Runoff Curve Number Determination for Feedlots in Montana

Natural Resources Conservation Service (NRCS), Conservation Practice Standard, Waste Storage Facility (313), requires that the design storage volume be large enough to contain: (1) the normal runoff from the facility's drainage area during the storage period; and (2) the 25-year, 24-hour runoff from the facility's drainage area.

The subject of much discussion in determining the amount of 25-year, 24-hour runoff is what Runoff Curve Number (RCN) should be used. The Agricultural Waste Management Field Handbook (AWMFH) on Page 10C-1, states that a paved feedlot typically has a RCN of about 97 and an unpaved feedlot has a RCN of about 90. There is no discussion as to how these curve numbers were derived. These numbers are typical of what one would select for a fallow area with a poor amount of crop residue on a C or D hydrologic soil (see Engineering Field Manual, Page 2-85, Table 2-3a). However, several engineers have witnessed rainfalls of up to 1.5 inches in a short period of time on a feedlot with a manure pack of 2 to 4 inches, without any runoff occurring. Therefore, a method of computing a more realistic curve number for the situation where there is a manure pack is needed.

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 cover 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 RCN during the summer months when the rainfall rates are highest, and then use a higher RCN 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. This methodology is dependent on there being an Operation and Maintenance (O&M) Plan that the cooperator agrees to follow to ensure that there is sufficient residue left in the feedlot during the critical rain producing months to allow using the lower runoff curve number.

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", shows 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 Hydro-meteorological Reports (HMR) 43, 57, and 55A. HMR 57 allows the user to adjust the Probable Maximum Precipitation (PMP) storm estimates on a seasonal basis. It shows that for the northwest portion of the state, an adjustment in the range of 80 to 85 percent of the all-season PMP amount can be made for September storms. October adjustments are 65 to 85 percent. HMR 43 gives the following seasonal variation (see next page).

Date	Central Montana	NW Montana
August 1	0.86	0.89
Sept. 1	0.74	0.79
October 1	0.58	0.66

Data from USGS Report 98-4100 indicates that the maximum precipitation recorded from mid-July to mid-August is 82 percent of the mid-May to mid-June maximum, and for mid-August to mid-September it is 58 percent. All of this data is in agreement that the likelihood of severe rainfall is greatly diminished during the fall.

The 25-year, 24-hour rainfall shown in NOAA Atlas II (see Page 13), is based on data for the entire year. The remainder of that paragraph addresses the applicability of performing seasonal adjustments, but then states that there is no convenient manner of applying the knowledge of seasonal adjustments. It appears reasonable, based on the data presented in the previous paragraphs, that the adjustments that can be made to the 25-year, 24-hour rainfall amount from NOAA Atlas II are those shown from HMR 43. Areas east of the Continental Divide should use the adjustments shown for Central Montana, while areas west of the Continental Divide should use the NW Montana adjustments.

The 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.

As an example, the Montana NRCS recommended feedlot stocking rate is about 400 sq.ft. per animal. However, the stocking rate varies considerably. If one assumes that the average beef cattle weight during confinement in the feedlot is 1,000 pounds, and that 0.95 cu.ft. of manure at a moisture content of 88.4 percent is excreted each day (11.6 percent total solids) for the seven month period of October through April (see AWMFH, Page 4-10, Table 4-8), the total weight of solids excreted in the 212-day period on 400 sq.ft. is (59.1 lb./day/1000#)(212 days)(0.116) = 1,453 pounds or 3.63 lb./sq.ft. and amounts to an equivalent residue rate of 79 tons per acre. Based on bagged steer manure having a weight of 23 pounds per cubic foot, this amounts to a fine-textured depth of dry solids of about 1.9 inches. The actual depth is likely to be greater due to air voids and unconsolidated matter within the manure pack. Unfortunately, the amount of voids and potential water storage cannot be readily calculated. Organic soils have water-holding capacities as high as 0.7 inch per inch. Therefore, 1.9 inches of manure could hold 1.3 inches of water, perhaps even more, before runoff begins.

