Small grain (wheat, oats, barley, flax) is planted in rows close enough that the soil surface is not exposed except during planting and shortly thereafter. Land treatments are those used with row crops.

Close-seeded or broadcast legumes or rotation meadows (alfalfa, sweetclover, timothy, and combinations of these) are either planted in close rows or broadcast. This cover may be allowed to remain for more than a year so that year-round protection is given to the soil.

Straight-row fields are those farmed in straight rows either up and down the hill or across the slope. Where land slopes are less than about 2 percent, farming across the slope in straight rows is equivalent to contouring and should be so considered when using Table 9–1.

Rotations are planned sequences of crops, and their purpose is to maintain soil fertility or reduce erosion or provide an annual supply of a particular crop. Hydrologically, rotations range from poor to good in proportion to the amount of dense vegetation in the rotation, and they are evaluated in terms of hydrologic effects. *Poor rotations* are generally one crop land use, such as continuous corn (maize) or continuous wheat or combinations of row crops, small grains, and fallow. *Good rotations* generally include alfalfa or another close-seeded legume or grass to improve tilth and increase infiltration. Their hydrologic effects may carry over into succeeding years after the crop is removed though normally the effects are minor after the second year. The carryover effect is not considered in Table 9–1.

Contoured fields are those farmed as nearly as possible on the contour. The hydrologic effect of contouring results from the surface storage provided by the furrows because the storage prolongs the time during which infiltration can take place. The magnitude of storage depends not only on the dimensions of the furrows, but also on the land slope, crop, and manner of planting and cultivation. Planting small grains or legumes on the contour makes small furrows that disappear because of climatic action during the growing season. The contour furrows used with row crops are either large when the crop is planted and made smaller by cultivation or small after planting and made larger by cultivation, depending on the type of farming. Average conditions for the

growing season are used in Table 9–1. The relative effects of contouring for all croplands shown in the table are based on data from experimental watersheds having slopes from 3 to 8 percent. Stripcropping is a land use and treatment not specifically shown in Table 9–1 because it is a composite of uses and treatments. It is evaluated by the method of Example 10–4 in Chapter 10. The terraced entries in Table 9–1 refer to systems that have open-end level or graded terraces, grassed waterway outlets, and contour furrows between the terraces. The hydrologic effects are due to the replacement of a low-infiltration land use by grassed waterways and to the increased opportunity for infiltration in the furrows and terraces. Closed-end level terraces, not shown in Table 9–1, are evaluated by the methods in NEH, Part 630, Chapter 12 (210-VI-NEH, June 2002).

Conservation tillage is an umbrella term used to represent specific residue management practices, such as no-till/strip-till, mulch-till, or ridge-till. These practices leave all or a portion of the previous crop’s residue on the soil surface to: reduce soil erosion caused by the forces of wind and water, reduce surface runoff, increase infiltration, and reduce evaporation. *No-till* is defined as managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while growing crops in narrow slots or tilled or residue-free strips in soil previously untilled by full-width inversion implements. *Mulch-till* is defined as managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while growing crops where the entire field surface is tilled prior to planting. *Ridge-till* is defined as managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while growing crops on preformed ridges alternated with furrows protected by crop residue (NRCS, 1999).

(b) Grassland in watersheds can be evaluated by means of the three hydrologic conditions of native pasture or range shown in Table 8–1, which are based on cover effectiveness, not forage production. The percent of area covered (or density) and the intensity of grazing are visually estimated. In making the estimates, consider that grazing on any but dry soils results in lowering of infiltration rates because of compaction of the soil by hooves, an effect that may carry over for a year or more even without further grazing. An alternative system of evaluation is shown in Table 8–2. In this system, density and air-dry weights of grasses and litter are used. The air-dry weights are determined by sampling. The field work can be kept to a minimum by sampling a small number of representative sites rather than a large number of random sites. In the table the classes with plus signs are midway between adjacent classes so that the CN for these classes must be obtained by interpolation in Table 9–1. Contour furrows on native pasture or range are longer lasting than those on cultivated land, their length of life being dependent on the soil, intensity of grazing, and on the density of cover. The dimensions and spacings of furrows vary with climate and topography. The CN in Table 9–1 are based on data from contoured grassland watersheds in the central and southern Great Plains. Terraces are seldom used on grassland. When they are, the construction methods expose bare soils, and for 2 or 3 years the terraced grassland is more like terraced cropland in its effect on surface runoff.

Table 8–1. Classification of native pasture or range.

