AGRICULTURAL WASTE MANAGEMENT FIELD HANDBOOK
210-I-AWMFH – AMENDMENT IA-3

Resources for Planning and Designing Animal Waste Facilities

This amendment includes animal waste and nutrient management references that are available from Iowa State University Extension Service, Midwest Plan Service, or from Iowa Department of Natural Resources. These values can to be used to assist with designing and planning animal waste collection; handling, storage, or utilization facilities; and for developing and planning manure management plans unless the producer provides manure sample test results. The resource list is not designed to be all inclusive. Other resources are available on the IMMAG website at **http://www.agronext.iastate.edu/immag/**

Sources of Information

Manure Management Publications

DOC #	TITLE
PM 287	Take a Good Sample to Help Make Good Decisions
PM 569	Warm-Season Grasses for Hay and Pasture
PM 869	Fertilizing Pastures
PM 1268	Establishing Realistic Yields
PM 1310	Interpretation of Soil Test Results
PM 1558	Management Practices: How to Sample Manure for Nutrient Analysis
PM 1584	Cornstalk Testing to Evaluate Nitrogen Management
PM 1609	You Can't Afford Not to Haul Manure
PM 1688	General Guide for Crop Nutrient Recommendations in Iowa
PM 1714	Nitrogen Fertilizer Recommendations for Corn in Iowa
PM 1003	Managing Manure Nutrients for Crop Production
PM 1901G	Resources Conservation Practices: Manure and Tillage Management
PM 1931	Developing Whole-Farm Nutrient Plans for Feedlots
PM 1941	Calibration and Uniformity of Solid Manure Spreaders
PM 1948	Calibrating Liquid Tank Manure Applicators
PM 1993	10 Questions about the Phosphorus (P) Index in Iowa
PM 2015	Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn Agricultural Nitrogen Management for Water Quality Protection in the Midwest
PM 2021	Data Collection Worksheet for RUSLE2 and Iowa Phosphorus Index

Other Useful Publications

DOC #	TITLE
PM 1518K	Manure Storage Poses Invisible Risks
MWPS-18	Livestock Waste Facilities Handbook
MWPS-18 S2	Manure Storages
MWPS-36	Rectangular Concrete Manure Storages
TR-9	Circular Concrete Manure Tanks
FS925-D	Covers for Manure Storage Units
Chapter 65	Chapter 65, Iowa Administrative Code

Precipitation and Runoff Tables

The precipitation table notes the monthly and annual precipitation, in inches, for the counties of Iowa. The runoff tables for unpaved lots and paved lots note runoff expressed, in inches, for each month and on an annual basis. They are to be used for determining runoff from normal precipitation in lieu of the present procedure shown in Part VI of Chapter 12 of the AWMFH. For designing roof runoff control structures (Roof Runoff Structure - 558) a table of 10- and 25-year, 5-minute storm event depth (inches) by county is included.

Normal Annual and Monthly Precipitation (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adair	34.86	0.89	1.01	2.23	3.50	4.40	4.48	4.51	3.92	3.83	2.56	2.12	1.19
Adams	35.31	0.83	1.01	2.27	3.39	4.52	4.48	4.58	3.96	4.09	2.63	2.18	1.15
Allamakee	33.72	0.92	0.92	1.90	3.61	3.80	4.44	4.35	4.59	3.29	2.28	2.22	1.17
Appanoose	37.17	1.01	1.13	2.31	3.47	4.74	4.49	5.03	3.98	4.02	2.87	2.46	1.45
Audubon	33.60	0.85	0.91	2.25	3.38	4.24	4.53	4.36	3.79	3.57	2.59	1.86	1.06
Benton	35.19	1.01	1.04	2.17	3.40	4.18	4.79	4.16	4.44	3.52	2.57	2.35	1.34
Black Hawk	34.53	0.93	1.02	2.11	3.34	4.16	4.99	4.26	4.35	3.22	2.52	2.22	1.21
Boone	34.13	0.88	0.91	2.16	3.30	4.27	5.04	4.34	4.22	3.11	2.50	2.03	1.16
Bremer	35.21	0.97	0.96	2.08	3.49	4.20	4.97	4.36	4.81	3.22	2.52	2.25	1.17
Buchanan	35.13	1.02	1.04	2.05	3.37	4.08	4.86	4.15	4.80	3.43	2.49	2.31	1.30
Buena Vista	31.83	0.67	0.63	2.05	3.32	3.84	4.85	4.13	4.31	3.12	2.19	1.67	0.84
Butler	34.40	0.88	0.90	2.05	3.34	4.20	5.12	4.42	4.42	3.23	2.51	2.12	1.12
Calhoun	32.06	0.79	0.71	2.08	3.21	4.17	4.66	4.06	3.90	3.23	2.33	1.71	0.98
Carroll	32.70	0.84	0.82	2.24	3.32	4.20	4.65	4.23	3.67	3.32	2.43	1.76	1.01
Cass	34.57	0.82	0.95	2.26	3.39	4.44	4.57	4.56	3.89	3.85	2.60	1.95	1.08
Cedar	36.24	1.29	1.28	2.48	3.42	4.23	4.42	3.96	4.54	3.47	2.61	2.52	1.80
Cerro Gordo	34.00	0.90	0.79	2.05	3.29	4.15	5.02	4.38	4.46	3.24	2.44	1.97	1.08
Cherokee	29.64	0.65	0.63	1.98	3.00	3.73	4.54	3.85	3.76	2.89	2.02	1.60	0.79
Chickasaw	35.34	0.98	0.93	2.08	3.59	4.16	4.84	4.42	4.87	3.26	2.50	2.25	1.24
Clarke	35.95	0.89	1.10	2.21	3.55	4.62	4.49	4.62	4.05	3.96	2.67	2.30	1.26
Clay	30.18	0.62	0.57	1.95	3.10	3.65	4.61	4.00	4.18	2.86	2.03	1.63	0.75
Clayton	34.23	1.03	1.10	2.05	3.54	3.88	4.52	4.10	4.66	3.21	2.35	2.32	1.26
Clinton	35.82	1.35	1.36	2.51	3.38	4.04	4.47	3.61	4.56	3.26	2.62	2.57	1.88
Crawford	31.32	0.75	0.72	2.17	3.16	4.12	4.45	3.99	3.57	3.29	2.33	1.61	0.95
Dallas	33.80	0.87	0.94	2.14	3.32	4.31	4.73	4.27	4.05	3.29	2.5	2.01	1.15
Davis	37.41	1.17	1.22	2.42	3.48	4.77	4.31	4.76	4.03	4.02	2.81	2.58	1.63
Decatur	36.53	0.89	1.14	2.32	3.51	4.67	4.40	4.77	3.95	4.07	2.92	2.35	1.32
Delaware	35.13	1.07	1.11	2.10	3.40	4.06	4.58	4.00	4.95	3.41	2.50	2.39	1.35
Des Moines	36.75	1.30	1.41	2.67	3.49	4.35	4.22	4.25	3.89	3.60	2.71	2.67	1.97
Dickinson	29.27	0.64	0.58	1.91	3.00	3.63	4.61	3.75	3.86	2.73	2.01	1.64	0.71
Dubuque	34.80	1.16	1.25	2.29	3.36	3.83	4.45	3.83	4.58	3.46	2.42	2.44	1.52
Emmet	30.04	0.73	0.59	1.86	3.08	3.65	4.64	3.92	4.01	2.74	2.14	1.68	0.77
Fayette	35.17	1.02	1.05	2.04	3.57	4.05	4.68	4.20	4.97	3.35	2.47	2.25	1.30
Floyd	34.57	0.94	0.84	2.01	3.39	4.18	5.06	4.40	4.57	3.31	2.46	2.07	1.12
Franklin	33.84	0.85	0.82	2.04	3.21	4.19	5.15	4.36	4.32	3.16	2.44	1.98	1.10
Fremont	34.03	0.77	0.91	2.35	3.27	4.51	4.37	4.79	3.81	3.49	2.52	1.98	1.04
Greene	33.02	0.87	0.87	2.14	3.23	4.19	4.80	4.23	3.94	3.13	2.42	1.88	1.11
Grundy	34.61	0.89	0.97	2.18	3.26	4.26	5.25	4.34	4.16	3.10	2.56	2.23	1.20
Guthrie	34.19	0.87	0.96	2.24	3.36	4.34	4.68	4.36	4.11	3.43	2.51	1.95	1.16
Hamilton	33.78	0.87	0.83	2.02	3.13	4.05	5.37	4.31	4.44	3.09	2.43	1.92	1.11
Hancock	32.15	0.80	0.72	1.93	3.21	3.89	4.81	4.23	4.22	3.02	2.26	1.83	1.01
Hardin	34.22	0.91	0.90	2.13	3.19	4.20	5.29	4.23	4.24	3.14	2.51	2.15	1.13
Harrison	31.69	0.73	0.75	2.25	3.15	4.33	4.42	4.03	3.42	3.37	2.39	1.68	0.94
Henry	36.96	1.28	1.32	2.59	3.40	4.47	4.17	4.45	3.99	3.89	2.69	2.66	1.84
Howard	34.80	0.98	0.87	2.04	3.48	3.97	4.66	4.47	4.89	3.44	2.4	2.19	1.19
Humboldt	32.37	0.83	0.72	2.05	3.20	3.94	4.77	4.22	4.20	3.12	2.28	1.80	1.02
Ida	30.71	0.77	0.67	2.11	3.14	3.97	4.59	3.85	3.78	3.01	2.17	1.57	0.89
Iowa	35.84	1.05	1.06	2.20	3.41	4.39	4.61	4.25	4.51	3.65	2.61	2.46	1.42
Jackson	35.24	1.21	1.32	2.36	3.34	3.91	4.48	3.55	4.54	3.52	2.51	2.56	1.71
Jasper	35.08	0.97	1.05	2.18	3.35	4.45	4.65	4.27	4.32	3.46	2.67	2.28	1.22

Normal Annual and Monthly Precipitation (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jefferson	36.48	1.22	1.23	2.46	3.39	4.55	4.08	4.45	4.00	3.87	2.77	2.55	1.70
Johnson	35.85	1.09	1.12	2.31	3.47	4.26	4.57	4.22	4.53	3.51	2.59	2.42	1.55
Jones	35.32	1.20	1.22	2.34	3.36	4.02	4.49	3.85	4.62	3.43	2.50	2.50	1.59
Keokuk	35.74	1.07	1.10	2.35	3.37	4.40	4.28	4.31	4.20	3.79	2.70	2.52	1.44
Kossuth	31.25	0.74	0.65	1.89	3.11	3.86	4.71	4.20	4.13	2.85	2.24	1.78	0.88
Lee	37.89	1.39	1.46	2.79	3.52	4.72	4.18	4.34	3.72	3.81	2.79	2.88	2.08
Linn	35.37	1.08	1.09	2.18	3.40	4.16	4.65	4.12	4.58	3.52	2.50	2.41	1.46
Louisa	36.19	1.24	1.32	2.58	3.44	4.29	4.11	4.17	4.17	3.57	2.67	2.57	1.85
Lucas	36.36	0.92	1.15	2.23	3.52	4.60	4.57	4.67	3.99	4.05	2.84	2.35	1.25
Lyon	27.16	0.53	0.55	1.87	2.71	3.35	4.24	3.43	3.58	2.52	1.94	1.54	0.67
Madison	34.86	0.94	1.05	2.20	3.53	4.39	4.56	4.37	3.98	3.70	2.56	2.18	1.20
Mahaska	35.87	1.02	1.14	2.18	3.40	4.49	4.38	4.37	4.18	3.83	2.73	2.56	1.36
Marion	35.49	0.92	1.10	2.11	3.64	4.49	4.47	4.38	4.17	3.68	2.75	2.33	1.23
Marshall	35.05	0.94	0.97	2.19	3.20	4.36	5.01	4.44	4.45	3.22	2.56	2.26	1.23
Mills	33.42	0.73	0.85	2.26	3.27	4.61	4.54	4.51	3.76	3.42	2.42	1.85	0.99
Mitchell	34.17	0.98	0.80	1.99	3.38	4.09	4.78	4.37	4.65	3.37	2.40	2.03	1.14
Monona	30.32	0.66	0.65	2.15	3.14	4.11	4.33	3.87	3.47	3.06	2.28	1.54	0.84
Monroe	36.72	1.05	1.17	2.26	3.51	4.63	4.45	4.84	3.94	4.03	2.72	2.52	1.40
Montgomery	35.36	0.85	1.03	2.29	3.45	4.63	4.62	4.63	3.93	3.9	2.58	2.08	1.13
Muscatine	36.08	1.27	1.30	2.53	3.38	4.18	4.32	4.09	4.32	3.46	2.63	2.54	1.83
O'Brien	29.38	0.65	0.65	1.89	2.98	3.58	4.59	3.90	4.00	2.68	1.95	1.57	0.71
Osceola	28.61	0.58	0.57	1.92	2.92	3.52	4.49	3.58	3.85	2.80	1.95	1.52	0.68
Page	35.37	0.86	1.00	2.34	3.30	4.59	4.54	4.78	3.98	3.82	2.63	2.21	1.10
Palo Alto	31.09	0.74	0.64	1.95	3.13	3.71	4.70	4.17	4.17	2.88	2.19	1.76	0.85
Plymouth	27.23	0.59	0.57	1.91	2.8	3.61	4.12	3.48	3.21	2.56	2.02	1.45	0.71
Pocahontas	32.00	0.81	0.70	2.07	3.20	3.90	4.66	4.20	4.23	3.11	2.20	1.77	0.93
Polk	34.40	0.89	1.02	2.15	3.35	4.32	4.81	4.30	4.29	3.24	2.55	2.09	1.19
Pottawattamie	33.30	0.76	0.84	2.28	3.30	4.50	4.55	4.48	3.57	3.60	2.41	1.80	0.99
Poweshiek	35.74	1.05	1.11	2.19	3.44	4.36	4.53	4.25	4.43	3.72	2.70	2.43	1.31
Ringgold	35.80	0.83	1.06	2.31	3.26	4.53	4.44	4.73	4.00	4.03	2.91	2.25	1.24
Sac	32.02	0.77	0.71	2.19	3.28	4.07	4.70	4.06	3.90	3.19	2.30	1.69	0.97
Scott	35.82	1.34	1.35	2.56	3.41	4.04	4.50	3.78	4.37	3.19	2.60	2.56	1.91
Shelby	33.11	0.78	0.81	2.21	3.28	4.26	4.48	4.22	3.69	3.86	2.53	1.77	1.00
Sioux	27.67	0.60	0.59	1.92	2.77	3.46	4.27	3.56	3.52	2.54	1.99	1.53	0.72
Story	34.61	0.87	0.91	2.14	3.19	4.21	5.19	4.62	4.40	3.10	2.48	2.14	1.14
Tama	35.48	0.99	1.05	2.20	3.33	4.27	5.07	4.37	4.37	3.43	2.62	2.32	1.26
Taylor	36.01	0.88	1.04	2.32	3.27	4.62	4.50	4.87	4.00	4.02	2.84	2.27	1.17
Union	35.15	0.87	1.05	2.21	3.45	4.48	4.45	4.55	3.8	3.96	2.64	2.27	1.21
Van Buren	37.14	1.30	1.28	2.49	3.51	4.69	4.16	4.55	3.72	3.93	2.79	2.65	1.84
Wapello	36.30	1.09	1.17	2.36	3.38	4.56	4.31	4.59	3.99	3.9	2.72	2.51	1.49
Warren	35.13	0.95	1.10	2.16	3.58	4.48	4.59	4.35	3.97	3.62	2.70	2.19	1.23
Washington	35.62	1.18	1.16	2.38	3.27	4.37	4.19	4.27	4.15	3.68	2.63	2.47	1.66
Wayne	36.91	0.95	1.14	2.31	3.52	4.63	4.42	4.95	3.97	4.10	2.93	2.41	1.35
Webster	33.39	0.86	0.79	2.10	3.27	4.16	4.98	4.31	4.22	3.17	2.37	1.86	1.08
Winnebago	32.44	0.84	0.67	1.90	3.19	3.92	4.83	4.27	4.51	2.95	2.30	1.86	0.99
Winneshiek	34.31	0.94	0.90	1.96	3.60	3.82	4.56	4.33	4.85	3.42	2.35	2.17	1.19
Woodbury	28.76	0.63	0.63	2.05	3.01	3.89	4.17	3.63	3.34	2.76	2.13	1.51	0.78
Worth	33.39	0.93	0.72	2.01	3.27	4.01	4.76	4.33	4.55	3.20	2.37	1.95	1.07
Wright	33.03	0.80	0.75	1.99	3.21	4.05	5.13	4.26	4.23	3.13	2.35	1.88	1.04

Normal Annual and Monthly Unpaved Lot Runoff – CN 90 (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adair	8.2	0.1	0.1	0.3	0.7	1.1	1.3	1.4	1.1	1.2	0.6	0.4	0.1
Adams	8.5	0.1	0.1	0.3	0.6	1.1	1.3	1.4	1.1	1.3	0.7	0.4	0.1
Allamakee	7.2	0.1	0.1	0.3	0.6	0.8	1.2	1.3	1.3	1.0	0.5	0.4	0.1
Appanoose	8.9	0.1	0.1	0.3	0.7	1.2	1.3	1.5	1.2	1.3	0.7	0.5	0.2
Audubon	7.9	0.1	0.1	0.3	0.6	1.1	1.4	1.3	1.1	1.1	0.6	0.4	0.1
Benton	7.9	0.1	0.1	0.3	0.7	0.9	1.3	1.2	1.3	1.1	0.6	0.4	0.1
Black Hawk	7.8	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.2	1.0	0.6	0.4	0.1
Boone	7.8	0.1	0.1	0.3	0.6	1.0	1.5	1.3	1.2	1.0	0.6	0.4	0.1
Bremer	7.7	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.3	1.0	0.5	0.4	0.1
Buchanan	7.7	0.1	0.1	0.3	0.6	0.9	1.4	1.2	1.3	1.0	0.6	0.4	0.1
Buena Vista	7.0	0.1	0.1	0.2	0.6	0.9	1.5	1.2	1.1	0.9	0.4	0.3	0.1
Butler	7.6	0.1	0.1	0.3	0.6	0.9	1.5	1.3	1.2	1.0	0.6	0.4	0.1
Calhoun	7.2	0.1	0.1	0.3	0.6	1.0	1.4	1.2	1.1	1.0	0.5	0.3	0.1
Carroll	7.5	0.1	0.1	0.3	0.6	1.1	1.4	1.3	1.0	1.0	0.5	0.3	0.1
Cass	8.1	0.1	0.1	0.3	0.6	1.1	1.4	1.4	1.1	1.2	0.7	0.4	0.1
Cedar	8.2	0.2	0.1	0.4	0.7	1.0	1.2	1.2	1.3	1.1	0.7	0.5	0.2
Cerro Gordo	7.5	0.1	0.1	0.3	0.6	0.9	1.5	1.3	1.2	0.9	0.5	0.3	0.1
Cherokee	6.5	0.1	0.1	0.2	0.5	0.8	1.4	1.2	1.0	0.8	0.4	0.2	0.1
Chickasaw	7.8	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.3	1.0	0.5	0.4	0.1
Clarke	8.6	0.1	0.1	0.3	0.7	1.2	1.3	1.4	1.2	1.3	0.7	0.5	0.1
Clay	6.5	0.1	0.1	0.2	0.6	0.8	1.4	1.2	1.1	0.8	0.4	0.2	0.1
Clayton	7.4	0.1	0.1	0.3	0.7	0.8	1.3	1.2	1.3	0.9	0.5	0.4	0.2
Clinton	7.9	0.2	0.1	0.4	0.7	0.9	1.3	1.1	1.3	1.0	0.7	0.5	0.3
Crawford	7.2	0.1	0.1	0.3	0.6	1.0	1.3	1.2	1.0	1.0	0.5	0.3	0.1
Dallas	7.9	0.1	0.1	0.3	0.6	1.0	1.4	1.3	1.1	1.0	0.6	0.4	0.1
Davis	9.0	0.2	0.1	0.4	0.7	1.1	1.2	1.4	1.2	1.3	0.7	0.5	0.2
Decatur	8.8	0.1	0.1	0.3	0.7	1.2	1.3	1.4	1.2	1.3	0.7	0.5	0.2
Delaware	7.7	0.1	0.1	0.3	0.7	0.9	1.3	1.2	1.4	1.0	0.6	0.4	0.1
Des Moines	8.6	0.2	0.1	0.4	0.7	1.0	1.2	1.3	1.1	1.1	0.7	0.5	0.3
Dickinson	6.3	0.1	0.1	0.2	0.5	0.7	1.4	1.1	1.0	0.7	0.4	0.2	0.1
Dubuque	7.7	0.1	0.1	0.3	0.7	0.8	1.2	1.1	1.3	1.0	0.6	0.4	0.2
Emmet	6.5	0.1	0.1	0.2	0.6	0.7	1.4	1.2	1.0	0.7	0.4	0.3	0.1
Fayette	7.7	0.1	0.1	0.3	0.7	0.9	1.3	1.3	1.4	1.0	0.5	0.4	0.1
Floyd	7.6	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.2	1.0	0.5	0.3	0.1
Franklin	7.6	0.1	0.1	0.3	0.6	0.9	1.5	1.3	1.2	0.9	0.5	0.3	0.1
Fremont	8.2	0.1	0.1	0.4	0.6	1.1	1.3	1.4	1.1	1.1	0.6	0.4	0.1
Greene	7.6	0.1	0.1	0.3	0.6	1.0	1.4	1.3	1.1	1.0	0.6	0.3	0.1
Grundy	7.8	0.1	0.1	0.3	0.6	0.9	1.5	1.3	1.2	0.9	0.6	0.4	0.1
Guthrie	8.0	0.1	0.1	0.3	0.6	1.1	1.4	1.3	1.2	1.1	0.6	0.4	0.1
Hamilton	7.6	0.1	0.1	0.3	0.6	0.9	1.6	1.3	1.2	0.9	0.5	0.3	0.1
Hancock	7.1	0.1	0.1	0.3	0.6	0.8	1.4	1.3	1.1	0.9	0.5	0.3	0.1
Hardin	7.7	0.1	0.1	0.3	0.6	0.9	1.6	1.3	1.2	0.9	0.6	0.4	0.1
Harrison	7.3	0.1	0.1	0.3	0.6	1.1	1.3	1.2	0.9	1.0	0.5	0.3	0.1
Henry	8.7	0.2	0.1	0.4	0.7	1.1	1.2	1.3	1.2	1.2	0.7	0.5	0.3
Howard	7.5	0.1	0.1	0.3	0.6	0.8	1.3	1.3	1.3	1.0	0.5	0.3	0.1
Humboldt	7.3	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.1	0.9	0.5	0.3	0.1
Ida	6.8	0.1	0.1	0.3	0.6	1.0	1.4	1.2	1.0	0.9	0.5	0.3	0.1
Iowa	8.2	0.1	0.1	0.3	0.7	1.0	1.3	1.3	1.3	1.1	0.7	0.5	0.2
Jackson	7.8	0.1	0.1	0.4	0.7	0.9	1.3	1.1	1.3	1.1	0.6	0.5	0.2
Jasper	8.1	0.1	0.1	0.3	0.6	1.0	1.4	1.3	1.2	1.1	0.7	0.4	0.1