Table 4-9, Page 4-11, of the AWMFH 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/1000# and the stored manure has a weight of 17.5 lb./day/1000#. Therefore, 41.6 lb./day/1000# 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/1000#, 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/1000#. For the 212-day storage period, 9,417 pounds of moisture (150.9 cu.ft.) is lost from the manure pack. This amounts to a depth of 4.5 inches on the 400 sq.ft. area. The NRCS curve number methodology (see National Engineering Handbook, Section 4, Chapter 10) 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 action 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 inches) = 0.9 inches. In the Engineering Field Manual (EFM), 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.

Example of runoff calculations:

Given: A beef feedlot in Central Montana with a stocking rate of 200 sq.ft. per animal. The feedlot is occupied from October through April with an average animal weight of 800 pounds. The 25-year, 24-hour rainfall is 2.6 inches. The feedlot is cleaned in mid- to late September. The feedlot is on a "C" hydrologic soil.

Determine the amount of manure moisture lost in long-term storage:

$$\text{Moisture loss} = \frac{(44.42 \text{ lb./day/1000\#})(212 \text{ days})(800\#/200 \text{ sq.ft.})}{62.4 \text{ lb./cu.ft.}} = 0.60 \text{ feet} = 7.24 \text{ in.}$$

Determine the initial abstraction:

$I_a = (7.24 \text{ inches})(0.2) = 1.45 \text{ inches}$

Determine the RCN:

From EFM, Page 2-89, Table 2.4, CN = 58

Determine the runoff amount to be used for this feedlot:

Use EFM, Page 2-40, Figure 2-26; EFM, Page 2-84, Table 2-2; or Technical Release (TR) 16 to determine runoff.

Summer precipitation = 2.6 inches, CN = 58, R.O.= 0.16 inches

Mid-September precipitation for Central Montana is 65 percent of the total season precipitation. See previous table from HMR 43.

September precipitation = (2.6 inches)(0.65) = 1.7 inches, CN = 90, R.O. = 0.84 inches.

In this case, the runoff from a September precipitation event on a cleaned feedlot (0.84 inches) is the greatest amount and is the amount that should be used in the design of the waste storage facility.

If the CN for the summer precipitation had been 69, as was computed for a feedlot with a stocking rate of 400 sq.ft. per animal, the runoff would have been 0.47 inches and the September runoff amount of 0.84 inches would still be the worst case scenario. In this case, the cooperator may choose to leave several inches of residue in the feedlot when it is cleaned, rather than scraping it down to bare earth, and get some relief from the fall storm runoff.

For September rains, a conservative estimate for dried manure would be that it can hold 0.4 inch of rain per inch of dried manure. Leaving 2 inches of dried manure would therefore have an initial abstraction of 0.8 inch and a resulting CN of 72 with 0.58 inches of runoff from a 2.6-inch rainfall. Using a CN of 90 and a rainfall of 2.6 inches, the runoff would be 1.62 inches. **Therefore, if the cooperator is willing to manage the timing and amount of cleaning done on the feedlot, a significant reduction in the volume of runoff that needs to be incorporated into the design of the facility can be achieved.**

In all cases, the CN should be representative of how the residue will be managed. For a cleaned feedlot, the runoff curve number should never come from the "A" hydrologic soil group. The use of an "A" hydrologic group is unreasonable due to the amount of organic matter that gets trampled into the subsoil and the bacterial sealing that takes place. **The design runoff amount should be based on having at least 10 percent of the feedlot area with a curve number of 90 (or appropriate fallow/bare soil hydrologic soil group curve number) to account for areas that will have minimal manure pack including; alleyways, roads, and non-uniform distribution of manure.**

COMPUTATION SHEET
NRCS-ENG-523A Rev. 10-97

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		***PROJECT*** EXAMPLE: Ag Waste Runoff		
BY M. Yerger	***DATE*** 6-1-05	***CHECKED BY***	***DATE***	***JOB NO.***
SUBJECT				***SHEET*** 1 ***of*** 1

Check amount of rainfall that can be absorbed by manure accumulation.

Total weight excreted = 59.10 lb./day/1000#

59.10 lb./day(212 days) = 12,529.2 lbs.

Weight of water = 12,529.2 lbs.(0.884) = 11,075.8 lbs.

Weight of Solids = 12,529.2 lbs.(0.116) = 1,453.4 lbs.