Vegetative Condition	Hydrologic Condition
Heavily Grazed – no mulch or has plant cover on <0.5 of area	Poor
Not heavily grazed – plant cover on 0.5 to 0.75 of area	Fair
Lightly grazed – plant cover on >0.75 of the area	Good

(c) Meadow is a field on which grass is continuously grown, protected from grazing, and generally mowed for hay. Drained meadows (those having a low water table) have little or no surface runoff except during storms that have a high rainfall intensity. Un-drained meadows (those having a high water table) may be so wet that they are the equivalent of water surfaces in the runoff computations of Chapter 10. If a wet meadow is drained, its soil-group classification as well as its land use and treatment class may change (see Chapter 7 regarding the change in soil classification and/or dual hydrologic soil groups).

(d) Woods and forest Woods are usually small isolated groves of trees being raised for farm or ranch use. The woods can be evaluated as shown in Table 8–3, which is based on cover effectiveness, not on timber production. The hydrologic condition is visually estimated. In areas where national or commercial forest covers a large part of a watershed, the NRCS hydrologist is guided by the letter between the U.S. Forest Service and the Soil Conservation Service dated November 8, 1954 (USDA, 1954).

Table 9-1 Runoff curve numbers for agricultural lands^{1/}

cover type	Cover description treatment ^{2/}	hydrologic condition ^{3/}	--CN for hydrologic soil group--			
			A	B	C	D
Fallow	Bare Soil	---	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
C & T + CR	Poor	65	73	79	81	
	Good	61	70	77	80	
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C & T	Poor	61	72	79	82
		Good	59	70	78	81
C & T + CR	Poor	60	71	78	81	
	Good	58	69	77	80	
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
		Poor	63	73	80	83
C & T	Good	51	67	76	80	

Table 9-1 continued on next page.
See footnotes at end of table.

Table 9-1 Runoff curve numbers for agricultural lands^{1/}— Continued

cover type	Cover description		--CN for hydrologic soil group--			
	treatment ^{2/}	hydrologic condition ^{3/}	A	B	C	D
Pasture grassland, or range- continuous forage for grazing ^{4/}		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		Good	30	58	71	78
Brush-brush-forbs-grass mixture with brush the major element ^{5/}		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	30 ^{6/}	48	65	73
Woods-grass combination (orchard or tree farm) ^{7/}		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods ^{8/}		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmstead-buildings, lanes, driveways, and surrounding lots		---	59	74	82	86
Roads (including right-of-way)						
Dirt		---	72	82	87	89
Gravel		---	76	85	89	91

^{1/} Average runoff condition, and $I_a = 0.2s$

^{2/} Crop residue cover applies only if residue is on at least 5 percent of the surface throughout the year

^{3/} Hydrologic condition is based on combinations of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good $\geq 20\%$), and (e) degree of surface toughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

For conservation tillage poor hydrologic condition, 5 to 20 percent of the surface is covered with residue (less than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

For conservation tillage good hydrologic condition, more than 20 percent of the surface is covered with residue (greater than 750 pounds per acre for row crops or 300 pounds per acre for small grain).

^{4/} Poor: < 50% ground cover or heavily grazed with no mulch.

Fair: 50 to 75% ground cover and not heavily grazed.

Good: > 75% ground cover and lightly or only occasionally grazed.

^{5/} Poor: < 50% ground cover.

Fair: 50 to 75% ground cover.

Good: > 75% ground cover.

^{6/} If actual curve number is less than 30, use CN = 30 for runoff computation.

^{7/} CNs shown were computed for areas with 50 percent woods and 50 percent grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

^{8/} Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.

Fair: Woods are grazed, but not burned, and some forest litter covers the soil.

Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Appendix B. Hydrologic Analysis of Open Lot Runoff

Assessing the runoff from open lots has historically neglected the impact of manure and/or bedding. Traditionally, NRCS guidance has recommended utilizing a Curve Number of 90 for open lots with a soil base. A Curve Number of 90 generates runoff amounts similar to that generated from a well traveled, gravel road. In 2005, Montana developed a methodology whereby the absorptive capacity of manure is considered and Curve Numbers are selected accordingly. This approach is documented in a Montana Supplement to Chapter 10 of Part 651 of the NRCS National Engineering Handbook. Following are pertinent sections from this Supplement.

Excerpts from

(210-VI-NEH-651, Amend. MT37, July 2005)

United States Department of Agriculture

Natural Resources Conservation Service

Chapter 10, Montana Supplement

RUNOFF CURVE NUMBER DETERMINATION FOR FEEDLOTS IN MONTANA

In Montana, cattle occupy most feedlots from October through April. During this time, a considerable amount of organic matter is excreted. Generally, this organic matter continues to cove the feedlot's soil during the summer months. Typically, in September when the feedlots are thoroughly dry as a result of evaporation and non-use over the summer months, they are cleaned prior to the start of the next period of occupation.