Normal Annual and Monthly Unpaved Lot Runoff – CN 90 (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jefferson	8.6	0.2	0.1	0.4	0.7	1.1	1.2	1.3	1.2	1.2	0.7	0.5	0.2
Johnson	8.2	0.1	0.1	0.3	0.7	1.0	1.3	1.3	1.3	1.1	0.6	0.5	0.2
Jones	7.8	0.1	0.1	0.4	0.7	0.9	1.3	1.2	1.3	1.0	0.6	0.5	0.2
Keokuk	8.4	0.1	0.1	0.4	0.7	1.0	1.2	1.3	1.2	1.2	0.7	0.5	0.2
Kossuth	6.9	0.1	0.1	0.2	0.6	0.8	1.4	1.3	1.1	0.8	0.4	0.3	0.1
Lee	9.1	0.2	0.1	0.4	0.7	1.1	1.2	1.3	1.1	1.2	0.7	0.6	0.3
Linn	8.0	0.1	0.1	0.3	0.7	0.9	1.3	1.2	1.3	1.1	0.6	0.4	0.2
Louisa	8.3	0.2	0.1	0.4	0.7	1.0	1.2	1.3	1.2	1.1	0.7	0.5	0.3
Lucas	8.7	0.1	0.1	0.3	0.7	1.1	1.4	1.4	1.2	1.3	0.7	0.5	0.2
Lyon	5.7	0.1	0.1	0.2	0.5	0.7	1.3	1.0	0.9	0.6	0.4	0.2	0.1
Madison	8.2	0.1	0.1	0.3	0.7	1.1	1.4	1.3	1.2	1.2	0.6	0.4	0.1
Mahaska	8.4	0.1	0.1	0.3	0.7	1.1	1.3	1.3	1.2	1.2	0.7	0.5	0.2
Marion	8.3	0.1	0.1	0.3	0.7	1.1	1.3	1.3	1.2	1.2	0.7	0.5	0.1
Marshall	8.1	0.1	0.1	0.3	0.6	1.0	1.5	1.3	1.2	1.0	0.6	0.4	0.1
Mills	8.0	0.1	0.1	0.3	0.6	1.2	1.4	1.4	1.1	1.1	0.6	0.4	0.1
Mitchell	7.3	0.1	0.1	0.3	0.6	0.8	1.3	1.3	1.3	1.0	0.5	0.3	0.1
Monona	6.7	0.1	0.1	0.3	0.6	1.0	1.3	1.2	0.9	0.9	0.5	0.2	0.1
Monroe	8.6	0.1	0.1	0.3	0.7	1.1	1.3	1.5	1.2	1.3	0.7	0.5	0.2
Montgomery	8.5	0.1	0.1	0.3	0.7	1.2	1.4	1.4	1.1	1.2	0.6	0.4	0.1
Muscatine	8.3	0.2	0.1	0.4	0.7	1.0	1.2	1.2	1.3	1.1	0.7	0.5	0.2
O'Brien	6.3	0.1	0.1	0.2	0.5	0.8	1.4	1.2	1.0	0.7	0.4	0.2	0.1
Osceola	6.0	0.1	0.1	0.2	0.5	0.7	1.3	1.1	1.0	0.7	0.4	0.2	0.1
Page	8.5	0.1	0.1	0.4	0.6	1.1	1.4	1.4	1.2	1.2	0.7	0.4	0.1
Palo Alto	6.8	0.1	0.1	0.2	0.6	0.8	1.4	1.3	1.1	0.8	0.4	0.3	0.1
Plymouth	5.9	0.1	0.1	0.2	0.5	0.8	1.2	1.0	0.8	0.7	0.4	0.2	0.1
Pocahontas	7.0	0.1	0.1	0.3	0.6	0.9	1.4	1.3	1.1	0.9	0.5	0.3	0.1
Polk	8.1	0.1	0.1	0.3	0.6	1.0	1.4	1.3	1.2	1.0	0.6	0.4	0.1
Pottawattamie	7.8	0.1	0.1	0.3	0.6	1.1	1.4	1.3	1.0	1.1	0.6	0.3	0.1
Poweshiek	8.2	0.1	0.1	0.3	0.7	1.0	1.3	1.3	1.3	1.2	0.7	0.5	0.2
Ringgold	8.6	0.1	0.1	0.3	0.6	1.1	1.3	1.4	1.2	1.3	0.7	0.5	0.1
Sac	7.2	0.1	0.1	0.3	0.6	1.0	1.4	1.2	1.1	0.9	0.5	0.3	0.1
Scott	7.9	0.2	0.1	0.4	0.7	0.9	1.3	1.1	1.3	1.0	0.7	0.5	0.3
Shelby	7.6	0.1	0.1	0.3	0.6	1.1	1.3	1.3	1.0	1.2	0.6	0.3	0.1
Sioux	5.8	0.1	0.1	0.2	0.5	0.7	1.3	1.1	0.9	0.6	0.4	0.2	0.1
Story	8.0	0.1	0.1	0.3	0.6	1.0	1.6	1.4	1.2	1.0	0.6	0.4	0.1
Tama	8.2	0.1	0.1	0.3	0.6	1.0	1.5	1.3	1.2	1.1	0.6	0.4	0.1
Taylor	8.6	0.1	0.1	0.3	0.6	1.2	1.4	1.5	1.2	1.3	0.7	0.5	0.1
Union	8.4	0.1	0.1	0.3	0.7	1.1	1.3	1.4	1.1	1.3	0.7	0.5	0.1
Van Buren	8.9	0.2	0.1	0.4	0.7	1.1	1.2	1.4	1.1	1.3	0.7	0.5	0.3
Wapello	8.5	0.2	0.1	0.4	0.7	1.1	1.2	1.4	1.2	1.2	0.7	0.5	0.2
Warren	8.3	0.1	0.1	0.3	0.7	1.1	1.4	1.3	1.2	1.2	0.7	0.4	0.1
Washington	8.2	0.2	0.1	0.4	0.7	1.0	1.2	1.3	1.2	1.2	0.7	0.5	0.2
Wayne	8.9	0.1	0.1	0.3	0.7	1.2	1.3	1.5	1.2	1.3	0.7	0.5	0.2
Webster	7.5	0.1	0.1	0.3	0.6	1.0	1.5	1.3	1.1	1.0	0.5	0.3	0.1
Winnebago	7.0	0.1	0.1	0.2	0.6	0.8	1.4	1.3	1.2	0.8	0.5	0.3	0.1
Winneshiek	7.4	0.1	0.1	0.3	0.6	0.8	1.3	1.3	1.3	1.0	0.5	0.3	0.1
Woodbury	6.3	0.1	0.1	0.2	0.5	0.9	1.3	1.1	0.9	0.8	0.4	0.2	0.1
Worth	7.2	0.1	0.1	0.3	0.6	0.8	1.4	1.3	1.2	0.9	0.5	0.3	0.1
Wright	7.4	0.1	0.1	0.3	0.6	0.9	1.5	1.3	1.1	0.9	0.5	0.3	0.1

Normal Annual and Monthly Paved Lot Runoff – CN 97 (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adair	19.5	0.3	0.4	1.0	1.8	2.5	2.7	2.8	2.4	2.3	1.5	1.1	0.5
Adams	20.0	0.3	0.4	1.1	1.8	2.6	2.7	2.9	2.4	2.5	1.5	1.1	0.5
Allamakee	18.5	0.3	0.3	0.9	1.8	2.1	2.6	2.7	2.8	1.9	1.2	1.1	0.4
Appanoose	21.2	0.4	0.4	1.1	1.8	2.7	2.7	3.2	2.4	2.5	1.6	1.3	0.6
Audubon	18.8	0.3	0.4	1.0	1.7	2.4	2.7	2.7	2.3	2.1	1.4	0.9	0.4
Benton	19.7	0.4	0.4	1.0	1.8	2.3	2.9	2.6	2.7	2.1	1.4	1.2	0.5
Black Hawk	19.2	0.3	0.4	1.0	1.7	2.3	3.0	2.6	2.6	1.9	1.4	1.1	0.5
Boone	18.9	0.3	0.3	1.0	1.7	2.4	3.0	2.7	2.6	1.9	1.4	1.0	0.4
Bremer	19.5	0.3	0.3	0.9	1.8	2.3	3.0	2.7	2.9	1.9	1.4	1.1	0.4
Buchanan	19.5	0.4	0.4	0.9	1.7	2.2	2.9	2.6	2.9	2.1	1.4	1.2	0.5
Buena Vista	17.2	0.2	0.2	0.9	1.6	2.1	2.8	2.5	2.6	1.8	1.2	0.8	0.3
Butler	18.9	0.3	0.3	0.9	1.7	2.3	3.1	2.7	2.6	1.9	1.4	1.1	0.4
Calhoun	17.6	0.2	0.3	0.9	1.6	2.3	2.8	2.5	2.3	1.9	1.3	0.9	0.3
Carroll	18.0	0.3	0.3	1.0	1.7	2.4	2.8	2.6	2.2	2.0	1.3	0.9	0.4
Cass	19.4	0.3	0.4	1.0	1.7	2.5	2.8	2.8	2.4	2.3	1.5	1.0	0.4
Cedar	20.3	0.5	0.5	1.2	1.8	2.4	2.7	2.5	2.7	2.2	1.5	1.3	0.7
Cerro Gordo	18.5	0.3	0.3	0.9	1.7	2.3	3.0	2.7	2.7	1.9	1.3	0.9	0.4
Cherokee	15.7	0.2	0.3	0.8	1.5	2.1	2.6	2.3	2.3	1.6	1.1	0.7	0.3
Chickasaw	19.4	0.3	0.3	0.9	1.8	2.3	2.9	2.7	2.9	1.9	1.4	1.1	0.4
Clarke	20.5	0.3	0.4	1.0	1.9	2.6	2.7	2.9	2.5	2.5	1.5	1.2	0.5
Clay	16.0	0.2	0.2	0.8	1.5	2.0	2.7	2.4	2.5	1.6	1.1	0.7	0.2
Clayton	19.0	0.3	0.4	0.9	1.8	2.1	2.7	2.5	2.8	1.9	1.3	1.2	0.5
Clinton	20.1	0.5	0.5	1.2	1.8	2.2	2.7	2.2	2.7	2.0	1.5	1.3	0.8
Crawford	17.2	0.2	0.3	1.0	1.6	2.3	2.7	2.4	2.2	1.9	1.3	0.8	0.3
Dallas	18.9	0.3	0.4	1.0	1.7	2.4	2.9	2.7	2.5	2.0	1.4	1.0	0.4
Davis	21.3	0.5	0.5	1.2	1.8	2.7	2.6	3.0	2.4	2.6	1.6	1.4	0.7
Decatur	20.8	0.3	0.5	1.1	1.8	2.7	2.7	3.0	2.4	2.5	1.7	1.2	0.5
Delaware	19.5	0.4	0.4	1.0	1.8	2.2	2.7	2.5	3.0	2.1	1.4	1.2	0.5
Des Moines	20.9	0.5	0.5	1.3	1.8	2.5	2.6	2.7	2.4	2.3	1.5	1.4	0.8
Dickinson	15.5	0.2	0.2	0.8	1.5	2.0	2.7	2.3	2.3	1.5	1.1	0.7	0.2
Dubuque	19.3	0.4	0.4	1.1	1.7	2.1	2.7	2.4	2.7	2.1	1.3	1.2	0.6
Emmet	15.9	0.2	0.2	0.7	1.5	2.0	2.7	2.4	2.4	1.5	1.1	0.8	0.2
Fayette	19.5	0.3	0.4	0.9	1.8	2.2	2.8	2.6	3.0	2.0	1.3	1.1	0.5
Floyd	19.0	0.3	0.3	0.9	1.7	2.3	3.0	2.7	2.7	2.0	1.3	1.0	0.4
Franklin	18.6	0.3	0.3	0.9	1.6	2.3	3.1	2.7	2.6	1.9	1.3	1.0	0.4
Fremont	19.2	0.3	0.4	1.1	1.7	2.6	2.7	3.0	2.3	2.1	1.4	1.0	0.4
Greene	18.3	0.3	0.3	1.0	1.6	2.3	2.9	2.6	2.4	1.8	1.3	1.0	0.4
Grundy	19.2	0.3	0.3	1.0	1.7	2.4	3.2	2.7	2.5	1.9	1.4	1.1	0.5
Guthrie	19.1	0.3	0.4	1.0	1.7	2.5	2.9	2.7	2.5	2.1	1.4	1.0	0.4
Hamilton	18.7	0.3	0.3	0.9	1.6	2.2	3.2	2.7	2.7	1.8	1.3	1.0	0.4
Hancock	17.4	0.2	0.3	0.8	1.6	2.1	2.8	2.6	2.5	1.8	1.2	0.9	0.3
Hardin	19.0	0.3	0.3	1.0	1.6	2.3	3.2	2.6	2.5	1.9	1.4	1.1	0.4
Harrison	17.4	0.2	0.3	1.0	1.6	2.4	2.7	2.5	2.1	2.0	1.3	0.8	0.3
Henry	21.1	0.5	0.5	1.2	1.8	2.5	2.5	2.8	2.4	2.5	1.5	1.4	0.8
Howard	19.0	0.3	0.3	0.9	1.8	2.2	2.7	2.7	2.9	2.0	1.3	1.0	0.4
Humboldt	17.6	0.2	0.3	0.9	1.6	2.2	2.9	2.6	2.5	1.8	1.2	0.9	0.4
Ida	16.6	0.2	0.3	0.9	1.6	2.2	2.8	2.3	2.3	1.7	1.2	0.7	0.3
Iowa	20.1	0.4	0.4	1.0	1.8	2.5	2.8	2.7	2.7	2.3	1.5	1.3	0.6
Jackson	19.7	0.4	0.5	1.1	1.7	2.2	2.7	2.2	2.7	2.1	1.4	1.3	0.7
Jasper	19.6	0.3	0.4	1.0	1.7	2.5	2.8	2.7	2.6	2.1	1.5	1.2	0.5

Normal Annual and Monthly Paved Lot Runoff – CN 97 (inches)

County	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jefferson	20.8	0.5	0.5	1.2	1.8	2.6	2.5	2.8	2.4	2.5	1.6	1.4	0.7
Johnson	20.1	0.4	0.4	1.1	1.8	2.4	2.8	2.6	2.7	2.2	1.4	1.3	0.6
Jones	19.8	0.4	0.4	1.1	1.7	2.2	2.7	2.4	2.8	2.1	1.4	1.3	0.7
Keokuk	20.2	0.4	0.4	1.1	1.8	2.5	2.6	2.7	2.5	2.4	1.4	1.3	0.6
Kossuth	16.6	0.2	0.2	0.8	1.6	2.1	2.7	2.6	2.5	1.6	1.3	0.8	0.3
Lee	21.6	0.6	0.6	1.3	1.9	2.7	2.5	2.7	2.3	2.4	1.6	1.5	0.9
Linn	19.8	0.4	0.4	1.0	1.8	2.3	2.8	2.6	2.7	2.1	1.4	1.2	0.6
Louisa	20.6	0.5	0.5	1.2	1.8	2.4	2.5	2.6	2.5	2.2	1.5	1.3	0.8
Lucas	20.7	0.3	0.4	1.1	1.8	2.6	2.8	2.9	2.4	2.5	1.6	1.2	0.5
Lyon	14.4	0.1	0.2	0.7	1.3	1.8	2.5	2.1	2.1	1.4	1.0	0.7	0.2
Madison	19.7	0.3	0.4	1.0	1.8	2.5	2.8	2.7	2.4	2.3	1.5	1.1	0.5
Mahaska	20.3	0.4	0.4	1.0	1.8	2.6	2.7	2.7	2.5	2.4	1.6	1.3	0.6
Marion	20.1	0.3	0.4	1.0	1.9	2.6	2.7	2.7	2.5	2.3	1.6	1.2	0.5
Marshall	19.6	0.3	0.4	1.0	1.6	2.4	3.1	2.8	2.7	2.0	1.4	1.2	0.5
Mills	18.7	0.3	0.3	1.0	1.7	2.6	2.7	2.8	2.3	2.1	1.4	0.9	0.4
Mitchell	18.5	0.3	0.3	0.8	1.7	2.2	2.9	2.7	2.8	2.0	1.3	1.0	0.4
Monona	16.5	0.2	0.3	0.9	1.6	2.3	2.6	2.4	2.1	1.7	1.2	0.7	0.3
Monroe	20.9	0.4	0.5	1.1	1.8	2.6	2.7	3.0	2.4	2.5	1.6	1.3	0.6
Montgomery	20.0	0.3	0.4	1.1	1.8	2.6	2.8	2.9	2.4	2.4	1.5	1.1	0.5
Muscatine	20.4	0.5	0.5	1.2	1.8	2.3	2.6	2.6	2.6	2.2	1.5	1.3	0.8
O’Brien	15.6	0.2	0.3	0.8	1.5	2.0	2.7	2.3	2.4	1.5	1.0	0.7	0.2
Osceola	15.2	0.1	0.2	0.8	1.4	1.9	2.6	2.1	2.3	1.5	1.0	0.7	0.2
Page	20.2	0.3	0.4	1.1	1.7	2.6	2.8	3.0	2.4	2.3	1.5	1.1	0.4
Palo Alto	16.5	0.2	0.2	0.8	1.5	2.0	2.7	2.5	2.5	1.6	1.2	0.8	0.3
Plymouth	14.4	0.1	0.2	0.8	1.4	2.0	2.4	2.1	1.9	1.4	1.1	0.7	0.2
Pocahontas	17.3	0.2	0.3	0.9	1.6	2.1	2.8	2.6	2.5	1.8	1.2	0.8	0.3
Polk	19.3	0.3	0.4	1.0	1.7	2.4	2.9	2.7	2.6	2.0	1.4	1.1	0.5
Pottawattamie	18.6	0.2	0.3	1.0	1.7	2.6	2.7	2.8	2.2	2.1	1.3	1.1	0.4
Poweshiek	20.0	0.4	0.4	1.0	1.8	2.5	2.8	2.7	2.7	2.3	1.5	1.3	0.5
Ringgold	20.4	0.3	0.4	1.1	1.7	2.6	2.7	3.0	2.4	2.5	1.7	1.2	0.5
Sac	17.6	0.2	0.3	0.9	1.6	2.3	2.8	2.5	2.3	1.9	1.2	0.8	0.3
Scott	20.1	0.5	0.5	1.2	1.8	2.3	2.7	2.3	2.6	2.0	1.5	1.3	0.8
Shelby	18.4	0.3	0.3	1.0	1.7	2.4	2.7	2.6	2.2	2.3	1.4	0.9	0.4
Sioux	14.7	0.2	0.2	0.8	1.3	1.9	2.5	2.1	2.1	1.4	1.0	0.7	0.2
Story	19.4	0.3	0.3	1.0	1.6	2.4	3.1	2.9	2.7	1.9	1.4	1.1	0.4
Tama	19.9	0.3	0.4	1.0	1.7	2.4	3.1	2.7	2.6	2.1	1.4	1.2	0.5
Taylor	20.5	0.3	0.4	1.1	1.7	2.6	2.7	3.1	2.4	2.5	1.6	1.2	0.5
Union	19.9	0.3	0.4	1.0	1.8	2.6	2.7	2.9	2.3	2.4	1.5	1.2	0.5
Van Buren	21.2	0.5	0.5	1.2	1.9	2.7	2.5	2.8	2.3	2.5	1.6	1.4	0.8
Wapello	20.7	0.4	0.5	1.1	1.8	2.6	2.6	2.9	2.4	2.5	1.6	1.3	0.6
Warren	19.8	0.3	0.4	1.0	1.9	2.6	2.8	2.7	2.4	2.2	1.5	1.1	0.5
Washington	20.1	0.4	0.4	1.1	1.7	2.5	2.6	2.7	2.5	2.3	1.5	1.3	0.7
Wayne	21.0	0.4	0.5	1.1	1.8	2.6	2.7	3.1	2.4	2.6	1.7	1.3	0.6
Webster	18.4	0.3	0.3	0.9	1.7	2.3	3.0	2.7	2.5	1.9	1.3	0.9	0.4
Winnebago	17.2	0.2	0.2	0.8	1.6	2.2	2.8	2.6	2.7	1.7	1.2	0.8	0.3
Winneshiek	18.9	0.3	0.3	0.9	1.8	2.1	2.7	2.6	2.9	2.0	1.3	0.9	0.4
Woodbury	15.5	0.2	0.3	0.8	1.5	2.1	2.4	2.2	2.0	1.5	1.1	0.7	0.3
Worth	18.0	0.3	0.3	0.9	1.6	2.2	2.8	2.6	2.7	1.9	1.3	0.9	0.3
Wright	18.2	0.2	0.3	0.9	1.6	2.2	3.1	2.6	2.5	1.8	1.3	0.9	0.4

10- and 25-Year – 5-Minute Precipitation Event by County (inches)

County	Precipitation Event		County	Precipitation Event	
	10 Year	25 Year		10 Year	25 Year
Adair	0.55	0.67	**Jefferson**	0.56	0.68
Adams	0.55	0.67	**Johnson**	0.53	0.65
Allamakee	0.52	0.61	**Jones**	0.53	0.65
Appanoose	0.56	0.69	**Keokuk**	0.56	0.68
Audubon	0.52	0.63	**Kossuth**	0.53	0.64
Benton	0.53	0.65	**Lee**	0.56	0.68
Black Hawk	0.52	0.61	**Linn**	0.53	0.65
Boone	0.51	0.62	**Louisa**	0.56	0.68
Bremer	0.52	0.61	**Lucas**	0.56	0.69
Buchanan	0.52	0.61	**Lyon**	0.50	0.61
Buena Vista	0.50	0.61	**Madison**	0.56	0.69
Butler	0.53	0.64	**Mahaska**	0.56	0.68
Calhoun	0.52	0.63	**Marion**	0.56	0.69
Carroll	0.52	0.63	**Marshall**	0.51	0.62
Cass	0.55	0.67	**Mills**	0.55	0.67
Cedar	0.53	0.65	**Mitchell**	0.53	0.64
Cerro Gordo	0.53	0.64	**Monona**	0.52	0.63
Cherokee	0.50	0.61	**Monroe**	0.56	0.69
Chickasaw	0.52	0.61	**Montgomery**	0.55	0.67
Clarke	0.56	0.69	**Muscatine**	0.53	0.65
Clay	0.50	0.61	**O'Brien**	0.50	0.61
Clayton	0.52	0.61	**Osceola**	0.50	0.61
Clinton	0.53	0.65	**Page**	0.55	0.67
Crawford	0.52	0.63	**Palo Alto**	0.50	0.61
Dallas	0.51	0.62	**Plymouth**	0.50	0.61
Davis	0.56	0.68	**Pocahontas**	0.50	0.61
Decatur	0.56	0.69	**Polk**	0.51	0.62
Delaware	0.52	0.61	**Pottawattamie**	0.55	0.67
Des Moines	0.56	0.68	**Poweshiek**	0.51	0.62
Dickinson	0.50	0.61	**Ringgold**	0.56	0.69
Dubuque	0.52	0.61	**Sac**	0.52	0.63
Emmet	0.50	0.61	**Scott**	0.53	0.65
Fayette	0.52	0.61	**Shelby**	0.52	0.63
Floyd	0.53	0.64	**Sioux**	0.50	0.61
Franklin	0.53	0.64	**Story**	0.51	0.62
Fremont	0.55	0.67	**Tama**	0.51	0.62
Greene	0.52	0.63	**Taylor**	0.55	0.67
Grundy	0.51	0.62	**Union**	0.56	0.69
Guthrie	0.52	0.63	**Van Buren**	0.56	0.68
Hamilton	0.51	0.62	**Wapello**	0.56	0.68
Hancock	0.53	0.64	**Warren**	0.56	0.69
Hardin	0.51	0.62	**Washington**	0.56	0.68
Harrison	0.52	0.63	**Wayne**	0.56	0.69
Henry	0.56	0.68	**Webster**	0.51	0.62
Howard	0.52	0.61	**Winnebago**	0.53	0.64
Humboldt	0.53	0.64	**Winneshiek**	0.52	0.61
Ida	0.52	0.63	**Woodbury**	0.52	0.63
Iowa	0.53	0.65	**Worth**	0.53	0.64
Jackson	0.53	0.65	**Wright**	0.53	0.64
Jasper	0.51	0.62			

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Animal Waste Regulations Guide

All producers should be encouraged to be familiar with federal, state, and local laws, rules, and regulations, and as promulgated by the Iowa Department of Natural Resources (IDNR), Environmental Protection Agency (EPA), or others. This document provides links to the different sections within the IDNR Chapter 65 regulations for animal waste management. Links are also provided for other sources of regulatory related information.