Find Weight of water when material is 45 percent moisture wet basis:

$$\frac{W_T}{W_T} = \frac{W_S}{W_T} + \frac{W_W}{W_T}$$

$$1 = \frac{W_S}{W_T} + W\%_{WB}$$

$$W_T(1 - W\%_{WB}) = \frac{W_S}{\cancel{W_T}}\cancel{W_T}$$

$$W_T = \frac{W_S}{1 - W\%_{WB}}$$

$$W_T = \frac{1453.4}{1 - 0.45}$$

$$W_T = 2642.5$$

Check: $\frac{W_S}{W_T} = \frac{1453.4}{2642.5} = 0.55$ ✓ ok ✓

$W_W = W_T - W_S$

$W_W = 2642.5 - 1453.4$

$W_W = 1189.1$ lbs.

Weight of water at 88.4% moisture is 11,075.8 lb.
Weight of water at 45.0% moisture is 1,189.1 lb.
Weight of water lost 9,886.7 lb.

$$\text{Volume} = \frac{9886.7\ \cancel{\text{lb.}}}{62.4\ \cancel{\text{lb.}}}(\text{ft.}^3) = 158.4\ \text{ft.}^3$$

$$\text{Depth} = \frac{158.44\ \text{ft.}^3}{400\ \text{ft}^2} = 0.396\ \cancel{\text{ft.}} \times \frac{12\ \text{in.}}{\cancel{\text{ft.}}} = 4.75\ \text{in.}$$

COMPUTATION SHEET
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U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		***PROJECT*** EXAMPLE: Ag Waste Runoff		
BY M. Yerger	***DATE*** 6-8-05	***CHECKED BY***	***DATE***	***JOB NO.***
SUBJECT				***SHEET*** 1 ***of*** 1

Notes from discussion with David Jones, retired NRCS Environmental Engineer.

1. Manure Density

   a) Air dried, scraped from lot 32 lb./ft.^{3}

   b) Mounded, consolidated, moist 40 lb./ft.^{3}

   c) Manure will have higher density than commercially available composted steer manure. Composted manure has had bulking agents (straw or wood chips) added. Large pieces of straw or wood chips get screened back out, but small pieces are still there resulting in lower density.

   d) There is a fair amount of shrinkage (40%) between as excreted and feedlot conditions.

      Excreted Feedlot

      $0.95 \frac{ft.^3/day}{1000\ lb.}(0.60) = 0.57 \frac{ft.^3/day}{1000\ lb.}$ for rough estimate

2. Runoff Observations

   a) For Slopes 4% - 8%:

      First 0.5 in. of rain produces no runoff
      Second 0.5 in. of rain starts to produce runoff.

   b) Beef Feedlots:

      Annual precipitation < 15 inches yields minimal runoff
      Annual precipitation > 15 inches to produce measurable runoff.

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		Example Ag Waste Project		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	7/6/2005	RWB	7/12/2005	
SUBJECT				SHEET__1__ OF__2__
Summary of Design Conditions				

The Example Ag Waste project is a beef operation located just north of Choteau, Montana. The total area of the feedlot including roads, alleys, buildings, and pens is 33.6 acres. The pen area is 27.6 acres. The system was originally designed with a curve number of 90 over the whole area. Collection basins located at the lower end of the pen areas collect the runoff and then deliver it to a central storage pond. The pond will be lined with 45 mil EPDM. Average annual rainfall for this area is 12.9 inches. The average yearly evaporation is 40.2 inches. The pond is designed as an evaporation pond.

The following is a summary of the design conditions considered for the Example Ag Waste Project. The 25-year, 24-hour storm for this area is 3 inches.

Condition 1: *The original design considered a runoff curve number of 90 over the whole feedlot. The following components were included to determine the pond size.*

Normal runoff minus evaporation		*29,941*	*cu. ft.*
25-year, 24-hour runoff from feedlot		*242,626*	*cu. ft.*
25-year, 24-hour storm of 3" on pond		*20,219*	*cu. ft.*
Residual solids - 0.25 feet		*20,219*	*cu. ft.*
	Total	***313,005***	*cu. ft.*
Pond Size	*150 feet by 540 feet*		

Condition 2: *Summer condition, 25-year, 24-hour storm of 3 inches.*
1000 head of bull calves at 1000 lb. avg. (9/15 to 6/1)
1500 head of steer and heifer calves at 1000 lb. avg. (9/15 to 7/15)
2500 head of yearling steers and heifers at 1200 lb. avg., year round cycle (150 day)