As a result of the seasonal variation of rainfall in Montana, there appears to be a potential to take advantage of the residue in the feedlot to lower the feedlot's runoff curve number during the summer months when the rainfall rates are highest, and then use a higher runoff curve number applicable to a near-fallow situation on the appropriate hydrologic soil type in the fall, when both the likelihood and amount of severe rainfall is reduced.

The period of greatest rainfall in Montana is from mid-May to mid-July. Data in the USGS Water Resources Investigations Report 98-4100, "Characteristics of Extreme Storms in Montana and Methods of Constructing Synthetic Storm Hyetographs", show that 67 percent of the extreme storms have occurred from April 16 to July 16. Only 4 percent of the extreme storms have occurred after September 15. Extreme storms are defined in this report as those storms that have a 10-year or greater return period. Similar data is presented in the seasonal analysis sections of Hydrometeorological Reports (HMR) 43, 57, and 55A.

Initial abstraction (the amount of precipitation that can fall before runoff begins) is the difference between the saturated manure water content and the early summer moisture content. The deeper the manure pack in the feedlot, the more precipitation can be held before runoff occurs. Therefore, an estimate of the initial abstraction has to be made in order to determine an appropriate runoff curve number.

Table 4-9, Page 4-11, of the AWMFH (1997) offers an alternative method of computing the amount of moisture that is lost from manure during storage. A portion of the moisture lost can obviously be re-absorbed into the manure pack before runoff occurs. Table 4-9 indicates that feedlot manure has a moisture content of 45 percent. Since Montana's heaviest and most

frequent rains occur during the period mid-May through mid-July, a moisture content of 45 percent seems reasonable early in the summer. From Table 4-8, the excreted manure has a weight of 59.1 lb/day/1,000 lb and the stored manure has a weight of 17.5 lb/day/1,000 lb. Therefore, 41.6 lb/day/1,000 lb of moisture is lost in long-term storage. In addition, the feedlot manure shows an increase in total solids (wasted feed, bedding, trampled dirt, etc.), of 2.82 lb/day/1,000 lb, which is included in the long-term storage weight, which needs to be accounted for in the moisture weight loss. The total change of moisture to be used is 44.42 lb/day/1,000 lb. For the 212-day storage period, 9,417 pounds of moisture (150.9 cubic feet) is lost from the manure pack. This amounts to a depth of 4.5 inches on the 400 square foot area. The NRCS curve number methodology (see NRCS, NEH, Part 630, Chapter 10, Estimation of Direct Runoff from Storm Rainfall) is based on the initial abstraction being 20 percent of the total storage. It is assumed that the soil in the feedlot is sealed by bacterial and that little to no infiltration occurs into the underlying soil. The total storage is all within the manure pack and is the computed 4.5-inch moisture loss. The initial abstraction is $(0.2)(4.5 \text{ inches}) = 0.9 \text{ inches}$. In the Engineering Field Manual (EFM), Chapter 2, Page 2-89, Table 2.4, shows that the Curve Number (CN) that goes with an initial abstraction of 0.9 inches is 69. In this example a CN of 69 would be used during the summer months, provided that the cooperator managed the feedlot to ensure the conditions stated.

Following is an outline of the process used to determine the appropriate CN.

Moisture Lost in long-term feedlot storage:

Required data:

- Moisture Lost (pounds/day/1,000 pound animal)
- Number of days held in confinement
- Average weight of animals held (pounds)
- Space provided per animal (feet²)

Moisture Lost in inches:

$$= \frac{(\text{Moisture Lost, lb./day/1,000 lb}) \times (\text{No. of days}) \times (\text{Avg wt animals, lbs}) \times (12 \text{ in/ft})}{(\text{Stocking density, ft}^2/\text{animal}) \times (\text{Density of water, lb/ft}^3)}$$

Initial abstraction:

Storage, S = Moisture Lost, inches

Ia = 0.20 x Moisture Lost, inches

In MontFARM, the above procedure is utilized to compute the Initial Abstraction on a monthly basis for the accumulated manure pack. As described in the User Guide, the initial abstraction is adjusted for the background moisture content of the manure. Manure packs with animals in the lot are assumed to have a background moisture content of 60%. Manure packs that are sitting in the lot after the animals have left, ie., no animals in the lot, are assumed to have background concentration of 37%. In computing the initial abstraction, manure is allowed to wet back up to a moisture content of 81%. The values used in MontFARM for manure moisture holding capacity are shown in Table B1.

Table B1. Moisture-holding capacity of manure on feedlot.