IDNR Regulations – Quick Reference

Topic	IAC 567, Chapter 65 Section(s)
Confinement Operations – Division I	
Minimum Manure Control Requirements and Reporting of Releases	65.2
Dry Manure Stockpiling Requirements for Confinement Feeding Operation	65.2(10)
Dry Manure Stockpiling Requirements for a Dry Bedded Confinement Feeding Operation	65.2(11)
Requirements and Recommended Practices for Land Application of Manure	65.3
Construction Permits	65.7 – 65.10
Confinement Feeding Operation and Stockpile Separation Distance Requirements	65.11
Storage Structure Design Requirements	65.15
Manure Management Plan Requirements	65.16 – 65.17
Manure Applicators Certification	65.19
Open Feedlot Operations – Division II	
Minimum Open Feedlot Effluent Control Requirements and Release Reporting	65.101
Land Application	65.101(6)
NPDES Permits	65.104
Construction Permits	65.105
Settled Open Feedlot Effluent Basins – Investigation, Design, and Construction	65.109
Alternative Technology Systems – Design Requirements	65.110
Nutrient Management Plan Requirements	65.112
Other – Separation Distances	Tables 6(a-d) & 7 Pp 176-186

Note: CAFO or combined CAFO means a Concentrated Animal Feeding Operation as defined in rule 567 IAC 65.100(455B,459,459A). Operator or producer must combine same type of animals, in confinement buildings and open lot pens that are under common ownership or management. If the combined animal capacity meets the large CAFO or medium CAFO definitions, then your operation is a CAFO.

For Site-Specific Permit Determinations and Current Rulings Contact:

Your Area IDNR Field Office and a map of field offices –

(***http://www.iowadnr.gov/InsideDNR/DNRStaffOffices/EnvironmentalFieldOffices.aspx***)

or

Iowa Department of Natural Resources (http://www.iowadnr.gov/)
Environmental Protection Division – Animal Feeding Operations
(515) 281-5918

Manure Management & Regulation Resource Websites

Environmental Protection Agency – Animal Feeding Operations
http://cfpub.epa.gov/npdes/home.cfm?program_id=7

Iowa Department of Agriculture and Land Stewardship
http://www.agriculture.state.ia.us/

Iowa Legislature (Administrative Code)
http://www.legis.iowa.gov

IDNR – Animal Feeding Operations
http://www.iowadnr.gov/Environment/LandStewardship/AnimalFeedingOperations

Iowa Manure Management Action Group
http://www.agronext.iastate.edu/immag/

MidWest Plan Service
http://www.mwps.org/

Natural Resources Conservation Service - Iowa
http://www.ia.nrcs.usda.gov/

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Emergency Action Plans

All producers should be encouraged to develop an Emergency Action Plan (EAP) to help prepare themselves, their employees, and/or individuals that may work at the facility for the possibility of an accident or emergency situation.

An emergency action plan should contain, at minimum, four items: action plan, detailed maps of the site, list names and contacts for personnel involved with the operation, and emergency personnel (fire, rescue, and etc. contact information). The phone numbers, directions to site, and E-911 address should be visibly posted near phones and entrances/exits.

A copy of a template EAP is available for download from the Internet at the following Iowa State University Extension website: **http://www.extension.iastate.edu/Publications/PM1859.pdf**

It is recommended to keep a copy of the EAP with the comprehensive manure or nutrient management plan or records, production records, or somewhere that is easily accessible to the producer, family members, or employees.

The plan shall indicate the actions that need to be taken quickly to reduce the impact of various emergencies. A well-designed and implemented EAP can reduce the severity of an emergency, reduce risk to humans and animals, reduce economic losses, and reduce the potential of environmental contamination. Having a response plan and spill kit, for example, can help when an unintentional manure spill occurs. Having a loader tractor or hay bales available will assist in the creation of retaining dams in a drainage way to reduce runoff to provide temporary containment of a manure spill. The plan shall consider all possible emergencies including: catastrophic animal mortality, weather-related emergencies (flooding, tornados, etc.), utility related failures (electrical, plumbing, etc.), or other mechanical failure at the site.

When a livestock production system includes manure storage, the plan shall include reminders about the dangers associated with entry into the storage and manure transfer area enclosed spaces for any purpose is strictly prohibited unless proper self-contained breathing apparatus is used. Agitation of under-building storage without proper building ventilation (maximum ventilation) may result in dangerous conditions for both humans and animals in the upper portions of the building.

Producers should be encouraged to contact the local emergency response personnel to evaluate the facility and determine areas where self-contained breathing apparatus may be required for future emergencies.

In an event of a manure spill or leak, every effort possible should be made to prevent the movement of manure off-site. If necessary, contact neighbors or nearby contractors that have earth-moving equipment available to assist with containment. If tile intakes are present, have devices on hand to cover or surround intakes to prevent manure from entering the tile lines. Contact neighbors with manure handling equipment to land-apply the spilled manure. Prevent manure from entering bodies of water or other environmentally sensitive areas such as sinkholes or agricultural drainage wells.

For assistance contact the local law enforcement agency or other emergency response personnel in the county. **State law requires that a manure spill or leak be reported to the Iowa Department of Natural Resources within 6 hours of noticing the problem (have contact number in plan).**

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Biofilters for Livestock Facility Odor Control

The purpose of this document is to provide more details concerning the design, construction, and maintenance of biofilters for odor control. Biofilters are composed of organic materials (woodchips and compost) which support microbes that remove odorous compounds from ventilation streams. Most common type of biofilter is the open-bed biofilter, which is exposed to the elements on the outside of the building.

Important elements in biofilter design and operation are ventilation, odorous contaminants and concentrations, media properties, biofilter size, moisture control, maintenance, and cost.

- Ventilation - Biofilters are generally sized to treat the maximum ventilation rate, i.e. the warm weather rate. A source of recommended ventilation rates can be found in MWPS-32 (Mechanical Ventilating Systems for Livestock Housing - Midwest Plan Service).
- Media – Important characteristics of the media include porosity, moisture holding capacity, nutrient content, and must have a slow decomposition rate. Typical mixtures of 20:80 to 40:60 ratio of compost to woodchips are recommended with a depth of 10 – 18 inches. A media life of 5 to 8 years can be assumed, the bed needs to be replaced once the media pore space decreases to the point where air has difficulty passing through the media.
- Biofilter Sizing – The volumetric flow rate (Q) (ft^3), Empty Bed Contact Time (EBCT) (seconds), and media depth (inches) are needed to determine the biofilter surface area. Media Volume, V_m, can be determined as follows: $V_m = Q*EBCT/60$. Biofilter area, A_m, (ft^2) can then be found by the following: $A_m = V_m/D_m$, where D_m is the media depth (ft). If space is limiting see other design references for more information on design criteria.
- Fan Selection – Fans must be able move air through the building and through the biofilter. Typical agricultural fan must be selected to handle of a pressure resistance of 0.1 to 0.12 inches of H_2O through the building. Biofilters may have an additional pressure resistance of 0.1 to 1.0 inches of H_2O through the filter media. Existing building fans may need to be replaced to handle the demands of the biofilter.
- Moisture Content – Bed media moisture content should be kept between 40 to 60%, on a wet basis, for optimal treatment. Moisture can be maintained with a garden sprinkler or soaker hose and a timer to facilitate automatic watering.
- Construction – Biofilters consist of ducts made of smooth and resistant materials (plywood) and a plenum to support the media. Ductwork connects the pit and/or wall ventilation to the biofilter plenum. The plenum is the structure underneath the bed that allows for air distribution and supports the biofilter media. Plenums have been made out of pallets with a mesh or screen on top to prevent the media from falling into the plenum.
- Costs – It is estimated that new biofilter costs $150 to $250 per 1,000 cfm for mechanically ventilated buildings. Operation and maintenance costs are estimated to be $5 to $10 per 1,000 cfm per year of operation.
- Maintenance – Biofilter maintenance involves maintaining proper moisture levels, weed removal, rodent control, and media bed pressure drop monitoring.

Resources: FS 925-C, Biofilters. 2005. Richard Nicolai and David Schmidt. South Dakota State University. Available at: http://pubstorage.sdstate.edu/AgBio_Publications/articles/FS925-C.pdf.

Biofilters for Odor Control. 2000. David Schmidt, et.al. University of Minnesota Extension. Available at: http://www1.extension.umn.edu/agriculture/manure-management-and-air-quality/air-quality/ for information.

Biofilter Design Information. 2004. David Schmidt, et.al. University of Minnesota Extension. Available at: http://www1.extension.umn.edu/agriculture/manure-management-and-air-quality/air-quality/biofilter-design-information/

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Vegetated Treatment Area Planning and Design

The purpose of this document is to provide guidance and resources concerning the design, construction, and maintenance of Vegetated Treatment Areas (VTAs) – (635). A VTA is an area of permanent vegetation used for the treatment of agricultural waste. The purpose of a VTA is to improve water quality by reducing the loading of nutrients, organics, pathogens, and other contaminants associated with livestock and other agricultural operations. VTAs may treat runoff originating from feedlots, compost areas, barnyards, and other livestock holding areas or treat process wastewater from other agricultural operations.

Design the VTA based on the need to treat the 25-year, 24-hour storm event from the agricultural animal management facility. Base the total treatment area for the VTA on the soil's capacity to infiltrate and retain runoff within the root zone and the vegetation's agronomic nutrient requirements. If the design or management objectives will not allow the complete infiltration of the volume of the design storm, then the volume not infiltrated shall be stored for future utilization or treatment.

Appropriate sections from the "Vegetative Treatment Systems for Open Lot Runoff" report compiled for the USDA-NRCS in June 2006 by a consortium of organizations is attached. These sections provide guidance on the planning, siting, design, construction, and operation and maintenance of VTAs. The specific sections are noted below.

Section 3 – System Options Based Upon Vegetated Treatment Areas

Section 4 – Siting Criteria for Vegetative Treatment Systems

Section 5 – Liquid – Solid Separation

Section 6 – Vegetative Treatment Area Design

Section 8 – Management Guidelines for Vegetative Treatment Systems

Appendix B – How Much Runoff Will Come from the Feedlot?

Appendix C – Example Sizing of Settling Basin

Appendix E – Tolerance Factors (for forages and legumes)

Appendix F – Records for VTA Systems

This guidance is to be used for open lot operations with less than 1,000 Animal Units (AU's) and are not required to have a National Pollutant Discharge Elimination System (NPDES) permit.

For open lot operations greater than 1,000 Animal Units or required to have an NPDES permit contact the State Conservation Engineer for direction regarding the design and implementation of a vegetated treatment area.

Section 3 System Options Based upon Vegetated Treatment Areas

Section 3 System Options Based upon Vegetated Treatment Areas

Contents

Tables

Figures

Section 3 System Options Based upon Vegetated Treatment Areas

Topics

- Common plant based treatment options
- Common systems involving VTAs

Purpose

VTSs will be considered by permitting authorities under the Voluntary Alternative Performance Standards of the ELG CAFO regulations. VTS application will be based upon the ability of a large CAFO to document that this alternative technology will meet or exceed the performance of baseline technologies (containment and land application). Chapter 3 reviews several systems utilizing a VTA or VIB as part of a system for managing runoff for their potential to be permitted under the CAFO regulations.

The work group that prepared this report determined that successful applications of a VTA to CAFOs requires:

- Systems providing multiple levels of treatment
- Passive or active management of release of liquids into a VTA
- Some level of short-term storage

These features are illustrated in six systems described in this report, four of which are believed to provide the greatest opportunity for success in large CAFO applications.

Common plant-based treatment options

Ikenberry and Mankin (2000) defined a vegetated filter as a band of planted or indigenous vegetation situated downslope of cropland or animal production facilities that provide localized erosion protection and contaminant reduction. Pasture, grassed waterways, or cropland (preferably with perennial vegetation) with planted or indigenous vegetation may be used to treat runoff through filtration, adsorption, settling, and infiltration.

The terminology VTS is used to refer to plant-based treatment systems (typically perennial grass or forage crops) intended to reduce environmental risk associated with runoff and other process waters from an open lot livestock system. These systems perform treatment functions including solids settling, soil infiltration, and filtering (soil biological and chemical treatment), thus, the term *treatment* is used as opposed to *filter*.

Several alternative types of plant based treatment components may be used in a VTS:

- *VTAs*—Perennial grass and forage filters can be applied to lower sloping land (sec. 6). Woody plants, trees, and annual forages may provide alternative plant materials for VTA, although, there is less experience with these plant materials. Total treatment area should be designed to match: (1) crop nitrogen uptake with estimated N in runoff or (2) volume of water runoff with soil infiltration capacity. Typically, the nutrient balance approach is the limiting design sizing method. Uniform flow across the vegetated slope is necessary, possibly requiring laser-guided land leveling equipment and other design considerations for distributing flow, as well as field maintenance to limit erosion and channeling.
- *Terraced VTAs* have been used to contain runoff on sloped areas. Both overflow and serpentine terraces have been used. Overflow terraces move runoff from one terrace to a second by cascading of runoff over the terrace top or by plastic tile drains. Serpentine terraces move runoff back and forth across the face of a slope. In both situations, the upper terrace is typically used for solids settling with succeeding terraces intended to encourage infiltration of liquids into the soil. Terraced systems are considered a sub-category of VTAs and may provide an optional approach for open lot systems located in steeper terrain.
- *VIBs* have many similarities to VTAs with the exception that they include sub-surface drainage and complete enclosure by a berm designed to prevent surface discharges (sec. 7). Runoff from an open lot is allowed to infiltrate through a soil system within 72 hours or less. Soil systems allow plant uptake of nutrients and water and soil chemical and biological properties for treatment of many pollutants. Systems generally use tile drainage to recover partially treated runoff, thereby, reducing ground water contamination. The collected drainage can be discharged to a VTA or other treatment system. Typically VIBs have used soil as the infiltration media. However, sand and organic matter beds, possibly without vegetation, can also be utilized to filter many contaminants in runoff.
- *Constructed wetlands* have been utilized to treat open lot runoff. Design and management is challenged by intermittent flow from open lots with resulting difficulty in maintaining wetlands function. Seasonal open lots used for winter livestock housing and empty during the summer may be a preferred system for constructed wetlands. Constructed wetlands are recognized as an alternative but are not discussed in detail in this publication. (For additional information on constructed wetland application to animal effluents, see Payne, 1992 and Gulf of Mexico Program, 1997.)

Most VTA systems rely on sedimentation for reducing pollutant concentration and infiltration to reduce runoff and pollutant mass. However, these systems typically are not designed to prevent discharge for all storm events. Extensive research has been conducted on solids and nutrient removal by VTA systems. Typically, VTAs remove 50 to 90 percent of most contaminants associated with runoff. With careful sizing of a VTA and controlled release of runoff, a VTA can eliminate most releases of contaminants.

Less research and field experience with VIBs is currently available. A 5-year study of a VIB on an Iowa State University feedlot has suggested removal of 70 to 90 percent of most contaminants from feedlot runoff prior to its collection of infiltrate by tile drain system.

The one exception to these reductions is with nitrate. In runoff, nitrate concentration is typically negligible. The aerobic environment in a VTA and VIB allows some conversion of ammonium to low concentrations of nitrate (commonly less than 10 ppm) during the treatment processes. Management of nitrate in the liquids released from a VTA and VIB will need to be considered. More detailed information on performance of VTAs and VIBs is presented in section 9, Literature Review.

Common VTS options

A VTS is a combination of treatment components, including plant-based treatment options and a management strategy. Assembling of an acceptable *system* is critical to minimizing environmental risk and obtaining a permit under the CAFO regulations. Permit requirements are more restrictive for VTS applications on large CAFOs than for small and medium CAFOs or unpermitted AFOs. Selecting an appropriate system for large CAFOs is the focus of this section.

The following discussion reviews six systems for their ability to minimize the potential for an unplanned release and to meet the CAFO requirements. Other options are possible including options that involve constructed wetlands. Ultimately, the opportunity for each option to be applied to a large CAFO will be based upon the site-specific performance comparison provided by the producer as part of the permit application. Thus, one limit on system options is the ability of the system to be modeled using weather data over a 25-year period.

All options will include pre-treatment by solids settling. Solids settling prior to a VTA or VIB is essential to sustaining performance within the vegetative area. Without solids settling, excess solids accumulation in the upper end of the VTA or VIB will lead to greater short circuiting of liquids, uneven distribution of nutrients, and loss of healthy vegetation.

Selecting the appropriate management strategy for controlling release of runoff is an important consideration for a successful system. The risk of a discharge from a VTA is significantly greater if feedlot runoff enters the VTA simultaneously with rainfall directly falling on the VTA. The infiltration rate of the soil can be overwhelmed with the two simultaneous sources of water. Delaying or limiting the release of runoff liquids until after the storm event reduces the potential of a discharge from a VTA. Three primary management strategies will be considered as part of the system:

- *Unrestricted runoff release.* The outlet of the settling basin is not restricted because of limited or no storage capacity in the settling basin. Runoff release is designed to match the peak flow rate of liquids into the settling basin when the basin is nearly full.
- *Passive runoff release control.* The outlet of the settling basin is restricted to delivering runoff slowly over a 36- to 72-hour period. The settling basin must be sized to handle a 25-year, 24-hour storm.

- *Active runoff release control.* The outlet of the settling basin can be physically controlled so that the manager determines the best timing for the release of basin liquids, presumably when the VTA soil conditions are most appropriate. This approach requires that the settling basin have sufficient capacity for normal runoff, as well as that necessary to handle a 25-year, 24-hour storm.

Cost share assistance may be available for systems involving a VTA or VIB. The NRCS Environmental Quality Incentives Program (EQIP) and Conservation Innovation Grant programs provide competitive cost share assistance. Many State environmental agencies provide low interest rate loan programs to industry. Program guidance and technical assistance may also be available from the local NRCS office.

Option 1: VTA and solids settling

Our base system is a settling basin followed by a grass treatment area with modest storage in the system (fig. 3–1). Settling of solids is essential to the successful management of any VTS. The basin typically would be sized to hold runoff from a high intensity storm for a 1-hour period or less (sec. 5). The liquid level in the settling basin would be passively managed. Flow rate from the basin to the grass system is controlled by design of the outlet pipe(s). The manager would not have control over timing and release rate of runoff.

Following settling of most suspended manure solids and soil, runoff water would be distributed uniformly over a grass treatment area. Sizing of this system would be based upon either nutrient balance or water balance within the VTA. Potential alternative VTAs would include a constructed wetland or a terraced VTA.

Large CAFO application: Potential to discharge is high. Sizing of VTA is critical to minimizing treated releases from VTA. Model comparison of option 1 with baseline technology will provide final determination of potential for this option to be applied to large CAFOs.

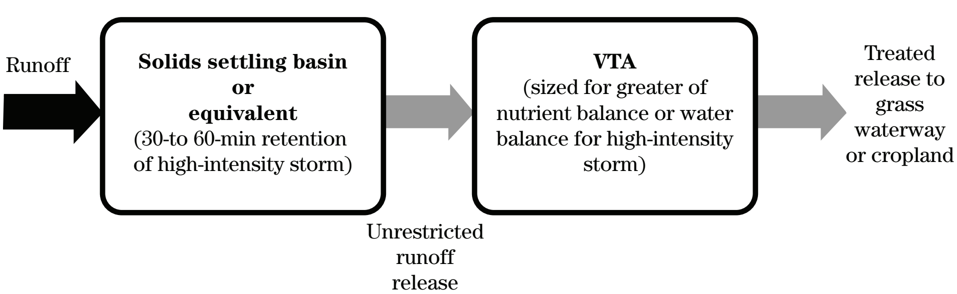
Small or medium CAFO application: Option 1 systems may reduce risk sufficiently to potentially prevent an AFO from being designated as a CAFO. The permitting authority should be consulted in any application of this system to AFOs that may have a direct connection to surface waters. This system alone may not be acceptable in all states or situations for cost share assistance from state or USDA conservation programs.

AFO application: For AFOs with sufficient distance or a lack of a direct connection to surface waters, the base system should be acceptable for most situations.

Advantages of option 1 system

- This system will eliminate some costs for land application of runoff from the open lot including management inputs for scheduling irrigation and equipment requirements for more expensive sprinkler irrigation system. However, a well-functioning VTA or VIB will require other critical management inputs (sec. 8), as well as similar levels of inputs associated with utilization of solids collected in the solids settling component.
- The cost of a settling basin component should be substantially less than the cost of a traditional storage basin.
- Because settling basins typically drain completely or with minimal retained volume, less potential for pollutant leaching (especially nitrate) to ground water and air emissions would be expected. In addition, abandonment of such facilities would likely present fewer costs and environmental challenges.