Bull calf area (5.37 acres with RCN of 52)	*2740*	*cu. ft.*
Steer and heifer calf area (8.05 acres with RCN of 48)	*1950*	*cu. ft.*
Yearling steer and heifer area (13.4 acres with RCN 61)	*18000*	*cu. ft.*
Sick and sorting area (0.75 acres with runoff = 0.137 in.)	*375*	*cu. ft.*
Alley area with manure (1.35 acres with runoff = 0.137 in.)	*670*	*cu. ft.*
Hard road area(4.65 acres with RCN of 90)	*33420*	*cu. ft.*
25-year, 24-hour storm of 3 inches on pond (100 by 250)	*6250*	*cu. ft.*
	63405	*cu. ft.*
Adding 6 inches for sediment will require a pond	***75905***	*cu. ft.*

Condition 3, Fall condition yielded higher runoff values. Pond size based on that.

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		Example Ag Waste Project		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	7/6/2005			
SUBJECT				
Summary of Design Conditions				SHEET__2__ OF__2__

Condition 3: *Fall condition after half the pens are cleaned. 25 year-24-hour storm of 2 inches. (seasonal reduction)*
2500 head of yearling steers and heifers at 1200 lb avg., year round cycle (150 day)
A weighted RCN of 55 was used for half of the pen area. (various stages of cleaning)
The other half is assumed cleaned with a RCN of 85.

Half pen (13.8 acres with RCN of 55)	*1002*	*cu. ft.*
Half pen (13.8 acres with RCN of 85)	*40090*	*cu. ft.*
Alley area with manure (0.675 acres with RCN 60)	*147*	*cu. ft.*
Alley area with manure (0.675 acres with RCN 85)	*1960*	*cu. ft.*
Hard road area (4.65 acres with RCN of 90)	*18400*	*cu. ft.*
25 year, 24-hour storm of 2 inches on pond (100 by 250)	*4167*	*cu. ft.*
	65766	*cu. ft.*
Adding 6 inches for sediment will require a pond	***78266***	*cu. ft.*

Pond Size *100 feet by 250 feet and 3-foot depth*

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U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT Curve Number and Runoff				***SHEET*** 1 ***of*** _____

From Ag Waste Questionnaire submitted by landowner and on-site meeting June 21, 2005, with NRCS staff:

Bull calves, 1000 head at 1000 lb. average (9/15 – 6/1 +/- 255 day)
Steer and heifer calves, 1500 head at 1000 lb. average (9/15 – 7/15 +/- 300 day)
Yearling steers and heifers, 2500 head at 1200 lb. average (year round, 150-day cycle)

Areas

1. North Pen	3.96 Acres		172498	Ft^2
2. D Pens	(600 x 205) +	(612 x 203)	247236	Ft^2
3. C Pens	(600 x 210) +	(610 x 206)	251660	Ft^2
4. B Pens	(600 x 203) +	(610 x 203)	245630	Ft^2
5. A Pens	(600 x 210) +	(610 x 208)	252880	Ft^2
Sick Pen		(410 x 80)	32800	Ft^2
→		27.6 Acres	1202704	Ft^2

Average stocking rate (for whole pen area)

$\frac{1202704\ Ft^2}{5000\ Animals}$ = 240 Ft^2/Animal ←

Sick pen area not as high of stocking rate. Average stocking rate without sick pen.

$\frac{1202704\ Ft^2 - 32800\ Ft^2}{5000\ Animals}$ = 234 Ft^2/Animal ←
(not significant: use 240 Ft^2/Animal)

Total Road/Alley Area		6.0 Acres
Alley Area with Manure		1.35 Acres 58806 Ft^2
Hard Road Area	RCN = 90	4.65 Acres 202554 Ft^2

25-year, 24-hour storm for feedlot = 3.0 inches

Hydrologic Soils Group for Both Crago and Niart (From NRCS Soil Survey) B

Residue Cover – Fair to Poor after Cleaning
EFM, Page 2-85, Tables 2-3a RCN = 85

Appears reasonable after site investigation on June 21, 2005.