Animal	Moist Manure Animals in the Lot (60% moisture) lb/d/1,000 lbs.	Dry Manure Empty (37% moisture) lb/d/1,000 lbs.
Beef Animal	38.9	48.9
Dairy Animal	23.9	32.6
Horse	29	37.8
Sheep	12	23
Other	38	48

Curve Numbers are selected for each month depending on the computed initial abstraction value. The extent to which the absorptive ability of the manure is considered is limited. N.A. Cole, in “Chemical Composition of Pen Surface Layers of Beef Cattle Feedyards” cited that manure packs develop three layers: a top loose layer, a middle, compacted dry layer, and a wet, compacted, lower layer. The depths of these layers varied but both T.E. Norton in “Cattle Feedlot Water Quality Hydrology” and L.L. Mink in “The Selection and Management of Feedlot Sites and Land Disposal of Animal Waste in Boise Valley, Idaho” noted that rain infiltrated 2 to 4 inches into the manure pack.

Limiting the initial abstraction to the top 3 inches of the manure pack and utilizing a water-holding capacity of 0.4 inches per inch of manure (Keeton, 1970, SCS Technical Note, Utah), generates a maximum allowable initial abstraction of 1.2 inches. This value represents a Curve Number of 62. Conditions are assumed to be dry as the manure moisture content was 7% to 38% in the Keeton study. During the winter and spring, manure within the lot is expected to have a fair amount of moisture, especially if cattle are in the lot. When cattle are in the lot, Curve Numbers are limited to a minimum value of 80. This represents a holding capacity 0.17 inches of moisture per inch manure which is supported by the work of L.L Mink.

Ultimately, the Curve Number is averaged for the various sub-lots and seasons. This value along with the precipitation amount are the driving variables for determining the volume of runoff for a given precipitation event (see NRCS, NEH, Part 630, Chapter 10, Estimation of Direct Runoff from Storm Rainfall).

References

- Cole, N.A., A.M. Mason, R.W. Todd, M Rhoades, and D.B. Parker. 2009. Chemical Composition of Pen Surface Layers of Beef Cattle Feedyards, *Professional Animal Scientist* 25(2009):541-552.
- Mankin, K.R., P.L. Barnes, J.P. Harner, P.K. Kalita, and J.E. Boyer. 2006. Field evaluation of vegetative filter effectiveness and runoff quality from unstocked feedlots. *Journal of Soil and Water Conservation*, 61(4):209-217.
- Mink, L.L., C.M. Gilmour, S.M. Beck, J.H. Milligan, and R.L. Braun. 1976. The Selection and Management of Feedlot Sites and Land Disposal of Animal Waste in Boise Valley, Idaho, *Groundwater*, Vol. 14, No. 6, Nov-Dec, 1976.
- Norton, T.E., R.W. Hansen. Book 1969. Cattle Feedlot Water Quality Hydrology. Colorado State University, Dept. of Agricultural Engineering, 1969. OCLC Number: 463318449, Series Title: AEP, 68/69-22.
- NRCS. January, 2009. National Engineering Handbook, Part 630, Hydrology, Chapter 7, Hydrologic Soil Groups.
- NRCS. December 2002. National Engineering Handbook, Part 630, Hydrology, Chapter 8, Land Use and Treatment Classes.
- NRCS. July 2004. National Engineering Handbook, Part 630, Hydrology, Chapter 9, Hydrologic Soil-Cover Complexes.
- NRCS. July 2004. National Engineering Handbook, Part 630, Hydrology, Chapter 10, Estimation of Direct Runoff from Storm Rainfall.
- NRCS. March 2008. National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, Chapter 4, Agricultural Waste Characteristics.
- NRCS. July 2005. National Engineering Handbook, Part 651, Agricultural Waste Management Field Handbook, Chapter 10, Montana Supplement, Runoff Curve Number Determination for Feedlots in Montana. 210-VI-NEH-651, Amend. MT37, July 2005.
- Soil Conservation Service. 1982. Technical Notes, Utah, Environment – Animal Waste, June, 1982.
- Suplee, Michael, V. Watson, A.Varghese, and J. Cleland, 2008. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana’s Wadeable Streams and Rivers. Prepared for Montana Department of Environmental Quality.
- Thompson, D. B., T. L. Loudon and J. B. Gerrish. 1978. Winter and spring runoff from manure application plots. ASAE Paper No. 78-2032. St. Joseph, Mich.: ASAE.
- Schmidt, D. and B. Wilson. 2008. Minnesota Feedlot Annualized Runoff Model (MinnFARM), Users Guide, Version 2.1, Department of Bioproducts and Biosystems Engineering, University of Minnesota, October, 2008.
- Schmidt, D. and B. Wilson. 2008. Minnesota Feedlot Annualized Runoff Model (MinnFARM), Technical Documentation, Department of Bioproducts and Biosystems Engineering, University of Minnesota, October, 2008.
- Young, R.A., M.A. Otterby, and A. Roos. 1982. An Evaluation System to Rate Feedlot Pollution Potential. *Agricultural Reviews and Manuals*, ARM-NC-17.