Figure 3–1 Option 1: VTA and solids settling



Disadvantages of option 1 system

- Treated discharges from this system are common, especially if size is not adequate. During major storms the grass treatment area will be receiving wastewater from the settling basin while saturated VTA conditions exist due to rainfall on the VTA. Open lot runoff events associated with frozen soil conditions would also produce potential conditions for runoff from the VTA. In many regions of the country, high-intensity rainfall events or extended wet periods during spring and summer produce the greatest potential for discharge.
- The footprint of a VTA will be greater than that of a runoff holding pond.
- Research has shown that small storms may not create sufficient flow to distribute the contaminated runoff over the VTA and will result in overloading of the VTA near the outlet from the settling basin.
- Grass systems tend to filter most solids and nutrients within the first 50 feet from the liquid inlet due to settling and contact with vegetation especially if solids settling is not included or undersized. This may contribute to high nutrient loads in the upper end of a VTA. Management considerations for monitoring and addressing nutrient loading issues are addressed in section 8.

Option 2: VTA replaced by VIB

Option 2 replaces the VTA with a VIB (fig. 3–2). No direct surface water discharge would result from this system for storm events up to a 25-year, 24-hour storm. Some discharge would be expected from the tile drain system of the VIB. The settling basin and VIB would provide better assurance of a consistent level of treatment (typically 90% or more of contaminant mass removal from feedlot runoff) even for major storm events or chronic wet periods. All runoff will infiltrate through 4 to 6 feet of soil prior to discharge.

The VIB also delays the start of the discharge to the grassed waterway or cropland for several hours and spreads the discharge out over a significantly longer time, thus reducing the chance that feedlot runoff will be discharged during the storm event.

Large CAFO application: Potential to discharge treated shallow ground water to surface water is high. The treatment efficiency of the VIB alone may not equal the performance of the baseline technology. Model comparison of Option 2 with baseline technology will provide final determination of potential for this option to be applied to large CAFOs.

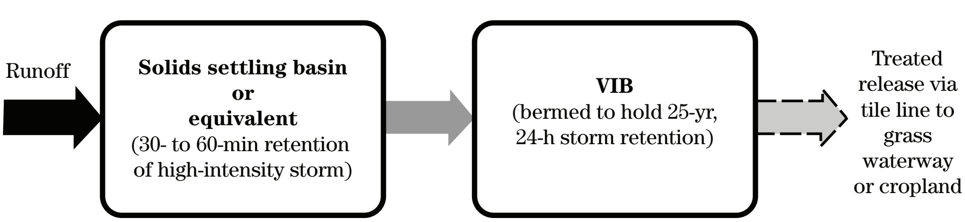
Small or medium CAFO application: This option should provide more consistent treatment than Option 1 and be applicable to many AFOs, preventing their definition or designation as a CAFO. The permitting authority should be consulted in any application of this system to AFOs that may have a direct connection to surface waters. The VIB may not be acceptable in all states or situations for cost share assistance from state or USDA conservation programs.

AFO application: For AFOs, option 2 should be acceptable for most situations.

Advantages of option 2 system

- This system should provide a more consistent level of pollutant reduction in all pollutants for a wide range of storm events, chronic wet periods, and frozen soil conditions.
- This system retains most of the advantages of Option 1 including low capital cost, low operation and maintenance cost for land application of runoff, minimal air quality concerns, and, if appropriate sites are selected for VIB, limited risk to ground water (see sec. 7 on VIBs).

Figure 3–2 Option 2: VTA replaced by VIB



Disadvantages of option 2 system

- Discharges from this system would be expected, but only after runoff has passed through settling basin and 4 to 6 feet of soil filtration.
- Ground water discharge from VIB will contain some pollutants, likely only 10 percent or less of the mass of pollutants in the original feedlot runoff. However, discharge from the VIB will still exceed concentrations acceptable for surface waters.
- Site-specific conditions will not allow VIBs to function in all soil conditions. Generally, a more restrictive soil layer is needed below the tile line within the VIB.

Option 3: Option 1 plus VIB

Option 1 has been enhanced with the addition of a VIB to the system (fig. 3–3). This approach is to ensure that no feedlot runoff is discharged from the system without first having three levels of treatment. In addition, no direct surface water discharge of runoff would be anticipated for storm events less than a 25-year, 24-hour storm due to the storage capacity in the VIB.

The VIB also delays the start of the discharge from the VIB to the VTA for several hours and spreads the discharge out over a significantly longer time (passive runoff release), thus reducing the opportunity for feedlot runoff to enter the VTA during the storm event.

Large CAFO application: Option 3 meets the ELG design size requirements of the CAFO ELG for baseline systems. It is attractive option for some large CAFOs because of its ability to minimize the risk of a discharge from the VTA plus provide substantial treatment for any releases that might occur. The permitting authority should be consulted early in the process to see if this system meets the requirements of the baseline ELG or will need to qualify under the voluntary alternative performance standards.

Small or medium CAFO application: Option 3 should be an acceptable option for many potential small or medium CAFOs. The permitting authority should be consulted in any application of option 3.

AFO application: Option 3 should be acceptable for all AFOs.

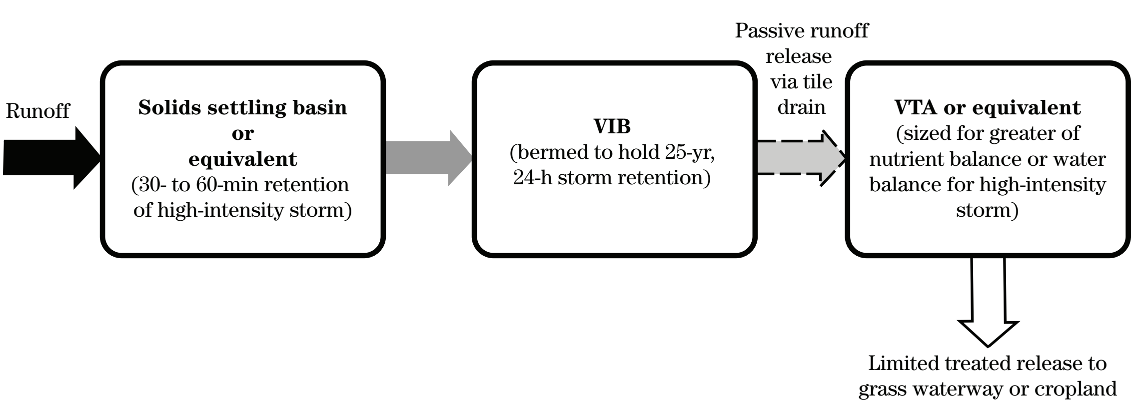
Advantages of option 3

- This system retains most of the advantages of option 1 including low operation and maintenance cost for land application of runoff, minimal air quality concerns, and limited risk to ground water if only appropriate sites are selected for VIB (see sec. 7 on VIBs).
- Potential for surface water discharges of feedlot runoff should be far less than with options 1 and 2 and equal to or less that potential for discharge from a baseline basin and irrigation system for many open lots.

Disadvantages of option 3

- The increased complexity of this system has likely eliminated some of the capital cost benefits of plant based treatment systems.
- Site-specific conditions will not allow VIBs to function in all soil conditions. Generally, a more restrictive soil layer is needed below the tile line within the VIB.

Figure 3–3 Option 3: Option 1 plus VIB



Option 4: Option 1 with storage included in settling basin

This system is similar to option 1, but design of the solid settling basin has two distinctive differences (fig. 3–4):

- Storage is included in the solids settling basin. Storage volume sized to meet the needs for a 25-year, 24-hour storm event and/or winter and early spring runoff could be included depending upon safety factor desired. The settling basin now has a volume of similar size to that of a standard runoff retention pond. However, this storage and settling basin may be a long, relatively shallow channel located down elevation from the bottom edge of the open lots for some systems as opposed to a rectangular pond.
- The outlet system for the settling basin allows the manager to control timing of runoff release to the VTA (active release control) or be carefully restricted to allow a release over a 36- to 72-hour period (passive release control).

Large CAFO application: Option 4 meets the ELG design size requirements of the CAFO ELG for baseline systems. It is attractive option for many large CAFOs because of its ability to minimize the risk of a discharge from the VTA. The permitting authority should be consulted early in the process to see if this system meets the requirements of the baseline ELG or will need to qualify under the voluntary alternative performance standards.

Small or medium CAFO application: Option 4 should be an acceptable option for many potential small or medium CAFOs. The permitting authority should be consulted in any application of option 4.

AFO application: Option 4 should be acceptable for most situations fitting this category.

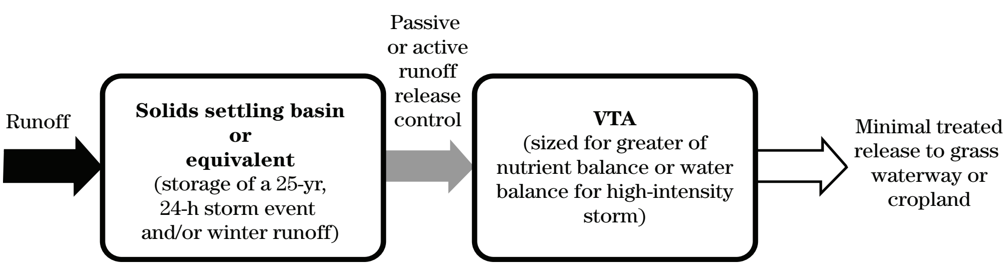
Advantages of option 4

- This system retains some of the advantages of option 1 including low operation and maintenance cost for land application of runoff (especially for a passive runoff release control) and minimal air quality concerns (passive runoff release control only).
- Storage in the settling basin will delay most (passive release control) or all (active release control) runoff addition to the VTA until the storm event has passed, minimizing discharges from the VTA during major or chronic storms or during frozen soil conditions.
- If sized correctly, the solids separation and storage basin could serve as a traditional storage basin if the VTA failed to perform as planned.

Disadvantages of option 4 (active release control)

- The size of the settling and storage basin will approach the size of the traditional storage basin and may have the same liner requirements and similar construction cost.
- The settling and storage basin will require a commitment to managing runoff release and maintenance of level gauges and records as required for traditional runoff control systems.
- The combination of settling and storage in the same structure has many management problems (difficulty with timely solids removal, damage to liner during solids removal, increased odors) and is typically not recommended for traditional systems.

Figure 3–4 Option 4: Option 1 with storage included in settling basin



Disadvantages of option 4 (passive release control)

- The size of the settling and storage basin will approach the size of the traditional storage basin.
- The settling and storage basin would require similar level gauges and records as required for traditional runoff control systems.
- The combination of settling and storage in the same structure has many management problems (difficulty with timely solids removal, damage to liner during solids removal, increased odors) and is typically not recommended for traditional systems.

Option 5: Option 1 with storage included in VTA

A partial or total berm around the VTA (similar to a VIB with no tile drainage) would be designed to minimize discharges from the system. The berm would need to create sufficient storage capacity for the open lot runoff, as well as the runoff from the settling basin and grass treatment area. Vegetation capable of withstanding occasional flooding would need to be selected.

Large CAFO application: Option 5 should minimize risk of discharge and improve the opportunity for this option to be approved under the ELG voluntary alternative performance standards. Ponding of effluent can create greater ground water risks causing concerns for state agencies that regulated ground water. The permitting authority should be consulted in any application of this system to a CAFO.

Small or medium CAFO application: Option 5 should be an acceptable option for most small or medium CAFOs. The permitting authority should be consulted in any application of option 5, especially where ground water issues are regulated.

AFO application: Option 5 should be acceptable for most situations fitting this category.

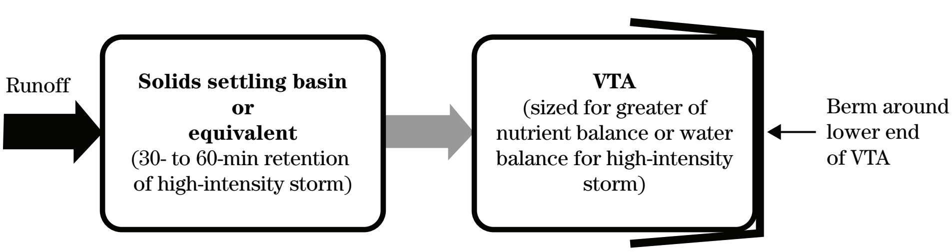
Advantages of option 5

- If the berm is sized properly for the 25-year, 24-hour storm, option 5 may meet the design size requirements of the ELG.
- This system retains most of the advantages of option 1 including low capital costs, low operation and maintenance cost for land application of runoff, and minimal air quality concerns.
- If the VTA has minimal slope, the storage within the VTA will provide improved distribution of the storm flows during major and chronic rainfall events.

Disadvantages of option 5

- Crop damage is possible if water due to ponding during major and chronic storms. Accumulated runoff during frozen soil conditions may also expose crop to submerged conditions for extended periods of time. During these periods, grass-based systems may become stressed, fail completely, or become displaced with undesirable species.
- The VTA may infiltrate runoff at times and rates that could lead to contamination of ground water (especially systems designed on a water balance as opposed to a nutrient balance).

Figure 3–5 Option 5: Option 1 with storage included in VTA



Option 6: Option 1 followed by storage basin

This system places the storage component after the VTA. It will also require a mechanical pumping and distribution system for transferring runoff back to the VTA. The active management of the irrigation of the VTA and the placement of the storage after the VTA should result in a truly *no-discharge* system.

Large CAFO application: Option 6 presents an additional alternative for most CAFOs that could meet all ELG requirements of the baseline technology. Nearly all risk of surface water discharge should be eliminated by this approach. The permitting authority should be consulted in any application of this system to a CAFO.

Small or medium CAFO application: Option 6 should be an acceptable option for most small or medium CAFOs. The permitting authority should be consulted in any application of option 6 to higher risk small and medium CAFOs.

AFO Application: Option 6 should be acceptable for most situations fitting this category.

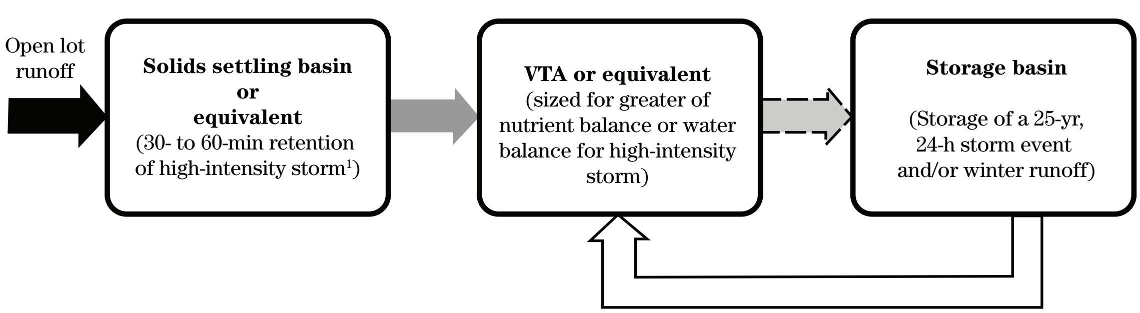
Advantages of option 6

- The system may be a true no-discharge system with advantages for surface water over the base system, as well as the traditional containment system. Option 6 meets the ELG design requirements of the CAFO regulations for beef and dairy systems and may not need to be permitted under the voluntary alternative performance standard.
- The treated wastewater stored in the storage basin will have little potential for odors or less potential for ground water contamination due to two stages of treatment before runoff is held in storage.

Disadvantages of option 6

- This system will have some significant cost and management time requirement associated with land application, possibly similar or greater than traditional systems.
- Remote power will be needed to recycle storage pond contents to VTA.
- The storage basin will have to be sized to store the effluent from the open lot, settling basin and the runoff from the VTA. This will require a larger storage basin than a traditional system.

Figure 3–6 Option 6: Option 1 followed by storage basin



1. Sizing for a 10-yr, 1-h storm may be preferable

Minimizing the potential to discharge

Two situations are commonly raised as having potential for producing a discharge from a VTS. First, during a storm event that last over an extended period, the runoff released from the solids settling into the VTA would coincide with precipitation falling on the VTA. The combination of feedlot runoff and direct precipitation could overwhelm the infiltration rate of the soil causing a potential discharge of diluted and partially treated feedlot runoff. Second, winter runoff events are a common concern, especially when soils are frozen.

To address the first situation when feedlot runoff and direct precipitation enter the VTA simultaneously, preferred system options will include significant storage in advance of the VTA (settling basin sized for a minimum 10-yr, 1-h storm or, preferably, a 25-yr, 24-h storm event) and either passive or active control of the settling basin release of liquid to the VTA (fig. 3–7). A VIB also slows the release of liquid into the VTA (similar to a passive runoff release) and extends the release over a much longer period of time, much of it after the storm event. A settling basin with an active runoff release can delay most runoff entry into the VTA until after the end of the storm events. Options 3 and 4 offer the preferred systems for controlling and delaying the runoff release into the VTA. Options 5 and 6 also minimize the risk of discharge by simply adding additional storage.

Winter runoff is typically associated with snowmelt or low-intensity rainfall events when the feedlot surface and VTA soils are frozen. The literature suggests that runoff associated with frozen soil conditions can be characterized as typically high in solids and low in volume. VTS options that include some storage should minimize a winter related runoff release into a VTA. System options 3, 4, 5, and 6 all include significant storage and may meet these criteria. A review of local weather records should provide additional insight as to a system's ability to store winter runoff. Comparing the precipitation related runoff for winter conditions with a settling basin capacity based upon a 10-year, 1-hour or 25-year, 24-hour storm event should provide some insight as to the need to release liquid into a VTA under frozen soil conditions.

A comparison for three sites in Nebraska (table 3–1) would suggest that the settling basin sized for a 25-year, 24-hour storm would be almost sufficient to handle all winter precipitation assuming 100 percent runoff and no release until spring. In reality, the average runoff of precipitation during December through March is less than 10 percent in Nebraska. A reasonable storage capacity of the settling basin or VIB in advance of a VTA should be able to minimize releases of liquid into a VTA under frozen soil conditions in Nebraska. A similar check for other sites should provide insight as the risk associated with frozen soil conditions.

If runoff must be release into the VTA under winter conditions, the sedimentation treatment role of a VTA is generally not restricted by dormant vegetation assuming that the VTA enters winter with thick vegetation. Some researchers have suggested thick matted vegetation in winter will equal or out-perform growing summer vegetation performance for encouraging settling. Fall VTA management is critical to achieving a desirable thick matted vegetation for winter treatment.

The infiltration treatment function of a VTA is lost if soils are frozen. Thus, all runoff would experience the normal reductions of solids and nutrients in the settling basin (about 50%) and VTA due to sedimentation (60 to 80%) for the few situations when runoff is released into a VTA when soil is frozen. However, frozen VTA soils create a significant potential for a discharge of the treated liquid runoff.

Thus, a VTS that includes some storage capacity and the ability to control release of runoff from the VIB or settling basin to the VTA should minimize the risk associated with these two more common higher risk situations.

Figure 3–7 Role of pre-treatment components of a vegetative treatment system (see options 3 and 4) for delaying and restricting flow in the VTA component

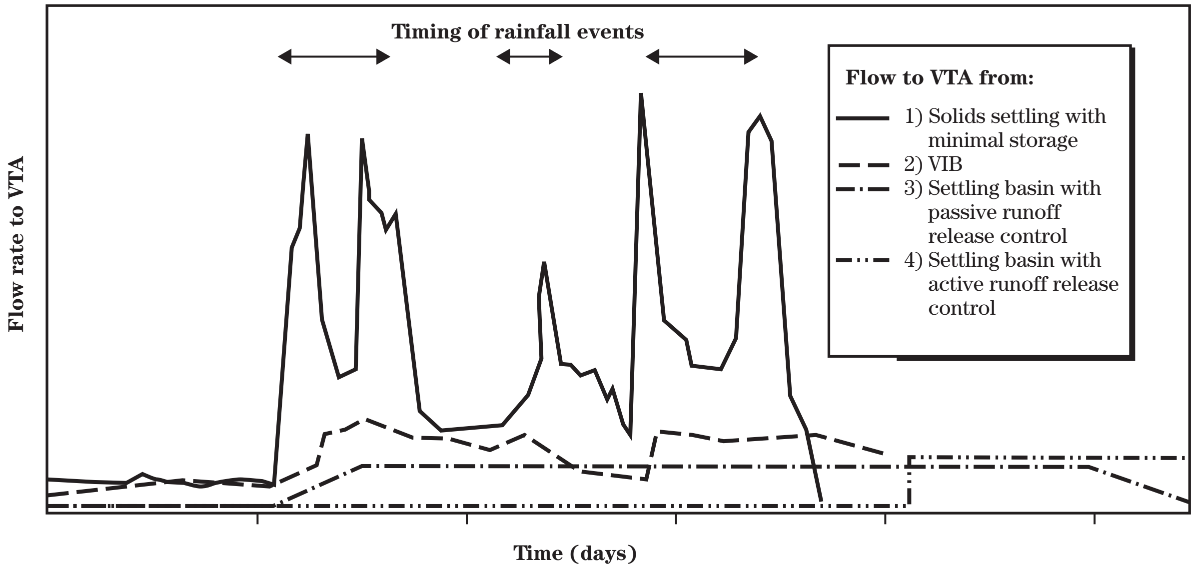


Table 3–1 Comparison of winter precipitation versus 25-yr, 24-h storm assuming settling basin was designed to contain such an event (references Soil Conservation Service 1992). Note settling basin capacity compares favorable to anticipated winter runoff.

	Eastern NE	Central NE	Western NE
Average winter runoff characteristics			
Precipitation (Dec – Mar)	4.4 in	3.6 in	2.6 in
Average runoff (Dec – Mar)	10%	<10%	<10%
Minimum settling basin capacity designed for:			
25-yr, 24-h storm	3.9 in	3.4 in	2.4 in
10-yr, 1-h storm	1.5 in	1.4 in	1.0 in

References

Ikenberry, C.D., and K.R. Mankin. 2000. Review of Vegetative Filter Strip Performance for Animal Waste Treatment. Presented at the 2000 ASAE Mid-Central Meeting, Paper No. MC00-128. American Society of Agricultural Engineers, St. Joseph, MI.

U.S. Department of Agriculture, Soil Conservation Service. 1992. Agricultural waste management field handbook. National Engineering Handbook. USDA Soil Conservation Service. *http://www.wcc.nrcs.usda.gov/awm/ awmfh.html*.

Section 4 Siting Criteria for Vegetative Treatment Systems

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Contents

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Topics

- Mapping of a potential VTA site
- Assessing ground water risks
- Assessing surface water risks
- Reducing odor nuisances
- Determining whether proposed site is acceptable

Introduction

Siting Criteria for Vegetative Treatment Systems identifies specific risk factors for reviewing a potential VTS site. Limits are not identified for any of these factors. Check with your state environmental agency or other appropriate conservation agencies for information on state-specific siting regulations or other limitations applicable to construction of a VTS.

Information from NRCS Agricultural Waste Management Field Handbook, Chapter 7, Geological and Ground Water Considerations and Chapter 8, Siting Agricultural Waste Management Systems is used in this section.

Purpose

VTSs typically offer significant value to siting runoff management systems within rural watersheds for open lot animal feeding facilities. These systems replace large holding ponds with natural grasslands or forage production areas which provide advantages for wildlife, reduce odors and other gaseous emissions, and enhance visual appearance of the livestock system.