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STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT RCN and Runoff Determination				***SHEET*** 2 ***of*** _____

Agricultural Waste Management Field Handbook, Part 651, Chapter 4, Waste Characteristics

Table 4-8	Excreted Manure Weight	59.1 lb./day/1000 lb.
Table 4-9	Minus Stored Manure Weight	– 17.5 lb./day/1000 lb.
	Moisture Lost in Long-Term Storage	= 41.6 lb./day/1000 lb.
	(Increase in Solids via Bedding/Feed Waste)	
	(9.6 lb./day/1000 lb. – 6.78 lb./day/1000 lb.)	+ 2.8 lb./day/1000 lb.
	Total Moisture Change ⟶	44.4 lb./day/1000 lb.

∴ Case 2: Summer Condition, 25-Year, 24-Hour = 3.0 inches

Bull Calf Area – 1000 head, 1000 lb. average, 255 day (9/15 – 6/1)
use from Page 1, 240 Ft^2/Animal.

Moisture from Manure = 44.4 lb./day/1000 lb. x 255 day = 11322 lb./1000 lb.

Storage $S = \frac{11322 \text{ lb.}}{1000 \text{ lb.}} \frac{1000 \text{ lb.}}{240 \text{ Ft}^2} \frac{\text{Ft}^3}{62.4 \text{ lb. Ft.}} \frac{12 \text{ inches}}{} = 9.07$ inches

Initial Abstraction Ia = 0.2S = 0.2 (9.07 inches) = 1.81 inches

From EFM, Page 2-89, Table 2.4 RCN = 52

$$\text{Runoff} = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(3 - 0.2(9.07 \text{ inches}))^2}{3 + 0.8(9.07 \text{ inches})} = 0.137 \text{ in.}$$

∴ Runoff Volume for Bull Calf Area

1000 head x 240 Ft^2/head = 240,000 Ft^2

$$\frac{0.137 \text{ in.}(240{,}000 \text{ Ft}^2)}{12 \text{ in./Ft.}} = 2740 \text{ Ft}^3$$

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STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT RCN and Runoff Determination				***SHEET*** 3 ***of*** _____

Cont. - Case 2: Summer Condition, 25-Year, 24-Hour = 3.0 inches

Steer and Heifer Calf Area – 1500 head, 1000 lb. average, 300 day (9/15 – 7/15)

Use from Page 1: 240 Ft^2/Animal

Moisture from Manure = 44.4 lb./day/1000 lb. x 300 day = 13320 lb./1000 lb.

$$\text{Storage S} = \frac{13320 \text{ lb.}}{1000 \text{ lb.}} \frac{1000 \text{ lb.}}{240 \text{ Ft}^2} \frac{\text{Ft}^3}{62.4 \text{ lb. Ft.}} \frac{12 \text{ in.}}{} = 10.67 \text{ in.}$$

Initial Abstraction Ia = 0.2S = 0.2(10.67 in.) = 2.13”

From EFM, Page 2-89, Table 2.4, RCN = 48

$$\text{Runoff} = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(3 - 0.2(10.67 \text{ in.}))^2}{3 + 0.8(10.67 \text{ in.})} = 0.065 \text{ in.}$$

$\therefore$ Runoff Volume for Steer and Heifer/Calf Area

$$\frac{1500 \text{ head} \times 240 \text{ Ft}^2}{\text{head}} = 360,000 \text{ Ft}^2$$

$$\frac{0.065 \text{ in.} \times 360000 \text{ Ft}^2}{12 \text{ in./Ft.}} = 1,950 \text{ Ft}^3$$

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SUBJECT RCN and Runoff Determination				***SHEET*** 4 ***of*** _____

Cont. - Case 2: Summer Condition, 25-Year, 24-Hour = 3.0 inches

Yearling Steer and Heifer Area – 2500 head @ 1200 lb. average, 150-day rotation

Use from Page 1: 240 Ft^2/Animal

Moisture from Manure = 44.4 lb./day/1000 lb. x 150 day = 6660 lb./1000 lb.

These animals occupy the feedlot the whole year. However, they are rotated through every 150 days.

But conservatively:

$$\text{Storage S} = \frac{6660 \text{ lb.} \quad 1200 \text{ lb.} \quad Ft^3 \quad 12 \text{ in.}}{1000 \text{ lb.} \quad 240\ Ft^2 \quad 62.4 \text{ lb.} \quad Ft.} = 6.4 \text{ in.}$$

For the whole year (some pens may have this)

$$\text{Storage S} = \frac{44.4 \text{ lb.} \quad 365 \text{ day} \quad 1200 \text{ lb.} \quad Ft^3 \quad 12 \text{ in.}}{\text{day} \quad 1000 \text{ lb.} \quad 240\ Ft^2 \quad 62.4 \text{ lb.} \quad Ft.} = 15.58 \text{ in.}$$

Ia(150 day) = 0.2S = 0.2(6.4 in.) = 1.28 in.

Ia(365 day) = 0.2S = 0.2(15.58) = 3.1 in.

From EFM, Page 2-89, Table 2.4, RCN = 61 (150 day)

RCN = 40 (365 day)

$$\text{Runoff(150)} = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(3 - 0.2(6.4 \text{ in.}))^2}{3 + 0.8(6.4 \text{ in.})} = 0.36 \text{ in.}$$

$$\text{Runoff(365)} = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(3 - 0.2(15.58 \text{ in.}))^2}{3 + 0.8(15.58 \text{ in.})} = 0$$

$$\text{Runoff Volume(150)} = \frac{0.36 \text{ in. x } (2500 \text{ head x } 240\ Ft^2)}{12 \text{ in./Ft.} \quad \text{head}} = 18000\ Ft^3$$

Obviously, this is conservative.

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SUBJECT RCN and Runoff Determination				***SHEET*** 5 ***of*** _____

Cont. - Case 2: Summer Condition, 25-Year, 24-Hour = 3.0 inches

Sick and Sorting Area – This area is basically the same as bull/calf and heifer/calf areas.

This area is 410 Ft. x 80 Ft. = 32,800 Ft^2

Page 2, using storage S = 9.07 in.

Ia = 1.81 in.

Runoff = 0.137 in.

Runoff Volume = $\frac{0.137 \text{ in. x } (32800 \text{ Ft}^2)}{12 \text{ in./Ft.}}$ = 375 Ft^3

Alley Area with Manure – This area between pens and windbreaks is also similar to bull/calf and steer/heifer calf area with manure.

From Page 1, measured 58806 Ft^2

Storage S = 9.07 in.

Ia = 1.81 in.

Runoff = 0.137 in.

Runoff Volume = $\frac{0.137 \text{ in. x } (58806 \text{ Ft}^2)}{12 \text{ in./Ft.}}$ = 670 Ft^3

Hard Road Area – Area = 202554 Ft^2

Precipitation = 3.0 in. CN = 90

EFM, Page 2-84, Table 2.2, Read Runoff = 1.98 in.

Runoff Volume = $\frac{1.98 \text{ in. x } (202554 \text{ Ft}^2)}{12 \text{ in./Ft.}}$ = 33420 Ft^3

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STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT RCN and Runoff Determination				***SHEET*** 6 ***of*** _____

Cont. - Case 2: Summer Condition, 25-Year, 24-Hour = 3.0 inches

Summary:

Location	Area Ft^2	Runoff Volume Ft^3
Bull Calf Area	234000	2740
Steer Heifer Calf	351000	1950
Yearling Steer and Heifer	585000	18000
Sick and Sorting Area	32800	375
Alley with Manure	58806	670
Hard Road	202554	33420
Total	1464160	57155 Ft^3

33.6 Acres ✓

25-Year, 24-Hour Storm of 3.0 inches on 100 Ft. x 250 Ft. = 6250 Ft^3

63405 Ft^3

Add 6-inch depth for sediment +/- 12500 Ft^3

Total 75905 Ft^3

COMPUTATION SHEET
NRCS-ENG-523A Rev. 10-97

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT RCN and Runoff Determination				***SHEET*** 7 ***of*** _____

From Page 1

Average Stocking Rate = 240 Ft^2/Animal

Total Pen Area	1202704 Ft^2
Alley with Manure	58806 Ft^2
Hard Road Area with RCN = 90	202554 Ft^2
33.61 Acre =	1464064 Ft^2

25-Year, 24-Hour Storm = 3.0 inches

Hydrologic Soils Group B, RCN = 85

From Page 2, Total Manure Moisture Change = 44.4 lb./day/1000 lb.

Case 3: Fall After Pens Are Cleaned.