However, VTS land requirements, as well as environmental risks associated with potential connection to surface and ground water, must be considered in the evaluation of a potential VTS site. Risk factors are introduced that should be closely evaluated during review of appropriate VTS site strengths and weaknesses. Some risk factors may be significant enough to eliminate a site from consideration for a VTS.

This section reviews key principles to be considered in siting of a VTA and related system components. Three steps should be considered in this process:

Step 1: Preparation of an overhead map of the area around the open lot livestock system including potential VTA sites and potential offsite impact areas

Step 2: Review of potential sites for environmental and neighbor risks

Step 3: Identification of a preferred site

Mapping a potential VTS site

Placement of a VTS to avoid unnecessary environmental and neighbor risks should begin by developing a map for use in evaluating potential sites. The following steps provide tools for use in potential site evaluation.

Step 1: Develop a base map of the area around the open lot system where a VTS is being considered (fig. 4–1).

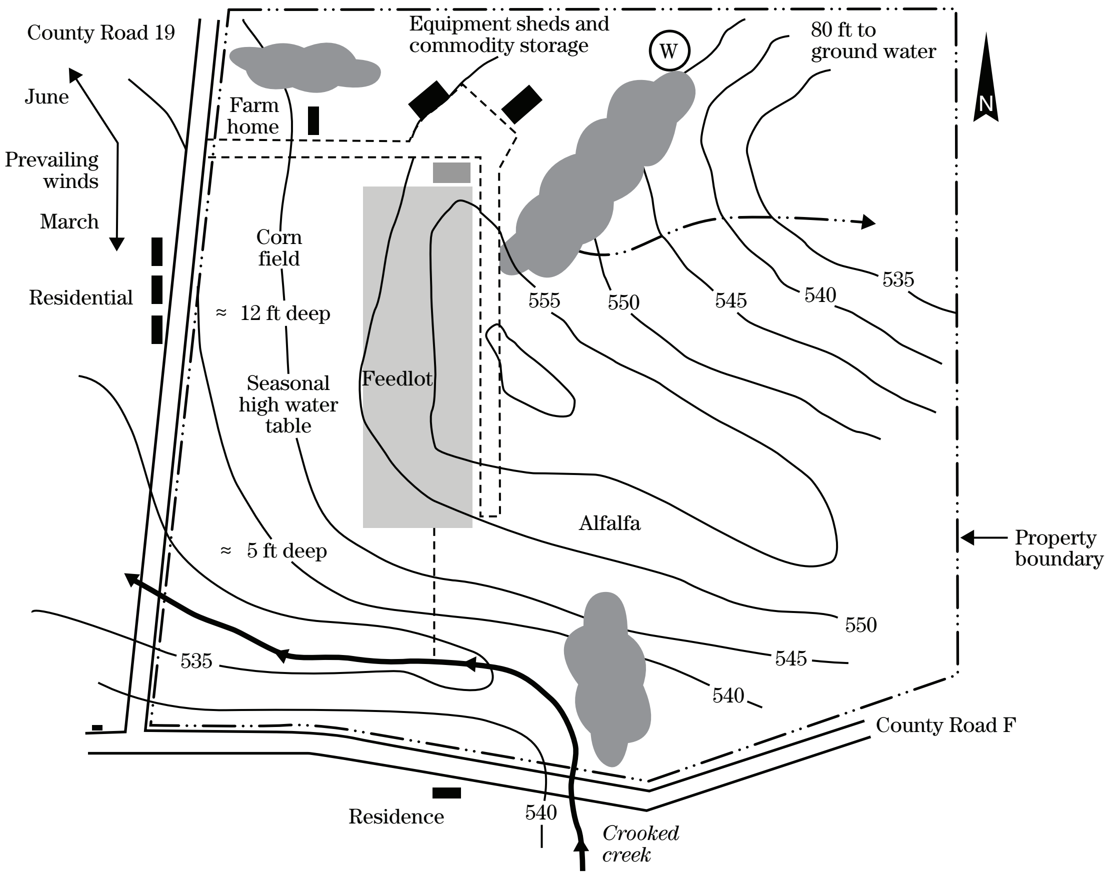
The planning process should begin with a base map. A topographic survey or aerial photograph is a preferred starting point. Potential sources of topographic maps are summarized in appendix A. Although the decision-maker's objectives will influence the scope and detail of the survey, the following data should be obtained and included on the map:

- Property lines, local roads
- Locations of adjacent residences, public facilities (schools, churches, parks), and business locations
- Positions of farm homes, buildings, other permanent structures, roads, and paved areas
- Edges of wooded areas
- Contour lines showing elevation—A USGS topographic map (or equivalent) should provide appropriate elevation information.
- Land uses
- North arrow
- Map scale

Key features that influence environmental risks that should be noted include:

- Soil types
- Location of wet areas, streams, and surface waters
- Prevailing summer and winter wind directions
- Depth to ground water—Regional water table maps, well logs for local wells, and knowledge of seasonal high water tables can be used to identify ground water location.
- Rock outcrops and other geological features
- Wells and septic systems
- Karst topography and sinkholes
- Flood plains

Figure 4–1 Base map for identifying potential VTS sites



USDA NRCS Agricultural Waste Management Field Handbook, Chapter 5, Role of Soils in Waste Management, discusses soil physical and chemical characteristics which could impact a particular soils suitability for VTA installation. [*ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/AWMFH/awmfh-chap5.pdf*]. Chapter 7, Geologic and Ground Water Considerations, discusses potential ground water issues on VTA suitability. [*ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/AWMFH/awmfh-chap7.pdf*]

Step 2: Conduct a site analysis to identify potential issues or problems (fig. 4–2).

The purpose of a site analysis diagram is to identify potential environmental risks and opportunities associated with installation of the VTA. A review of potential surface water, ground water, and odor risks is provided later in this section including three assessment tools for reviewing a site (tables 4–1, 4–2, and 4–3). Individual state regulatory agencies may have state-specific tools for evaluating site-related risks that emphasize issues of regional concern. Any potentially permitted facility should identify if state-specific rules or evaluation procedures apply. If not, tables 4–1, 4–2, and 4–3 will assist with a review off-site strengths and weaknesses. Higher risk issues identified should be identified on the base map or within a summary of site considerations.

Figure 4–2 Base map after identification of site issues than may influence location of a VTS

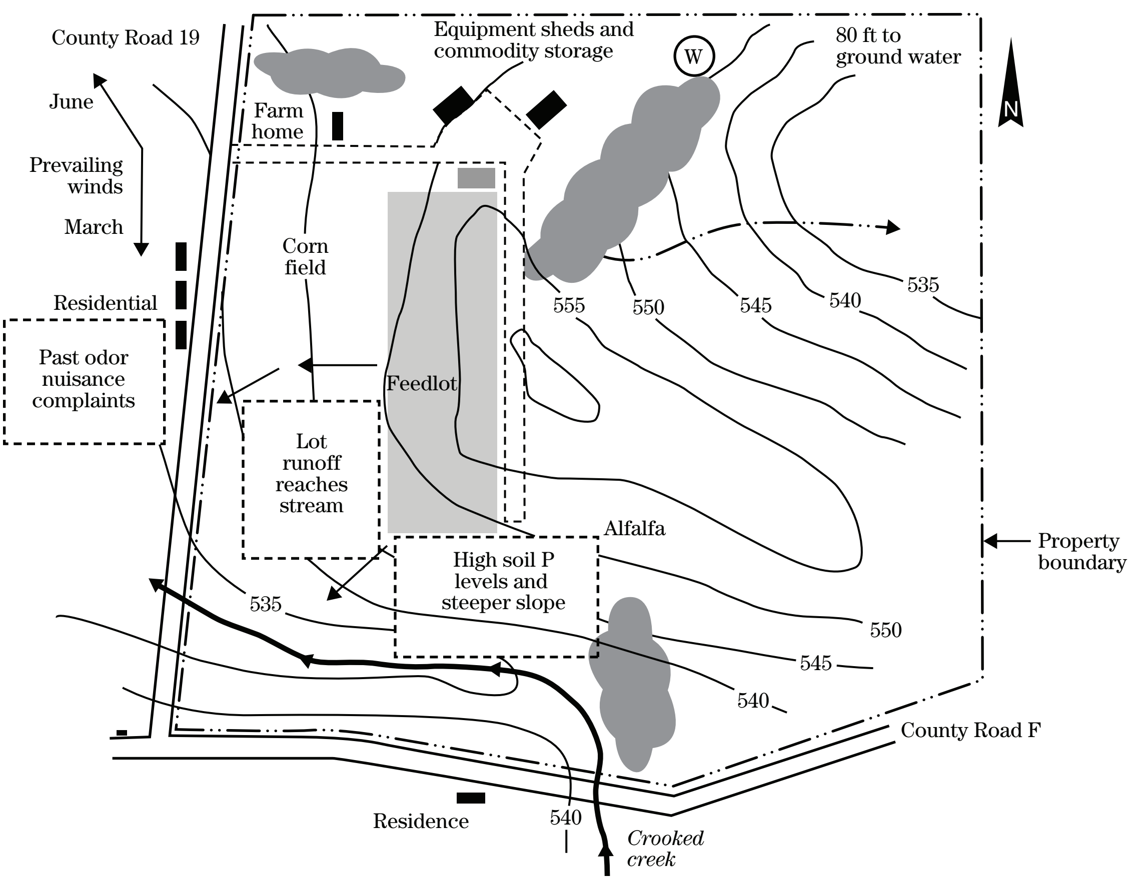


Table 4–1 Risk assessment tool for evaluating connections to ground water associated with a VTS. Use this tool to identify high risk situations that should be identified on a base map for potential VTS location.

Issue	High risk	High-moderate risk	Moderate-low risk	Low risk
Characteristics of soil (below storage site and solids settling basin; see surface water discussion for soil properties for VTAs)	Coarse-textured soils: Clean gravel (GP), or clean sands (GW, SW, SP)	Fine sand, silty, sand and gravel mixes (SM, GM, GW-GM, GP-GM, SW-SM, SP-SM)	Medium-textured soils: silt, clay, and sand-silt-clay mixes, organic mixes, organic silts, and organic clays (GC, , SC, MH,ML, ML-CL, GW-GC, GC-GM, SW-SC, SP-SC, SC-SM)	Fine-textured soils: clay (CL or CH)
Travel distance and time:				
Soil depth below VTA to fractured rock, coarse-textured soils or Karst	Very shallow soils (<20 in)	Shallow (20–30 in)	30–48 in deep	>48 in deep
Soil depth below storage or settling basin to fractured rock, coarse-textured soils or Karst	<4 ft below storage bottom or depth is unknown		High risk geology is more than 4 ft below storage bottom	Impermeable layer of clay or unfractured bedrock exists between storage and high-risk geology
Flow distance from feedlot and VTS to:				
Private well	<100 ft down slope of barnyard/feed lot/ VTA site		100–200 ft down slope of barnyard/ feed lot	>200 ft downslope or well is located upslope from barnyard/feed lot/VTA
Public water well	<1,000 ft down slope of barnyard/feed lot/ VTA or Less than separation distance required by state or local regulations		>1,000 ft down slope of barnyard/feed lot/ VTA	>2,000 ft downslope or Well is located upslope from yard/ feed lot/VTA or More than separation distance required by state or local regulations
Ground water flow direction: Location of water well in relation to pollution sources	Well is in or near depression near and down gradient of pollution source or Surface water runoff from livestock yard, settling basin, or VTA can reach well head	Down slope from most pollution sources	Upslope from or at grade with pollution sources. No surface water runoff reaches drinking water source	Upslope from all pollution sources; all surface water is diverted away from drinking water source
Depth to ground water	<10 ft	10–20 ft	20–50 ft	>50 ft
Higher risk site features or other connections to ground water within area of proposed VTA	___Karst material ___Sink-holes ___Drainage wells, ___Shallow fractured bedrock ___Exposed bedrock	___Depressions		

Table 4–2 Risk assessment tool for evaluating connections to surface water associated with a VTS. Use this tool to identify high risk situations that should be identified on a base map for potential VTS location.

Issue	High risk	High-moderate risk	Moderate-low risk	Low risk
Flood plain	VTS system in located in 10-yr flood plain	VTS system in located in 25-yr flood plain		VTS system is located outside of 25-yr flood plain
Soil: Infiltration rates:	<0.6 in/h or > 2 in/h for VIB <0.2 in/h or > 2 in/h for VTA			0.6–2.0 in/h for VIB 0.2–2.0 in/h for VTA
Are there areas of excessive soil compaction, which inhibit plant growth and infiltration?	Soil compaction is a common problem, limiting plant growth			There is little or no soil compaction. It is not limiting to plant growth
What is the slope of the area to be used for:				
VTAs	>10%	5–10% or <1%	1–3%	1–5%
VIBs	Dependent upon earth moving costs to create a flat basin	>3%		0–1%
Is there damage from gully, sheet or rill erosion	Erosion sites are not controlled and perpetually get worse	Erosion control measures installed, some are failing, and no signs of improvement are apparent	Control measures have been installed, but few signs of potential failure are showing	There is no damage occurring or control measures are very successful
Area for VTS	<0.5 acres of VTS to 1 a of feedlot	>.5 and <1 a of VTS per 1 a of feedlot	1–2 a of VTS to 1 a of feedlot	>2 a of VTS to 1 a of feedlot
Discharges from VTA:				
Where would discharge drain	Excess water is released directly to surface water	Excess water is released into ditch, waterway, or ravine	Excess water is released into crop or pasture land	Topography does not allow water to runoff from proposed VTA site
Down gradient distance to surface water from edge of proposed VTA?	<100 ft	100–199 ft	200–500 ft	>500 ft
Soil phosphorus levels	P Index review suggest a very high risk or >150 ppm Bray 1 or comparable soils analysis	P Index review suggest a high risk or >100 ppm Bray 1 or comparable soils analysis		P Index review suggest a low to moderate risk or <50 ppm Bray 1 or comparable soils analysis

Table 4–3 Risk assessment tool for evaluating odor nuisance risks associated with a VTS. VTAs alone will produce little or no odor. A runoff collection basin, settling basin, and the feedlot are more likely odor sources. Answer the following questions relative to these three odor sources. Use this tool to identify high risk situations that should be identified on a base map for potential location of storage or settling basins.

Issue	High risk	High-moderate risk	Moderate-low risk	Low risk
Direction: Neighbors are…	Located downwind for prevailing winds during wet seasons of the year (typically spring)		Located downwind for prevailing winter winds only	Located upwind for prevailing winds during wet seasons of the year (typically spring)
Homes, public use areas, or businesses				
Distance:				
300 a.u. and less	<¼ mile	¼–½ mi	½–1 mi	>1 mi
>300 a.u.	<½ mi	½–1 mi	1–2 mi	>2 mi
Elevation: Neighbors are located at…	Lower elevation than odor source **and** in valley	Lower elevation than odor source **and** in open area	Similar elevation than odor source **and** in open area	Higher elevation than odor source or sizeable hill, shelterbelt, or other change in topography lies between neighbor and odor source
Typography	Open flat terrain is located between odor source and neighbor			Significant variation in terrain exists between the odor source and neighbor resulting from forests, shelterbelts, buildings, or hills
Visibility (feedlot and runoff storage component of VTS)	Odor source is highly visible due to location close to road	Odor source is recessed from neighbors and road but visible	Partial screening by topography or vegetation of odor sources from neighbors and roads	Full screening by topography or vegetation of odor sources from neighbors and roads
Wind speed	Odor source is located in protected area (due to trees or topography) with low wind speeds			Odor source is located in open area with no trees or topography slowing wind speed

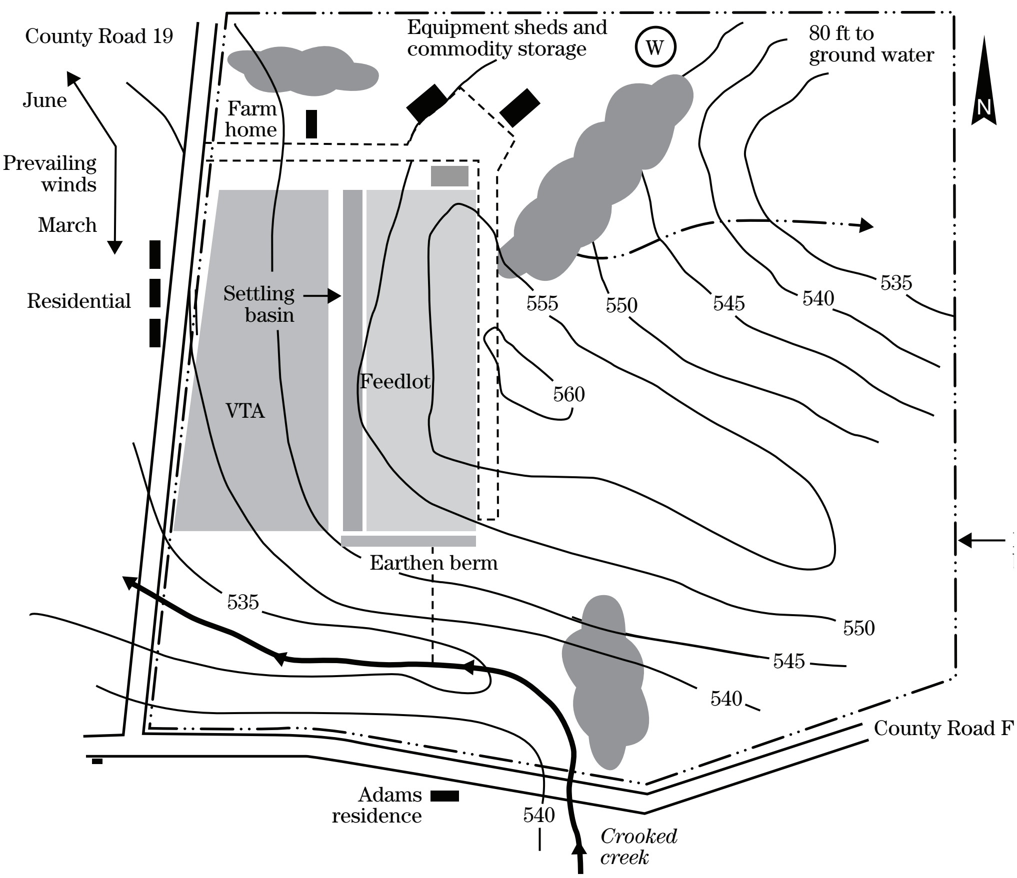
After completing these risk assessments, some of the following issues may also be important:

- Are there conflicts or incompatibilities in land use within the neighborhood (VTA bordering a neighbor's home)?
- Will potential VTA sites fit with normal traffic pattern (animals, equipment, and people)?
- Is there a history of neighbor odor concerns? Are storage and settling basin components being added that may cause odor concern?
- Are there potential neighbor or general public visual concerns?
- Will potential VTS sites require expensive relocation of buildings and utilities?
- Is a potential VTA site already high in soil P levels?
- Does a potential VTA site include areas of potential erosion?

Step 3: Develop an initial concept plan showing potential site(s) of a proposed VTS (fig. 4–3).

Next, a concept plan or plans are developed to evaluate alternative VTA component locations (fig. 4–3). The areas required for collection, storage, solids removal, and VTA are determined and displayed at this step of the process. At the concept plan stage, assume that a VTA area at least equal to the area of the feedlot and related drainage area will be needed. A site should then be evaluated for the ability to provide sufficient space for adequate VTA area. If the space appears to be marginal, a more exact estimate of VTA or VIB should be reviewed. If sufficient space still is not available, a conventional runoff holding pond and land application site should be considered.

Figure 4–3 Base map after identifying preferred VTS site



Additional related VTA siting issues, such as associated use areas, access ways, water management measures, vegetated buffer areas, and ancillary structures should be drawn freehand to approximate scale and configuration directly on the site analysis plan or an overlay. In instances where several sites may satisfy the decisionmaker's objectives, propose the site that best considers cost differences, neighbor concerns, environmental impacts, legal ramifications, and operational capabilities.

The final step in this process is a finalized site plan for the proposed VTS. However, before proceeding to a final site map, a number of environmental issues associated with site selection should be reviewed in greater depth. As those risks are reviewed, consider if high risks can be identified on your base map. With each environmental risk, an associated assessment tool is included (tables 4–1, 4–2, and 4–3).

Assessing ground water risks

A proposed VTA site should be evaluated for potential risks to ground water. More critical factors specific to a VTA installation that impact ground water are reviewed and can be assessed for an individual site using table 4–1. A more complete description of these factors critical to any manure management system can be found in NRCS Agricultural Waste Management Field Handbook, chapter 7, (*http://www.info.usda.gov/CED/ftp/CED/neh651-ch7.pdf*).

Soil characteristics—Many biological, physical, and chemical processes break down, lessen the potency, or otherwise reduce the volume of contaminants moving through the root zone of surface soils. These processes, collectively called attenuation, retard the movement of contaminants into deeper subsurface zones. The soil's attenuation potential increases as clay content increases, the soil deepens, and distance increases between the contaminant source and the well or spring. The cation exchange capacity of clay soils limits movement of positively charged contaminants such as ammonium (NH_4^+). Clay also has a very low permeability, thus slowing contaminant movement and increasing the contact time that allows more opportunity for attenuation. Deeper soil increases the contact time a contaminant will have with mineral and organic matter of the soil. Longer contact time provides greater opportunity for attenuation.

Travel distance and time—The greater the travel time of a contaminant, the greater the opportunity for attenuating the contaminant. The depth to ground water and the horizontal distance between the source of the contamination and a well, spring, or other ground water supply influences the time of travel.

Ground water flow direction—A desirable site for a VTS is in an area where ground water flows from the facility in a direction away from a well, spring, or potable aquifer source. The direction of flow in a water table aquifer generally can be ascertained from the topography. In most cases, the slope of the land indicates the ground water flow direction. However, radial flow paths and unusual subsurface geology can too often invalidate this assumption. Local information on ground water flow direction may be available through a Soil and Water Conservation District or NRCS office or through private well drillers. In addition, a VTS site should be checked for its potential location within a recharge area for a public water source. The local rural water district or municipal water supplier should be able to identify these recharge areas.

Proximity to designated use aquifers, recharge areas, and well-head protection areas—A potential VTA site should be reviewed for its proximity to sensitive ground water areas including:

- Sole source or other types of aquifers whose uses have been designated by the state
- Important recharge areas
- Well-head protection areas

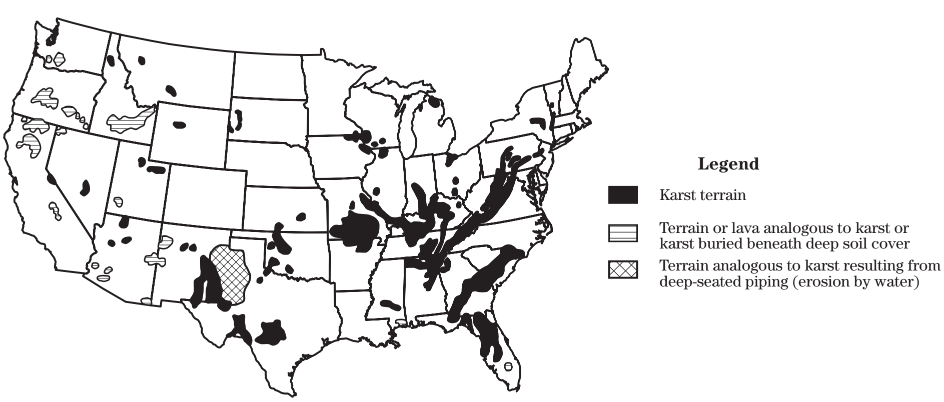
Depth to ground water—The elevation and shape of the water table may vary throughout the year. Obtain preliminary estimates of the depth to seasonal high water table from well logs, published soil surveys, and the NRCS National Soil Characterization database. Site-specific ground water depths may vary from values given in these sources. Stabilized water levels observed in soil borings or test pits provide the most accurate determination in the field. Seasonal variations in the water table also may be inferred from the logs of borings or pits. Perennially saturated soil is typically gray. Perennially aerated soil is typically various shades of red, brown, or yellow.