USGS Water Resources Investigation Report 98-4100 shows 67 percent of the extreme storms occurred April to July. HMR 57 allows reductions of PMP on a seasonal basis.

$$\left[\left(\frac{0.74 + 0.58}{2} = 0.66 \right) \right]$$

For September 15 or later use 66 percent of 25-Year, 24-Hour = 1.98 in. ←

Curve numbers for the fall condition:

First of all it is ultra-conservative to design for the case: 33.6 acres are cleaned September 15 to October 1. It is reasonable to design for the case where half of the feedlot is cleaned to bare ground, (not recommended anyway) and half remains with curve numbers from the summer condition. The yearling steers are in the feedlot continuously. 150-day cycle.

RCN for bare soil (hydrologic soils B) = 85

	CN	Area	Product
Bull Calf Area	52	5.37 Acres	279.2
Steer and Heifer Calf	48	8.05	386.4
Yearlings	61	13.4	817.4
Sick and Sorting SAY	50	0.75	37.6
		27.6	1520.6

Weighted Curve Number = 1520.6/27.6 = 55

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		Example Ag Waste Project		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	6/27/2005			
SUBJECT				SHEET 8 OF
RCN and Runoff Volumes for Fall Condition				

Case 3 Continued, Fall condition: 25 Year 24 Hour = 1.98 in. (Seasonal Variation in the Fall)
Use 2.0 in.

Ref. Table 2-2 p. 2-84 EFM (For Runoff)

Location	RCN	Area (Ft^2)	Runoff (in)	Runoff Volume (Ft^3)
1. Half Pen	55	601352	0.02	1002.3
2. Half Pen	85	601352	0.8	40090.1
Alley w/ manure	60*	29403	0.06	147.0
Alley Cleaned	85	29403	0.8	1960.2
Roads	90	202554	1.09	18398.7
		1464064		**61598**

** Used Runoff Curve Number of 60 for Yearlings. (See page 4)*

Note: For Location 1, Half Pen:
An RCN of 60 for the Yearling Steers (Year Round) would yield about 3000 ft^3 of runoff. Not a major factor in the overall total, particularly since the pens will be at varying degrees of cleaning.

However keep this in mind when selecting final pond size.

COMPUTATION SHEET
NRCS-ENG-523A Rev. 10-97

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE Montana		***PROJECT*** EXAMPLE: Ag Waste		
BY Baker	***DATE*** 6/05	***CHECKED BY*** RWB	***DATE*** 7/05	***JOB NO.***
SUBJECT Evaporation Pond Sizing				***SHEET*** 9 ***of*** _____

Runoff volume for Case 1
Summer Condition, 25-Year, 24-Hour = 3.0 inches
RCN of 90 on everything — 242646 Ft^3

Runoff volume for Case 2
Summer Condition, 25-Year, 24-Hour = 3.0 inches
RCN's based on stocking rates — 57155 Ft^3

Runoff volume for Case 3
Fall Condition, 25-Year, 24-Hour = 2.0 inches
Half of feedlot cleaned
Half of feedlot RCN's based
on stocking rates → 61600 Ft^3

$\therefore$ Choose for Design Case 3
but add storage for 2.0-inch rainfall.
25-Year, 24-Hour, 2.0 inches or 0.167 Ft.
on 100 Ft. x 250 Ft. — 4167 Ft^3

Storage capacity required → 65767 Ft^3
without sediment considerations

Sediment: The collection basins located below the feedlot pens will collect the sediment in the runoff. A site investigation, however showed manure up to 15 inches deep collected outside of the feedlot. This was likely due to wind erosion from manure piles located on the east edge of the feedlot. It is unknown how many years this had been going on, but at least five. Three to four inches of depth per year would fit measured field depths.

For two-year cleanout:

Add 6-inch depth for sediment and safety using
estimated 100 Ft. x 250 Ft. x 6 inches $\approx$ — 12500 Ft^3

Look for total capacity of about — 78300 Ft^3

Determine pond that will contain $\approx$ — 66000 Ft^3
then add 6-inch depth.

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		Example Ag Waste Project		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	6/27/2005	RWB	7/05	
SUBJECT				SHEET 10 OF
Storage Pond Volumes - Final Design				

1}	2.5	TL=	265	Bottom Elevation =	4039.00
2}	2.5	TW=	115		
3}	2.5	BL=	250		
4}	2.5	BW=	100		
		ES1=	3		
SUM	10	ES2=	3		
		SS1=	3		
		SS2=	3		
5}	2.5				
6}	2.5	HW=	2.5		
7}	2.5	B1=	30475		
8}	2.5	MM=	27681.25		
9}	2.5	B2=	25000		
10}	2.5				
11}	2.5				
12}	2.5		2564.81	Cubic Yards	69250 Cubic Feet
SUM	20		1.59	Acre Feet	
13}	2.5				
14}	2.5				
15}	2.5				
16}	2.5				
17}	2.5				
SUM	12.5				

This pond size meets the requirement of 66,000 cubic feet for Condition 3. In fact it is large enough to handle the runoff for the yearling steers with a RCN of 60.

The depth of the pond will be deepened to three feet to account for sediment.

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		*Example Ag Waste Project*		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	*6/27/2005*			
SUBJECT				SHEET 11 OF
Storage Pond Volumes - Final Design				

1}	3	TL=	268	*Bottom Elevation* =	*4039.00*
2}	3	TW=	118		
3}	3	BL=	250		
4}	3	BW=	100		
		ES1=	3		
SUM	12	ES2=	3		
		SS1=	3		
		SS2=	3		
5}	3				
6}	3	HW=	3		
7}	3	B1=	31624		
8}	3	MM=	28231		
9}	3	B2=	25000		
10}	3				
11}	3				
12}	3		3139.78	Cubic Yards	84774 Cubic Feet
SUM	24		1.95	Acre Feet	
13}	3				
14}	3				
15}	3				
16}	3				
17}	3				
SUM	15				

Capacity of 100 Ft. x 250 Ft. pond with 3’ depth.

Excel Spreadsheet

U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

STATE		PROJECT		
Montana		Example Ag Waste Project		
BY	DATE	CHECKED BY	DATE	JOB NO.
BAKER	6/28/2005			
SUBJECT				SHEET 12 OF
Storage Pond Evaporation and Pond Size				

Minimum Pond Volume Required : ***66000 cu ft***

Pond	W	L	d	Volume (pitcalc)	Surface Area Ft^2
A	100	200	3	68424	20000
B	100	225	2.75	69498	22500
C	100	250	2.5	69250	25000
D	100	275	2.3	69347	27500
E	100	300	2.1	68403	30000

Month	Ave. Precip. in.	Ave. Evap in.	Evap ft.	Evap Pond A Ft^3	Evap Pond B Ft^3	Evap Pond C Ft^3	Evap Pond D Ft^3	Evap Pond E Ft^3
Jan	0.55	0.61	0.051	1016.7	1143.8	1270.8	1397.9	1525.0
Feb	0.46	0.68	0.057	1133.3	1275.0	1416.7	1558.3	1700.0
Mar	0.53	1.24	0.103	2066.7	2325.0	2583.3	2841.7	3100.0
Apr	1.28	2.54	0.212	4233.3	4762.5	5291.7	5820.8	6350.0
May	2.21	4.14	0.345	6900.0	7762.5	8625.0	9487.5	10350.0
June	2.55	5.42	0.452	9033.3	10162.5	11291.7	12420.8	13550.0
July	1.4	7.9	0.658	13166.7	14812.5	16458.3	18104.2	19750.0
Aug	1.41	7.74	0.645	12900.0	14512.5	16125.0	17737.5	19350.0
Sep	0.91	5.1	0.425	8500.0	9562.5	10625.0	11687.5	12750.0
Oct	0.49	2.82	0.235	4700.0	5287.5	5875.0	6462.5	7050.0
Nov	0.53	1.4	0.117	2333.3	2625.0	2916.7	3208.3	3500.0
Dec	0.55	0.64	0.053	1066.7	1200.0	1333.3	1466.7	1600.0
	12.9	40.2	3.35	67050.0	75431.3	83812.5	92193.8	100575.0

Worst Case: No manure or sediment in the pond, and excess runoff occurs. From page 11, volume of pond with 6-inches of depth provided for sediment is 84774 cubic feet. Pond C will evaporate an equivalent volume, as well as provide the "Required Volume".

Choose Pond Size C