Depth to bedrock—Storage systems may be restricted by shallow depth to bedrock because of physical limitations or state and local regulations. Vegetative practices, such as filter strips, may be difficult to establish on shallow soil or exposed bedrock. Waste stored or land applied in areas of shallow or outcropping rock may contaminate ground water because fractures and joints in the rock provide avenues for contaminants.

For runoff holding ponds and solids settling basins, shallow bedrock generally is a serious condition requiring special design considerations. Bedrock of all types is nearly always jointed or fractured when considered as a unit greater than 0.5 to 10 acres in area. Fractures in any type of rock can convey contaminants from an unlined storage to an underlying aquifer. Fractures have relatively little surface area for attenuation of contaminants. In fact, many fractures are wide enough to allow rapid flow. Pathogens may survive the passage from the site to the well, and thereby cause a health problem. Consider any rock type within 2 feet of the design to be a potential problem.

High risk geological features—Sinkholes, karst topography, or underground mines may disqualify a site. The physical hazard of ground collapse and the potential for ground water contamination are severe limitations. Common regions of the United States with karst topography are illustrated in figure 4–4.

Figure 4–4 Generalized map of areas of karst and analogous terrains. State and local soils and geological surveys should provide a more accurate local characterization of high risk geological features such as karst topography.



Reducing odor nuisances

The movement or dispersion of airborne emissions from an animal production facility is affected by many factors including topography, prevailing winds, and facility orientation. Odor plumes decrease exponentially with distance, but long distances are needed if no odors, gases, or dust are to be detected downwind from a source.

VTSs are unlikely to be a source of odor nuisances. However, if storage is included in the VTS, the storage can produce some odors. A settling basin with significant accumulation of wet solids is also likely to cause odor concerns. Solids storage and composting areas can also cause odors. However, none of these sources is likely to be as large of a source as the open lot where cattle are housed. Despite the lower odor risk of a VTS, it is still important that basic principles of siting a facility to reduce neighbor risk be considered (table 4–3).

Prevailing winds should be considered so facilities are sited to minimize odor transport to close or sensitive neighbors. Odor moves the same direction as wind direction and disperses laterally very little. By recognizing prevailing wind direction especially during wetter periods of the year, one can begin to identify those neighbors at greatest risk. If options exist for siting of any runoff storage, solids settling basin, or temporary stack of harvested solids, location of those facilities to avoid placing neighbors immediately downwind based upon prevailing winds can offer significant nuisance reduction.

For open lot systems, spring and early summer conditions can often be the period of greatest odor nuisances. Prevailing winds are often changing during the spring from being dominated by winter weather pattern to being driven by summer weather patterns. Officials associated with local airports may have statistical data on prevailing wind direction versus time of year.

Distance is a second key consideration. Although models are beginning to be developed for predicting distance of odor travel, general distance recommendations are difficult to make. However, more is always better. If sources of odor can be located to increase distance to the neighbor, there may be value in reducing odor nuisances.

Elevation is also an important consideration. Avoid location of an odor source upslope from a nearby neighbor. During times of greatest potential odor risks, calm evening hours, odors settle near the ground and tend to move downslope. Downslope neighbors, especially those located in a valley or depression, are at greatest risk from an upslope odor source.

Downwind of a facility, variable topography is preferable to flat terrain. Hills, shelterbelts, stacked bales of hay, and buildings all encourage mixing of the odors from an odor source with fresh air thus encouraging dilution and reduced impact on neighbors. If facilities, hills, or trees can be located between a neighbor and an odor source, the odor nuisance can be reduced.

Wind speed is important for mixing fresh air with odorous air and reducing the area impacted by an odor source. High wind speeds contribute to greater turbulence, greater dilution of odorous air, and less chance of neighbors being impacted by an odor source. It is preferable to avoid locations for an odor source downwind of a shelter belt or hill. Open locations where few obstructions slow the wind speed are preferred locations for odor sources.

Connections to surface water

A review of surface water risks associated with a VTS should consider several risk factors. Table 4–2 can be used to assess those risks for an individual site.

Flood plain—VTAs and associated storage and treatment components should be located outside the 25-year flood plain. State and local regulations should be checked for separation requirements from even less frequent flood events. Information on flood plains can be obtained locally from county planning and zoning agencies, Soil and Water Conservation Districts, and NRCS offices.

Soil type—Identification of the soils in the proposed location of the alternative treatment system gives prior knowledge of suitability for construction of VIBs or VTAs and nutrient treatment capabilities. Soils with moderate permeability are best for VIBs and VTAs. Soils with high permeability will reduce potential for discharge from a VTA, but increase the risk to ground water. Soils with a low permeability improve protection of ground water, but increase the potential for a discharge from the VTA. For VIBs, soils with 0.6 to 2 inches per hour to a 5-foot depth are recommended. For VTAs, soils with 0.2 to 2 inches per hour to a 5-foot depth are suggested.

Slope—Zero slope is preferred for VIBs. Slopes from 1 to 5 percent provide the maximum opportunity time for treatment of effluent within a VTA.

Erosion damage—The site should be reviewed for past damage due to erosion. Gully erosion will require greater investment in land leveling to ensure uniform runoff flow over the VTA. Past indication of gully or sheet erosion will also suggest that the soils may not be suitable for withstanding erosion from additional runoff flow volumes.

Sufficient area for VTA—A rough rule of thumb for assessing the area available for a VTA is 1 acre of potential VTA area for every acre of feedlot. Thus, a 10-acre feedlot will require approximately 10 acres of VTA. Additional area may be required for solids settling and possibly runoff storage. If the available land base is less than this rough rule of thumb, a more accurate calculation of VTA and VIB area should be made using procedures in sections 5 and 6. Greater areas than the 1 to 1 ratio of VTA to runoff area further reduce the risk of a discharge from a VTA. Some systems have been designed with as large as a 2 to 1 area ratio.

Separation requirements between VTAs and environmentally sensitive areas are intended to reduce the potential impact of discharges from VTAs on designated streams, rivers, lakes, and wetlands. For some VTSs, discharge is likely and treatment within VTA will not reduce pollutant concentration to acceptable levels for discharge to surface waters. Additional separation distance allows opportunity for infiltration of pollutants into soil or their dilution. Separation distances are arbitrary (more is better) and may be established by state or local regulations. Drainage from a VTA into pasture or crop land is preferred over drainage into ditch or waterway where channel flow occurs directly into surface waters.

VTS site soil P level—A thorough soil testing program should be conducted for sites considered for a VTS. Soil P test levels should be obtained within the potential VTA or, better yet, a P index evaluation conducted on any potential VTS site. A VTS should not be located where high soil P levels already exist. The poultry industry has learned that pasture sites with high P levels from past litter applications will produce significant off-site movement of P with runoff water. Although feedlot runoff should not contribute significant P to a VTS (assuming good solids settling in advance), a site with high P levels from past manure applications should be avoided due the potential for soluble P movement from these sites.

Is a proposed site unacceptable?

Not every site is suitable for a VTS. Because of the limited past experience with VTS on commercial farms, a relatively high standard for VTS sites will need to be followed until better field experience is available. In the end, a site-specific analysis must be prepared by the producer comparing the baseline technology performance with that of the VTS as described in section 2 to determine if a site is acceptable. However, before making this substantial investment in such an analysis, ask the following questions:

- Does your site violate any minimum requirements established by the permitting authority or state environmental agency (likely to be one in the same)? A Yes answer is most likely a VTS stopper.
- Have any high or high to moderate risk factors been identified in tables 4–1 and 4–2? There are significant differences in the degree of importance of individual risk factors in these two tables. The level of risk is often specific to local or regional conditions. Any high or high to moderate risk factors should be reviewed with independent experts before proceeding further.
- Do any of the higher risk factors identified represent a VTS stopper? This answer should be determined locally based upon state-specific regulations and local environmental priorities. However, there are some factors that will make application of a VTS a substantial challenge for almost all circumstances. Some of these include:
  - Slopes greater than 8 to 10 percent. Research and field experience with VTS options on high slopes is almost non-existent and the risk of runoff is substantial.
  - Less than 1 acre available for the VTS (VTA and settling basin) per acre of feedlot surface. To encourage significant infiltration and modest runoff release from a VTA, space limitations should not be violated.
  - High soil P levels. Dissolved P moves from sites with high P levels in spite of permanent vegetation. Sites with a direct connection to surface waters and high soil P levels should be avoided.
  - High risk geological features. If a VTS cannot be separated from high risk geological features such as Karst material, shallow fractured or exposed bedrock, or drainage wells, a VTS should not be installed.
  - Less than 100 feet to private wells or 1,000 feet to public water supplies (check local Wellhead Protection Area regulations for greater setback requirements) produce too great of liability for all runoff control systems including VTS.

Conceptual design

The risk assessment of a proposed VTS site should lead one to some preliminary design decisions including the following:

- *Siting*—Is the proposed site still acceptable after completing the risk assessment? Are there alternative sites that may have advantages? At the conclusion of this process, a preliminary decision should be made as to the preferred site for a VTS.
- *VTS system options*—Several options were discussed in section 3. Which of these options is the better fit for a proposed site? If space is limited, systems involving a VIB may be preferred. If close proximity to surface waters is of concern, options that include greater storage and passive or active management of runoff release, oversized VTAs, or additional treatment (VIB prior to VTA) might be considered.
- *Location of VTS components*—What is the relative location for the solids removal component? VTA? Other selected components?
- *Utilities*—Does this design allow for gravity flow of runoff liquids through the system, or will electrical service be required to pump runoff? Is there a need for other utilities in the area around the VTS (water supply, roads for equipment access)? Identify the utilities and services that will need to be provided to the VTS site.
- *Footprint of components*—One should do a preliminary size estimate for individual components and compute the area required for these components? Don't forget to include space for berms and access roads. The footprint of these components should be added to the developing map for the proposed site. Sections 5, 6, and 7 provide tools for sizing settling basins, VTAs, and VIBs.

With these conceptual design decisions made, the proposed VTS is now ready to endure the scrutiny of the design process for the individual components (sec. 5 through 7) and the comparison of the proposed alternative technology with the baseline system (sec. 1). Selection of a preferred site is especially critical for the comparison process of alternative versus conventional treatment systems. Several site-specific conditions are required for this comparison process including soil types, slopes, and dimensions of VTS components. Refer to section 2 for additional site specific information required of the performance comparison process.

Section 5 Liquid-Solid Separation

Section 5 Liquid-Solid Separation

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Section 5 Liquid-Solid Separation

Topics

- Settling basin design
- Alternative solids settling facilities
- Active versus passive management

Purpose

The liquid-solid separation component within a VTS is intended to:

- Intercept all open lot runoff
- Remove most settleable solids from feedlot runoff. Solids removal is critical to reducing nutrient and related pollutant loading on the VTA or VIB and minimizes vegetation damage due to solids accumulation.
- Release liquids to VTA or VIB in a controlled manner. Controlled release of liquids to a VTA at an appropriate time is critical to minimizing the potential for discharge.

This section describes the design features of the liquid-solid separation component critical to achieving these three goals.

Some of the information in this section is from Livestock Waste Facilities Handbook (MWPS-18), Chapter 5, Liquid Solids Separation. Printed with the permission of the Midwest Plain Service, 1985.

Liquid-solid separation is an essential pre-treatment component for both CAFO and AFO applications of a VTA or VIB.

Description

Liquid-solid separation within feedlot runoff is most commonly achieved by flow velocity reduction to allow settling of solids from the runoff. Settled solids can be collected from the liquid-solid separation component and land applied according to a nutrient management plan.

Settling basins are the most common type of liquid-solids separation used to treat runoff from an animal feeding operation feedlot or pen surface. Alternative settling facilities include settling benches, silt fences, and gravel spreaders. Settling tanks and settling channels can also be used in certain situations.

A settling basin, when preceding a VTA, may also be designed to delay or spread out the release of liquids over a significant period of time to minimize the risk of a discharge from the VTA. This may require the settling facility to include storage with active or passive control of the release of liquids over time.

The initial treatment of any open feedlot runoff control system should be solids removal, as is currently required by many state laws. Properly designed and managed solids settling basins should remove about 30 percent of the N and P from the runoff from swine lots and 50 percent or more of each from cattle lot runoff. For additional information on the performance of solids settling, see the literature review in section 9.

Solids removal design issues

Contaminated runoff from lots carries organic matter and other solids. Typical open lot runoff characteristics are summarized in table 5–1. See section 9 for addition information on characteristics.

Settling facilities are designed to intercept all lot runoff, settle out most of the solids, and release liquids to a VTA or VIB. Settling separates solids from dilute liquid slurry by reducing velocity. Fast moving liquids pick up and transport solids; when velocity slows, some of those solids settle by gravity.

Solids separation and periodic solids removal is the key to successful treatment of precipitation runoff from beef and dairy feedlot surfaces. Liquid that is to be released to a VTA or VIB should always have solids removed first minimizing solids, nutrient, and salt buildups within the vegetated area. Buildups of these materials would potentially harm vegetation in the treatment area and negatively impact soil structure and water intake characteristics.

Physical size of the settling facility is typically based upon two considerations:

- Solids settle at a rate of approximately 4 feet per hour. Based upon a selected depth for a settling basin, a minimum holding time (hydraulic retention time) can be established. For example, a 2-foot deep basin would require a 30-minute minimum holding time (2 ft deep ÷ 4 ft/h = ½ h)
- A basin size designed to hold a selected frequency precipitation event. The most critical design situation is the high-intensity, short-duration rainfall event. A large water volume picks up manure and carries it in the runoff. Experience has shown that the 10-year, 1-hour storm (app. B) is

Table 5–1 Average chemical characteristics of runoff from beef cattle feed yards in the Great Plains (see sec. 9 for additional information on characteristics)

Source	Total solids (ppm)	Volatile solids (ppm)	Electrical conductivity (mmhos/cm)	Total nitrogen (ppm)	Total phosphorus (ppm)	Potassium (ppm)
Feedlot runoff[1]						
Average	11,200		6.5	580	120	1,020
Range	3,000–17,500		3.2–8.6	80–1,080	50–300	340–1,320

1 Sweenten 1991

acceptable for designing settling facilities tied to VIBs and runoff holding ponds. A larger 25-year, 24-hour storm (app. B) may be appropriate for settling basins in advance of a VTA on a large CAFO, especially where runoff release to the VTA is actively or passively managed. When a larger storm occurs than the design volume, the percent of manure solids removed by the basin is reduced slightly. However, a system can manage larger runoff peak flows and lose little in treatment efficiency if the minimum holding time is not substantially reduced.

Control over the release of liquids from a settling basin into the VTA is a second critical design feature. Allowing feedlot runoff water to pass through the settling basin and into the VTA simultaneously with a rainfall event has the potential to exceed the infiltration capacity of the soil in the VTA and result in discharges. VTAs have gained limited acceptance within the regulatory community for CAFO applications due to this concern. Two options are available for controlled release of liquid from the settling facility to a VTA:

- Restrict the settling facility outflow to extend flow over 30 to 72 hours (passive runoff release control). This minimizes the contaminated runoff addition to the VTA during the storm event to minimize the chance of exceeding infiltration rates.
- Actively manage the outflow to avoid any release during a storm event (active runoff release control). Contaminated runoff stored in the settling facility would then be released after the storm event. If released at a slow enough rate, smaller VTAs may be possible while retaining a match between soil infiltration rate and release of liquid from the settling basin.

A combination of a settling facility with significant storage capacity (sized for a 25-yr, 24-h storm) in combination with active or passive release of liquids to the VTA will minimize the potential for a discharge from the VTA.

Settling basin design

A settling basin temporarily retains runoff and permits liquids to drain to a waste storage pond, lagoon, or VTA in a controlled manner. Solids remain in the basin for drying and later removal with a front-end loader or similar equipment.

The best basin shape is relatively large and shallow. If solids are removed from the basin with conventional solid manure handling equipment, basin depth should normally be 3 feet deep or less. Settled solids can be removed by driving unloading equipment on the basin floor. In arid areas where settling basins dry out readily, earthen basins may be satisfactory (fig. 5–1).

In humid areas, concrete bottoms or complete concrete basins may be necessary so equipment can enter the basin for clean out (fig. 5–2). Provide at least one vertical wall when constructing settling basins of concrete. This will provide a bucking wall for a front-end loader when removing separated solids from the basin.

Access ramp slope should be 10:1 (horizontal length: vertical fall) or flatter, for front-end loaders. Basin bottoms are often provided with a slight uniform grade (0–5 in/100 ft) to the discharge point to ensure proper drainage at low flows and prevent ponding and encourage drying of the solids in the basin.

Build earthen basins with 3:1 side slopes; if erosion is a problem, use a 4:1 slope or flatter slope on the inlet side. The top width of earth basin ridges must be at least 12 feet wide if planned for vehicle traffic; a minimum 3-foot ridge top width would be required to maintain the design height of earthen settling basin ridges. Plant and maintain grass cover where possible on all settling basin ridges. The bottom of the basin where solids accumulate may need to be concrete in higher precipitation areas, while earthen bottoms are typically satisfactory in more arid climates.

Maintenance and pen clean-out frequency greatly influence settling basin treatment efficiency. A properly managed open lot and settling basin can retain up to 85 percent of the non-floating solids in the lot or basin, regardless of lot slope. Research indicates that solids can accumulate at a rate 0.5 acre-inch settled solids per acre of unpaved lot per year. This value is much less for paved lots.

The required frequency of basin cleaning varies considerably depending on basin size, type of lot surface, amount of manure on the lot surface, and storm runoff characteristics. In some instances, cleaning may be necessary after each large storm, but a cleaning frequency of 2 to 6 times per year is adequate if the basin is designed large enough to store the accumulated solids. Provide temporary storage areas for separated solids (within the area from which runoff is collected) unless they are transported directly from the basin to the final end use (land application).

Figure 5–1 Earthen sidewall settling basin. For dry regions, an earthen base for the basin is acceptable. In higher rainfall areas, the base should be concrete.

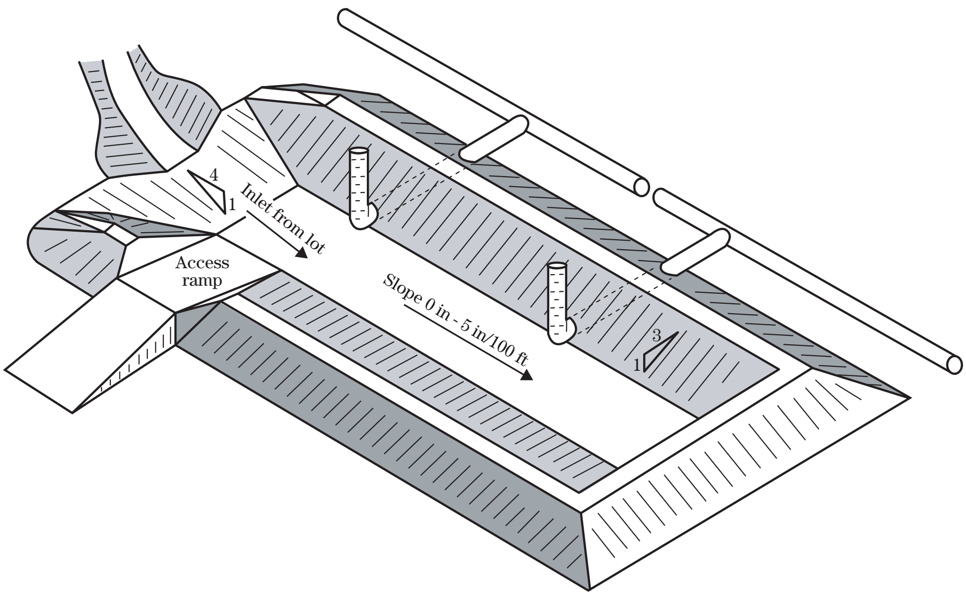
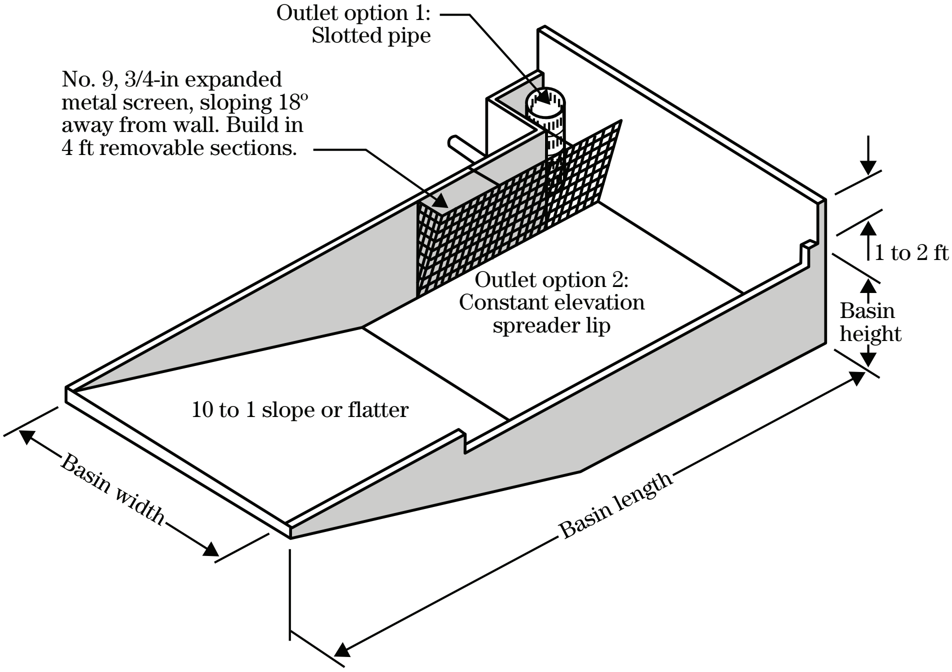


Figure 5–2 Concrete settling basin for regions with higher precipitation



Settling basin outlets

Several types of basin outlets are available to drain liquids from the full depth of the settling basin and dewater solids. Perforated or slotted pipe risers, and porous plank dam are examples.

Manure plugs, outlet openings, debris, and bedding tend to plug even large openings. As the settling basin drains, the liquid drains through fewer slots or perforated openings and solids concentration increases further adding to the plugging problems. Cleaning of outlet openings is commonly required to allow the settling basin to fully drain and solids to dry allowing their removal. The outlets should be designed for easy cleaning. A portable propane weed/brush burner will clean most debris from a metal screen but does not work on a PVC pipe.

Consider adding a slanted expanded metal screen around the settling basin outlet to increase the screening area (fig. 5–2). These screens are usually expanded steel, usually .75 inch, No. 9 or heavy quarry screen, with about 1- to 1.5-inch openings. In practice, the screens tend to be bulky and are seldom removed during tractor cleaning of the basin. Therefore, place the screens on the sidewall, not the bucking (or end) wall. Any settling facility that passes runoff liquids through a screen requires screen cleaning of solids after each runoff event. This maintenance is critical to drying solids for their eventual removal.

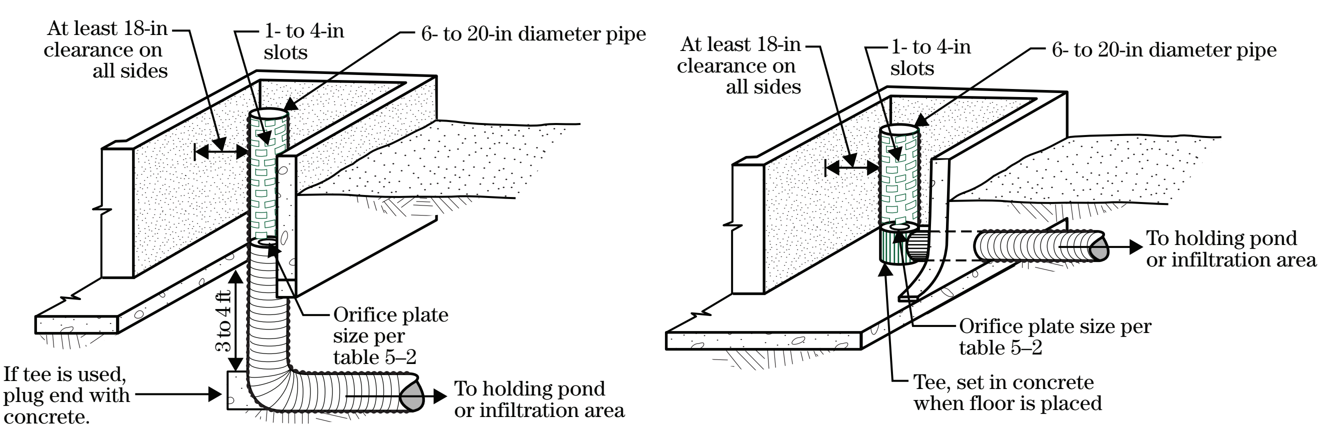
Perforated pipe outlets

Perforated pipe may be constructed with PVC plastic, galvanized steel (can have limited life), or concrete. The perforations can be 5/8- to 1-inch diameter holes or 1- by 4-inch slots. Where excessive clogging of perforated pipes is a problem, a removable trash screen ahead of the perforated pipe improves performance (fig. 5–2).

The outlet is sized to drain anticipated design discharge rates while providing adequate detention time. Basin outlet flow rate should be controlled with a properly sized orifice plate (fig. 5–3). Flow rate through the holes or slots in the perforated pipe should be checked to ensure that this estimate of flow rate exceeds that of the orifice. Because of the likelihood of clogging the holes or slots, a safety factor should be included in their design.

The outlet is sized to maintain sufficient flow to prevent overflow of the settling basin, while providing adequate detention time to allow solids to settle. When a settling basin is installed in conjunction with a VTA, the outlet flow may be controlled to slow the release of liquids over an extended period of time (30 h to 3 d). To achieve this level of control, a properly sized orifice plate is essential to achieving these objectives for settling basins tied to VTAs.

Figure 5–3 Riser pipe outlets for settling basins



Orifice plates should be sized to provide the design flow rate (table 5–2). They are placed at the base of the riser pipe, typically a PVC end cap with a hole of specified size drilled in the center. The orifice plate permits outflow control while permitting large perforations in the riser pipe to reduce plugging. The equation for estimating flow rate from an orifice plate (MWPS 1985) is:

$$Q_o = C \times A \times (2 \times g \times h)^{0.5} \quad (1a)$$

where:
Q_o = flow rate of orifice in ft^3/s
C = orifice constant: assumed to be 0.61. The actual value varies with type of orifice. The assumed value is conservative.
A = open orifice area in ft^2
g = 32.2 ft/s^2
h = head on orifice in ft

With an orifice plate, make the flow rate of the slotted pipe (Q_S) at least 25 percent larger than the flow rate of the orifice (Q_o). Orifice plates should be vented with a .75-inch diameter PVC pipe, or PE tubing from just below the orifice plate to the elevation of the maximum anticipated settling basin depth. The equation for estimating flow rate through the slotted pipe (MWPS 1985):

$$Q_S = C \times A \times (2 \times g \times h)^{0.5} \quad (1b)$$

where:
Q_S = flow rate of slots in slotted pipe in ft^3/s
C = slot constant: assumed to be 0.61. The actual value varies with type of slot. The assumed value is conservative.
A = open slot area in ft^2
g = 32.2 ft/s^2
h = head on openings in ft

The pipe height was divided into 0.5-foot increments. The head on all slots in the first 0.5-foot increment is assumed to be 0.25 foot. The head on the subsequent 0.5-foot pipe increments increases at 0.5 foot for each increment.

Porous dams

Select a material for porous dams that can be easily cleaned by scraping the surface with a hoe. Spaced planks, welded wire fabric, or expanded metal mesh can be scraped clean. Design of the spaced plank porous dams is illustrated in figure 5–4.

Porous dam outlets are acceptable for controlling runoff to holding ponds and VIBs. However, for settling basins designed with a slow release to a VTA, the porous dam approach is not recommended for this application. Plugging and challenges with construction of a porous dam with the desired flow rate makes this outflow approach unacceptable for this application.

Figure 5–4 Porous dam outlet design for settling basins (MWPS 1985)

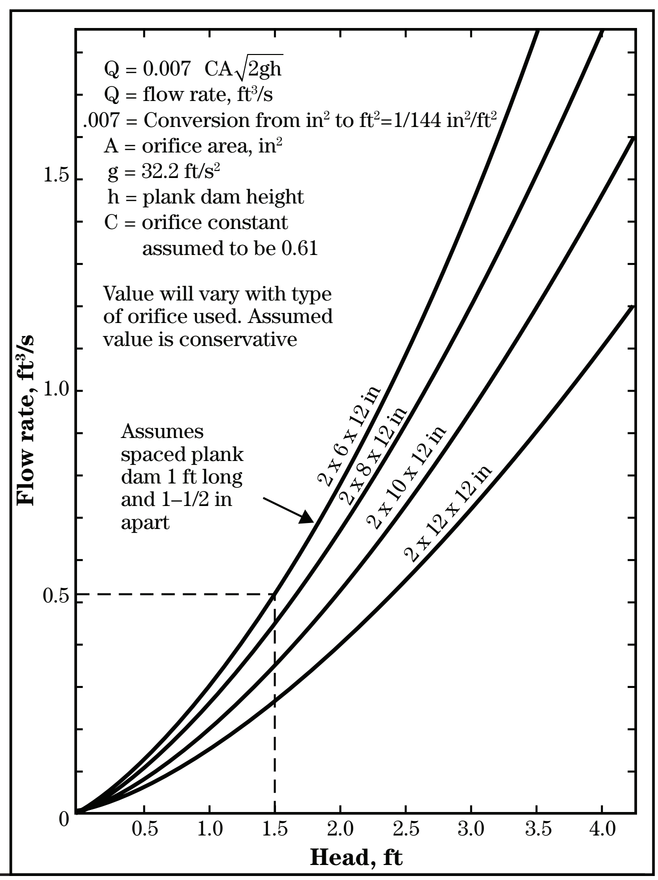


Table 5–2 Orifice plate opening design for settling basins. Boxed values refer to example in appendix C (MWPS 1985)

Diameter area		Head, ft						
in	ft²	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		------------------------------Flow rate, ft³/s ----------------------						
1.00	0.005	0.027	0.033	0.038	0.042	0.046	0.050	0.053
1.25	0.009	0.042	0.051	0.059	0.066	0.072	0.078	0.083
1.50	0.012	0.060	0.074	0.085	0.095	0.104	0.112	0.120
1.75	0.017	0.082	0.100	0.116	0.129	0.142	0.153	0.163
2.00	0.022	0.107	0.131	0.151	0.169	0.185	0.200	0.214
2.25	0.028	0.135	0.165	0.191	0.214	0.234	0.253	0.270
2.50	0.034	0.167	0.204	0.236	0.264	0.289	0.312	0.334
2.75	0.041	0.202	0.247	0.285	0.319	0.350	0.378	0.404
3.00	0.049	0.240	0.294	0.340	0.380	0.416	0.449	0.480
3.25	0.058	0.282	0.345	0.399	0.466	0.488	0.527	0.564
3.50	0.067	0.327	0.400	0.462	0.517	0.566	0.612	0.654
3.75	0.077	0.375	0.460	0.531	0.593	0.650	0.702	0.751
4.00	0.087	0.427	0.523	0.604	0.675	0.740	0.702	0.751
4.25	0.099	0.482	0.590	0.682	0.762	0.835	0.902	0.964
4.50	0.110	0.540	0.662	0.764	0.855	0.936	1.011	1.081
4.75	0.123	0.602	0.737	0.852	0.952	1.043	1.127	1.204
5.00	0.136	0.667	0.817	0.944	1.055	1.156	1.248	1.334
5.25	0.150	0.736	0.901	1.040	1.163	1.274	1.376	1.471
5.50	0.165	0.807	0.989	1.142	1.276	1.398	1.510	1.615
5.75	0.180	0.882	1.081	1.248	1.395	1.529	1.651	1.765
6.00	0.196	0.961	1.177	1.359	1.519	1.664	1.797	1.922
6.25	0.213	1.043	1.277	1.474	1.648	1.806	1.950	2.085
6.50	0.230	1.128	1.381	1.595	1.783	1.953	2.110	2.255
6.75	0.249	1.216	1.489	1.720	1.923	2.106	2.275	2.432
7.00	0.267	1.308	1.602	1.849	2.068	2.265	2.447	2.615
7.25	0.287	1.403	1.718	1.984	2.218	2.430	2.624	2.806
7.50	0.307	1.501	1.839	2.123	2.374	2.600	2.890	3.002
7.75	0.328	1.603	1.963	2.267	2.535	2.776	2.999	3.206
8.00	0.349	1.708	2.092	2.416	2.701	2.958	3.195	3.416

Settling basin emergency spillway

At shallow depths, the design flow into the basin exceeds outflow, so detention results. As the basin fills, outflow rate increases. When the basin is full, outflow rate should equal inflow rate. With feedlot runoff, however, outlet openings often clog to some degree, reducing the outflow rate. To prevent overflowing, provide a larger basin outlet (spillway) to handle peak flow when the basin is completely full (fig. 5–5).

Settling basin sizing

Runoff solids settle at a rate of 4 feet per hour. Therefore, a detention time of 30 minutes in the settling basin is an acceptable design criterion for a 2-foot deep basin, where no other criterion is available. When local design criteria are not available, use the following design procedure. An example using this procedure is illustrated in appendix C.

Step 1

Determine rainfall volume for a 10-year, 1-hour storm (fig. B–1) and the 25-year, 24-hour storm (fig. B–1) if the settling basin is matched to a VTA.

Step 2

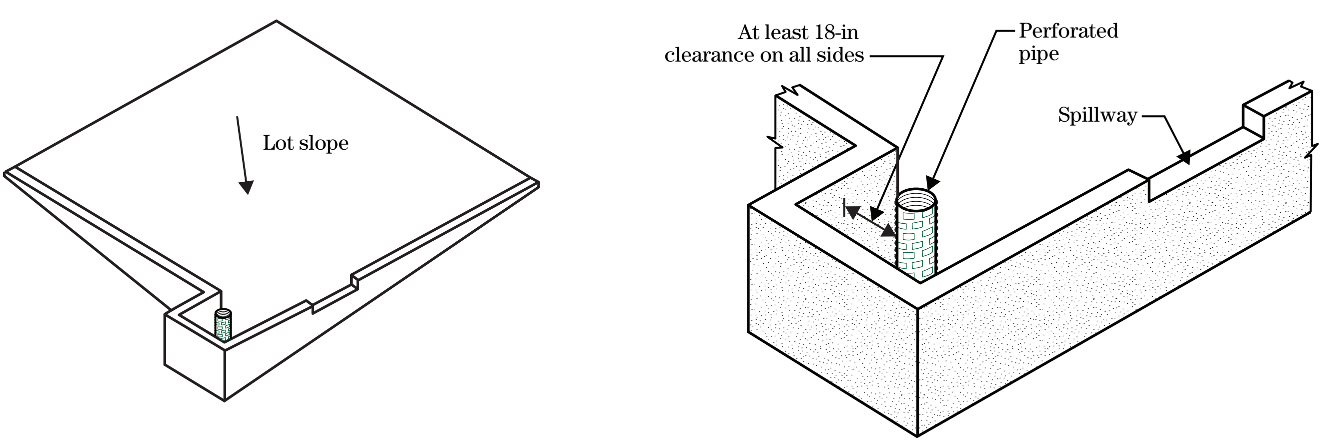
Peak flow rate off the lot:

$$\text{Peak flow rate} = \frac{(\text{lot area} \times \text{rainfall intensity})}{43{,}200} \qquad (2)$$

Units: Peak flow rate in ft^3/s
Lot area in ft^2
Rainfall intensity (in/h) for 10-yr, 1-h storm is approximated as volume/1-h duration
43,200 is derived from 3,600 s/h x 12 in/ft

Step 2 produces an estimate of peak flow rate and may be unsatisfactory for larger open lots. The runoff rate from a lot depends on three basic factors: surface con-

Figure 5–5 Spillway should be included for storm intensities that exceed design capacity and flow rate of settling basin



dition, slope(s) of the surface, and flow length. The small lots can be represented by the longest flow path from the top of the lot to the inlet to the settling basin. Larger lots have more than one flow surface, normally to an interceptor ditch that collects the flow from multiple surfaces and conveys them to the settling basin. Relatively slow velocities result in the overland section and rapid flows in the ditches. There is a wide range of conditions including flow, length, and slope(s). A more precise methodology is presented in the NRCS Engineering Field Handbook, chapter 2.

Step 3

Surface settling rate equals 4 feet per hour if the basin will be at least 2 feet deep. If site limitations (lack of fall away from lot) restrict depth to less than 2 feet, over design the basin area by using a surface-settling rate less than 4 feet per hour (2 ft/h is a reasonable compromise).

Step 4

Basin surface area:

$$\text{Area} = \frac{(\text{flow rate off lot x } 3{,}600 \text{ s/h})}{\text{surface settling rate}} \qquad (3)$$

Units: Area in ft^2
Flow rate off lot in ft^3/s
Surface settling rate in ft/h (from step 3)

Step 5

Basin liquids storage depth:

$$\text{Liquid storage depth} = \text{surface settling rate} \times \text{detention time} \qquad (4)$$

Units: Surface settling rate in ft/s (from step 3)
Detention time in h. 1/2 h is considered a minimum.
Maximum depth is 4 ft because excessive depth makes access difficult and hinders dewatering.

Step 6

The larger volume from the calculation based on detention time or storm event size should be selected for the liquid storage volume. First, calculate liquid storage volume based upon selected detention time:

$$\text{Liquid volume} = \text{Liquid storage depth} \times \text{basin surface area} \qquad (5)$$

Units: Liquid volume in ft^3
Liquid storage depth in ft (step 5)
Basin surface area in ft^2 (step 4)

A settling basin volume should also be checked to ensure a liquid storage capacity for a 10-year, 1-hour storm if preceding a holding pond or a VIB, or a 25-year, 24-hour storm if preceding a VTA (see app. B, fig. B–1). See appendix B for estimating runoff from a single storm event.

The larger volume of detention time estimate and storm event estimate should be selected. If the storm event estimate is larger, the liquid depth should remain constant and surface area recalculated.

Step 7

Solids storage volume:

$$\text{Solids storage volume} = \text{Sludge buildup rate} \times \text{feedlot area} \times \text{fraction of year} \times \frac{43{,}560 \text{ ft}^2/\text{a}}{12 \text{ in/ft}} \qquad (6)$$

Units: Solids storage volume in ft^3
Sludge buildup rate in a-in/a/yr
Feedlot area in a
Fraction of yr between basin solids removal

Use a sludge buildup rate of 0.5 acre-inch/acre of unpaved lot per year, and 0.1 acre-inch/acre of paved lot per year. Increase these values by 50 percent if lots have steep slopes (>8–10%) or are poorly maintained (pens cleaned less frequently than twice per year).

Step 8

Solids storage depth:

$$\text{Solid storage depth} = \frac{\text{solids storage volume}}{\text{basin surface area}} \quad (7)$$

Units: Solid storage depth in ft
Solids storage volume in ft^3
Basin surface area in ft^2

For vertical wall structure, use area at top of structure. For sloped wall structure, use average area of top and bottom of structure.

Step 9

Overall basin depth:

$$\text{Overall basin depth} = \text{liquids depth} + \text{solids storage depth} \quad (8)$$

Units: Liquids depth in ft (step 5 or 6)
Solids storage depth in ft (step 8)

Step 10

Size the sloping screen prior to riser pipe (if used). Screen area is sized to limit flow velocity through the screen to less than 2.5 feet per minute when basin is full. Assume an expanded metal screen has 60 percent open area.

$$\text{Screen area} = \frac{(\text{flow rate off lots} \times 60\ \text{s/min})}{(0.6 \times 2.5\ \text{ft/min})} \quad (9)$$

Units: Screen area in ft^2
Screen length in ft
Flow rate off lots in ft^3/s
Screen height in ft

Step 11

Basin length:

$$\begin{aligned}\text{Minimum basin length} &= \text{Ramp length} + \text{screen length}\\ &= (\text{Overall basin depth, ft}\\ &\quad \times \text{ramp slope}) + \text{screen length}\end{aligned} \quad (10)$$

Units: Minimum basin length, ft
Ramp length, ft Ramp slope should be 10:1 or flatter
Overall basin depth, ft
Screen length, ft

Step 12

Basin width

$$\text{Basin width} = \frac{\text{Basin surface area, ft}^2}{\text{basin length}} \quad (11)$$

Units: Basin surface area, ft^2

Basin length in feet should not be less than minimum basin length calculated in step 11. If site limitations restrict basin width, increase basin length and recalculate. The basin width must be at least 10 feet wide for equipment access to remove solids.

Step 13

Flow rate from basin to VTA

For a settling basin that precedes a VTA, flow rate should equal design storm volume spread over a 30- to 72-hour period. This would be encouraged for VTAs applied to all size livestock operations and specifically recommended for EPA permitted CAFO operations. The exception would be where the VTA's lower end is bermed or the runoff is collected in a holding basin. The outlet will need to have an orifice plate that provides control over outflow rate.

a. Estimate flow rate:

$$\text{Outlet flow rate} = \frac{\text{liquid volume}}{(\text{flow period} \times 3{,}600)} \quad (12)$$

Units: Outlet flow rate, ft^3/s
Liquid volume, ft^3 as estimated by the storm event method in step 7
Flow period, h (30–72 h recommended)
3,600 is the conversion from h to s

b. Size orifice from table 5–2

c. Determine the required open area/feet of pipe height from table 5–3 for the riser pipe.

d. Increase the open area of the riser pipe by 25 percent.

e. Size the riser pipe diameter using table 5–4. Minimum riser pipe diameter should be at least 2 inches greater than orifice diameter.

For a settling basin that precedes a holding pond or VIB, allow outflow to equal the peak flow rate off the lot (step 2) when the basin is full, using the following procedure:

a. For a riser pipe with an orifice, follow the procedure described above with the exception of selecting flow rate from step 2.

b. For a perforated pipe without an orifice plate, determine the required open area/foot of pipe height from table 5–3. Then size the riser pipe diameter using table 5–4.

c. For a porous dam, determine required dam length from figure 5–4.

Step 14

Select an underground discharge pipe from figure 5–6. Size the pipe to discharge at the peak flow rate off the lot. Determine pipe slope as shown in figure 5–6.

Figure 5–6 Capacity of pipe. Although developed for clay tile drainage lines, these charts approximate the capacity of low pressure lines (MWPS 1985, fig. 4–5).

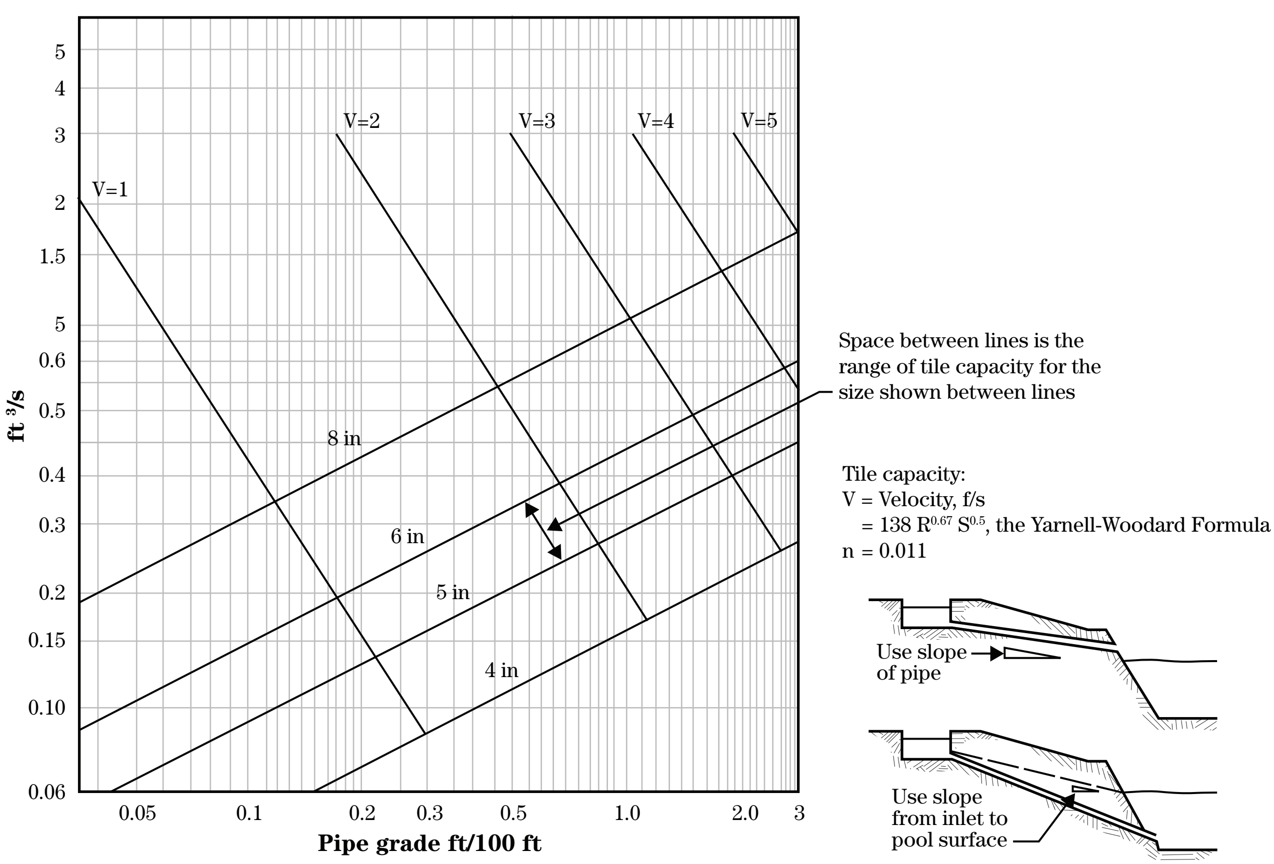


Table 5–3 Riser pipe open slot design for settling basin outlets. Determine open slot area per linear ft of pipe for design flow; then, increase that value by 25%. Boxed values refer to example in appendix C (MWPS 1985).

Open slot area/ft of pipe height, in²/ft	Head, ft							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Flow rate, ft^3/s							
4	0.034	0.093	0.169	0.259	0.361	0.473	0.596	0.728
6	0.051	0.139	0.253	0.388	0.541	0.710	0.894	1.091
8	0.068	0.186	0.338	0.518	0.721	0.947	1.192	1.455
10	0.085	0.232	0.422	0.647	0.902	1.183	1.480	1.819
12	0.102	0.279	0.507	0.776	1.082	1.420	1.788	2.183
14	0.119	0.325	0.591	0.906	1.262	1.657	2.086	2.546
16	0.136	0.371	0.675	1.035	1.443	1.894	2.384	2.910
18	0.153	0.418	0.760	1.164	1.623	2.130	2.682	3.274
20	0.170	0.464	0.844	1.294	1.803	2.367	3.980	3.638
22	0.187	0.511	0.929	1.423	1.984	2.604	3.277	4.001
24	0.204	0.557	1.013	1.542	2.164	2.840	3.575	4.365
26	0.221	0.603	1.097	1.682	2.344	3.077	3.873	4.729
28	0.238	0.650	1.182	1.811	2.525	3.314	4.171	5.093
30	0.255	0.696	1.266	1.940	2.705	3.550	4.469	5.456
32	0.272	0.743	1.351	2.070	2.885	3.787	4.767	5.820
34	0.289	0.789	1.435	2.199	3.066	4.024	5.065	6.184
36	0.306	0.836	1.519	2.329	3.246	4.260	5.363	6.548
38	0.323	0.882	1.604	2.458	3.426	4.497	5.661	6.911
40	0.340	0.928	1.688	2.587	3.607	4.734	5.959	7.275

Table 5–4 Sizing of riser pipe. Capacity of smooth plastic riser pipe (ft^3/s) at design water depth

Riser diameter, in	Head, depth of water over inlet							
	0.5	1	1.5	2	2.5	3	3.5	4
	ft^3/s							
3	0.18	0.26	0.31	0.36	0.41	0.44	0.48	0.51
4	0.33	0.47	0.57	0.66	0.74	0.81	0.87	0.94
6	0.76	1.08	1.32	1.52	1.70	1.87	2.01	2.15
8	1.37	1.93	2.37	2.74	3.06	3.35	3.62	3.87
10	2.15	3.04	3.72	4.30	4.81	5.27	5.69	6.08
12	3.11	4.40	5.38	6.22	6.95	7.61	8.22	8.79
14	4.24	6.00	7.35	8.48	9.48	10.39	11.22	12.00
16	5.55	7.85	9.61	11.10	12.41	13.59	14.68	15.70

Minimum riser pipe diameter selected should be the largest of the following three possibilities: (1) the diameter of the mainline, (2) 2 in larger than the planned orifice diameter , or (3) the diameter from table 5–4 with capacity of 1.5 times design flow rate.

Alternative solids-settling facilities

Several alternative, low-cost solids-settling facilities may be practical in some circumstances. All of these alternatives balance reduced cost against greater maintenance requirements. If maintenance requirements are not followed closely, higher solids will move into the VTA or VIB, increasing the potential for loss of vegetation and short-circuiting in the VTA.

These alternative solids-settling facilities do not provide control over the rate of feedlot runoff entering the next stage of treatment. Thus, high-intensity storms will cause high flow rates from these settling options into the VTA. For a CAFO permitted under current EPA regulations, precise control of the release timing or rate of flow into the VTA is important for reducing the risk of runoff exiting the VTA. Thus, application of these alternative solids-settling facilities in permitted CAFOs would not be recommended unless this concern is offset by lower risk system options (sec. 3) or more conservative VTA sizing.

Settling bench

A settling bench (fig. 5–7) is an area of relatively flat slope of a width such that the low velocities produce runoff flow rates producing significant solids settling. Maintaining vegetation on the settling bench improves settling efficiency. Solids must be removed at appropriate intervals to maintain the settling and distribution function. Reseeding of grass will likely be necessary after each solids removal.

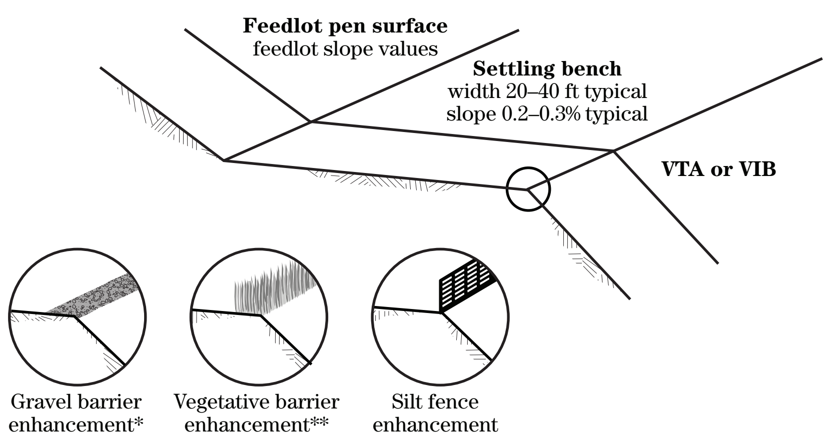
Design recommendations:

- Width: 20 to 40 feet
- Minimum length: Preferably the width of the bottom edge of the feedlot
- Slopes: 0.002 to 0.003 feet per foot towards the VTA
- Location relative to feedlot and VTA. It is preferable to locate the bench just below the feedlot pens (not within the pen itself) since flow may already be distributed over a fairly wide area. The settling bench should also be located directly between the feedlot and VTA or VIB.

Operation and maintenance recommendations:

- Monitor solids accumulation closely; remove any significant solids which will disrupt distributive flow.
- Solids removal will impair the grass stand; therefore, seeding may be required after solids removal.
- Grade control will be required on the bench to maintain the flow producing characteristics of the bench.
- A geotextile fabric placed below the bench surface may be beneficial for allowing vehicle traffic for solids removal only in higher rainfall climates.

Figure 5–7 Typical settling bench



* Reference: "Ground Level Lip Spreader for Barnyard" Pennsylvania NRCS Drawing
** Reference: "Vegetative Barrier" Texas NRCS Conservation Practice Standard Code 501

Geotextile fabric (silt fence)

A barrier or series of barriers of semi-porous material is set at right angles to the flow (*http://www.salixacc.com/siltfence.html*). This method can be used without additional settling options, or in conjunction with a settling bench to remove suspended solids.

Recommended design and construction criteria

- Silt fences should not impound water more than 18 inches in depth from a 10-year, 1-hour storm assuming no drainage through the fabric.
- Place silt fence on the contour, turning ends upslope in order to impound water.
- Soil should be sliced and fabric placed and compacted.
- Post spacing should not exceed 6 feet.
- Fabric is wired directly to the posts.
- Steel T-posts weighing at least 1.25 pounds per foot of post are required.

Recommended operation and maintenance

- Silt fence may need to be replaced at 1- to 2-year intervals. Geotextiles usually cannot be recycled. Check with the supplier of the material as to recycling opportunities. Also, visit with the local landfill as to the costs for disposal of this material.
- Inspect fence after every runoff event. Watch for undercutting of fence by water.
- Remove solids on a regular basis to prevent substantial buildup of materials.

Gravel spreader/barrier

Gravel spreader/barrier is a small ridge of graded gravel with a uniform elevation and width used as a solids removal and settling enhancement. This practice lends itself well to use with a settling bench. Placed at the downstream edge of a settling bench, it reduces sheet flow velocities, traps solids, and enhances flow distribution. Gravel benches could also be placed at the upper end of a VIB allowing the solids settling and VIB to be combined into a single structure.

Recommended design criteria

- Height of barrier 6 inches, top width 1 foot
- Ends of barriers turned upslope

Operation and maintenance

- Gravel will require periodic maintenance due to accumulated solids plugging the flow paths through the gravel. Gravel may need to be replaced or redistributed to a level grade.
- Remove solids on a regular basis to prevent substantial buildup of materials.

Vegetative barrier

Permanent strips of stiff, dense vegetation along the general contour of slopes or across concentrated flow areas are installed to reduce erosion, manage runoff flow, and trap solids (NRCS Conservation Practice Standard 601, Vegetative Barrier, *http:www.nrcs.usda.gov/technical/Standards/nhcp.html*). This method will normally be used in conjunction with other practices such as a filter strip or VTA.

Recommended design and construction criteria

- Vegetative barriers will be planted to vegetation having large enough stems to keep the barrier upright during runoff events.
- Gaps between plants will be no greater than 3 inches at the end of the first growing season.
- Species must be adapted to local soil and climate conditions, be easily established, long-lived, and manageable.
- Species will be selected that exhibit characteristics required for adequate function.
- Barriers may be established from transplanted vegetation or from seed.
- Barrier widths will be the largest of 3 feet wide or 0.75 times the design vertical interval.

Recommended operation and maintenance

- Establishment failures will be replanted or reseeded immediately; short gaps in seeded barriers may be re-established with transplanted plant material.
- Mowing herbaceous barriers may be used as a management practice to encourage the development of a dense stand and prevent shading of other vegetation. Mowing will not be closer than 15 inches or the recommended height for the species, whichever is taller. Mowing in concentrated flow areas is discouraged because it will lower the vegetative stiffness index (VSI) by reducing average stem diameter.

- Weed control will be accomplished by mowing, spraying, or wick application of labeled herbicides.
- Vegetation in the barrier will be tolerant to or protected from herbicide used in surrounding cropped fields.
- Washouts or rills that develop will be filled and replanted immediately. Short gaps in established barriers will be re-established with transplanted plant material.
- Vegetative barriers will not be used as a field road or turn row. Vegetative barriers in concentrated flow areas will not be crossed with machinery.
- Vegetative barriers will not be crossed with water furrow plows or similar implements to cut drainage ditches to allow the passage of surface and subsurface water. If necessary, water should be drained by underground outlets installed up gradient of the barrier.
- Crop tillage and planting operations will be parallel with vegetative barriers.
- Pest control in adjacent fields will be performed with techniques and pesticides that will not damage the vegetative barrier.

Active versus passive management

Two distinct strategies are suggested for management of the outflow from a settling basin to a VTA. The producer's choice as to the appropriate management strategy may depend upon whether state or federal regulations apply to the facility and regulatory agency's interpretation as to how a VTA should be managed.

Active management

Active management of release of liquid from the settling basin involves producer control over release of all collected runoff until the liquid can infiltrate readily into the soil. This approach would minimize outflow onto the VTA when soils are frozen or saturated. The producer would actively prevent release of liquids until desired soil conditions were acceptable.

Advantages of active management strategy

- The least risk of a discharge from the VTA
- Maximum solids removal from the runoff
- May allow a smaller VTA (see sizing discussion in sec. 6)

Disadvantages of active management strategy

- The settling basin must be sized, designed, and managed as a runoff holding pond.
- The advantages of reduced seepage from the holding pond to ground water and air emission offered by the VTA system are less.
- For wetter climates, very large holding pond structures need to be installed in advance of the VTA.

Passive management

Passive management of the outflow of the settling basin into a VTA allows continuous outflow during the storm event. To minimize risk of VTA discharge, the flow rate from the settling basin is carefully controlled by the sizing of the settling basin discharge. Successful functioning of this system is dependent upon the ability to control flow so that it is released over an extended period of time, 30 to 72 hours after the storm event. This produces a situation where the settling basin liquid addition to the VTA represents only a small fraction of the precipitation falling directly on the VTA, and, thus, adds little risk to increased runoff. Because the contaminated runoff liquids are applied to the upper end of the VTA, the risk of runoff is further reduced.

Advantages of passive management strategy

- Low risk of runoff from the VTA
- Environmental failures of the collection and distribution system due to poor management are eliminated.
- Although the settling basin has significant size, it is still less than required for a holding pond.
- Liquids remain in the settling basin for less than 72 hours after any one storm event, reducing the risk of seepage to ground water and aerial emissions.

Disadvantages of passive management strategy

- Discharge from the VTA may occur for runoff events resulting during frozen soil conditions or for more intense storms that occur during extended wet periods.
- Permitted CAFO may need to record discharges and sample discharge for reporting to the permitting authority.

If outflow of the settling basin is to a holding pond or VIB, the preferred management strategy should always be a passively managed system. Both the holding pond and VIB have little chance of a discharge, unless poorly managed and the storm event exceeds the design storm capacity of a 25-year, 24-hour event. Alternative settling facilities will always be operated as a passive system as determined by the nature of their design.

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Section 6 Vegetative Treatment Area Design

Section 6 Vegetative Treatment Area Design

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Section 6 Vegetative Treatment Area Design

Topics

VTA design recommendations for:

- Size
- Encouraging sheet flow
- Plant materials
- Slope limitations
- Options for reducing discharge

Purpose

VTA is a fairly simple technology having modest design requirements. However, for a VTA to function properly and minimize the potential for release of polluted runoff, several fundamental design requirements must be considered including sizing, maintenance of sheet flow, and selection of plant materials. These few, but critical considerations, must be carefully evaluated to ensure that the environment is protected. This section reviews those critical design considerations for a properly functioning VTA.

Past research has documented that contaminants contained by feedlot runoff is too concentrated, even after treatment by a VTA, to be discharged into surface waters. It should also be recognized, that the NPDES permit granted to a CAFO will require equal or better performance for a VTA as compared to a conventional holding pond and land application. A properly designed VTA is critical to limiting VTA runoff and protecting surface and ground water. Proper design must address:

- Minimum size requirements
- Distribution of flow and nutrients within the VTA
- Proper selection of forage or grass
- Recognizing VTA slope limitations

VTA definition

A VTA is an area of planted or indigenous vegetation situated downslope of animal production facilities that provides localized erosion protection and contaminant reduction. Planted or indigenous vegetation preferably includes perennial vegetation including forages, grasses, or pasture. These crops are used to treat runoff through evapotranspiration, adsorption, settling, and infiltration. Thus, the word treatment in the term describes an important function of these soil- and plant-based systems. VTS refers to a collection of treatment components, including at least one component based upon vegetation treatment that is used to manage the runoff from an open lot production system or other process waters.

A summary of the treatment performance of these systems is included in Section 9, Literature Review. This technology has received significant research evaluation and development with more than 30 research applications of VTAs to manure or runoff from animal agriculture applications.

Four alternative types of soil- and plant-based runoff treatment components have been used to treat animal manures, open lot runoff, or other process waters:

- *VTAs*—Perennial grass and forage filters can be applied to lower sloping land (sec. 6). Woody plants, trees, and annual forages may provide alternative plant materials for VTA, although there is less experience with these plant materials. Proper sizing, plant selection, and creating and maintaining sheet flow of runoff are critical design considerations for optimum performing VTAs.
- *Terraced VTAs* have been used to contain runoff on sloped areas. Both overflow and sepentine terraces have been used. Overflow terraces move runoff from one terrace to a second by cascading of runoff over the terrace top or by plastic tile drains. Serpentine terraces move runoff back and forth across the face of a slope. In both situations, the upper terrace is typically used for solids settling with succeeding terraces intended to encourage infiltration of liquids into the soil. Terraced systems are considered a subcategory of VTAs and may provide an optional approach for open lot systems located in steeper terrain.
- *VIBs* have many similarities to VTAs with the exception that they include subsurface collection and drainage and complete enclosure by a berm designed to prevent surface discharges. Runoff from an open lot is allowed to infiltrate through a soil system within 30 to 72 hours. Section 7 focuses on the design of VIBs.
- *Constructed wetlands* have been utilized to treat open lot runoff. Design and management is challenged by intermittent flow from open lots with resulting difficulty in maintaining wetlands function. Seasonal open lots used for winter livestock housing and empty during the summer may be a preferred system for constructed wetlands. Constructed wetlands are recognized as an alternative, but are not described in detail in this publication. For additional information on constructed wetland application to animal effluents, see Payne 1992 and Gulf of Mexico Program 1997.

VTA sizing

Proper VTA sizing is essential to:

- Minimizing excess nutrient accumulation and leaching within a VTA
- Limiting the potential for an unplanned release of runoff from the VTA

Two approaches are currently used for sizing the area required by a VTA. One approach is based upon a balance between the nutrients contained within the runoff with the nutrients harvested by the forage or grass grown within the VTA. A second approach is based upon a water balance, matching the rate of runoff water collected from an open lot and additional drainage area with the water infiltration rates of the land area used for the VTA. The following discussion examines these two sizing procedures in greater detail and reviews their strengths and weaknesses.

Sizing of a VTA based upon a water balance method offers several environmental advantages:

- Infiltration of feedlot runoff into the VTA for most storm events, thus, minimizing the potential for contaminated runoff from the VTA
- The limited potential for release of runoff from a VTA and the presence of perennial vegetation results in minimum potential contamination of surface water from soil, phosphorus, and pathogen movement. This advantage is most distinct when compared to baseline systems based upon row crop production.

Sizing of a VTA based upon a nitrogen balance method should produce the same advantages as one based upon a water balance with one additional environmental benefit:

- Reduced nitrogen leaching to ground water resulting from a rough balance between nitrogen applied and nitrogen harvested within a VTA. Because of the non-uniform infiltration of runoff and the associated nitrogen into the VTA soils, nitrogen leaching remains a potential concern within some areas of a VTA.

Alternative sizing procedures target runoff contact time with vegetation in the VTA and/or flow depth at the entrance to the VTA. These alternative design methods may be adequate for AFOs that have modest risk of being classified as a CAFO, but should only be used as design refinements for VTAs on CAFOs to assure distribution throughout the VTA. Sizing methods that assure infiltration of feedlot runoff for most precipitation events are critical for CAFOs.

The Iowa State University VTA performance model discussed in section 2 uses a comprehensive water balance method for estimating VTA size. It allows factors such as multiple soil layers, shallow ground water tables, timing of runoff release into the VTA, and other factors to be considered in a robust water balance estimate of performance. This performance model estimates surface water releases of water and the four required contaminants, but currently makes no prediction of nitrate movement to ground water.

VTA sizing by nutrient balance

To design a VTA that minimizes release of feedlot runoff nutrients to surface and ground water, four critical questions must be answered. This section provides information for answering those questions.

What is the volume of runoff from the feedlot?

The volume of runoff from a feedlot for a given storm is commonly estimated using the NRCS curve number method and a selected storm event. This method is described in the NRCS National Engineering Handbook, Part 630, chapter 10. A summary of this procedure along with an example problem is provided in appendix B.

What is the mass of nutrients in the feedlot runoff?

VTAs are usually designed to retain nitrogen. This method is primarily intended to limit potential leaching of nitrate to ground water. Additional considerations to protect ground water are discussed in section 3 on site selection and section 8 on management to protect ground water.

Nitrogen is generally the limiting nutrient in VTA design for feedlot runoff. Limited movement of phosphorus with runoff and settling of significant portions of the phosphorus in the settling basin limits the phosphorus risk. It is further assumed phosphorus that is not attached to the settleable solids will become adsorbed in the soil profile or utilized by the crop once the runoff water infiltrates the soils of the VTA. VTAs with perennial vegetation should have minimal risk associated with phosphorus buildup and runoff. Regular harvesting of VTA vegetation will help keep phosphorus levels in check. Soil phosphorus levels should be monitored regularly (sec. 8) for confirming that assumption.

Three methods are used to estimate the mass of nitrogen leaving a feedlot through runoff:

Method 1 requires a runoff nitrogen concentration from similar paved and unpaved feedlots and assumes these concentrations will be representative of the runoff from the feedlot under consideration for a VTA. Annual runoff volume can be determined from figures B–2 and B–3 of appendix B.

As illustrated in table 5–1 (sec. 5), considerable variation exists in nitrogen concentration in runoff. It is best to use numbers from the feedlot for which a VTA is being designed or numbers collected from the region in which the feedlot is located. Precipitation rates and patterns influence the concentration of nutrients in runoff and regionally specific runoff nutrient concentrations should be used. *If no local data on feedlot runoff nutrient concentration is available, this method may not be acceptable.*

Method 2 is described in lesson 22 of the Mid-West Plan Service Livestock and Poultry Environmental Stewardship Program. This method uses a relationship between annual runoff and annual rainfall as represented in figure 6–1.

Method 1

Annual N leaving feedlot	=	Annual runoff volume	×	N concentration in runoff

Method 3 is based upon standard values for as excreted nitrogen in manure and estimates of nitrogen in runoff and availability of nitrogen to the crop. Section 9 summarizes the research literature basis for these estimates. This method assumes that:

- Nitrogen leaving the lot as runoff represents 5 percent of the annual excreted nitrogen
- Nitrogen entering the VTA after solids removal represents 50 percent of the nitrogen in runoff (the remaining 50 percent is retained as settled solids in a settling basin or comparable solids removal treatment)
- Nitrogen available for crop uptake is 50 percent of nitrogen entering VTA (losses due to ammonia volatilization and denitrification)

These estimates are adequate to design systems that utilize open lot runoff. When in operation, the stored runoff should be sampled to determine the actual nitrogen concentration and the wastewater applied accordingly. Runoff application rates to the VTA may not be adjustable. However, record keeping on rainfall events (which can be used to approximate application rate), runoff nutrient concentration and other indicators of N management (section 8) should be used in adjustment of any additional nitrogen fertilizer application to the grass or forage system (table 6–1).

Some systems based upon a VTA may include additional pre-treatment in advance of the VTA. For example, VTS option 3 described in section 3 includes both solids removal and VIB in advance of the VTA. Based upon past research and experience, the VIB will consistently remove at least 75 percent of the nitrogen in advance of the VTA. Thus, for VTS option 3, reduce the previous estimates for N reaching the VTA by 75 percent to account for the additional pre-treatment resulting from both the solids removal and VIB.

Figure 6–1 Method 2 estimate of annual N released from paved and earthen feedlot surfaces. Refer to figure B–2 appendix B, for value for annual runoff percent to enter on x-axis.

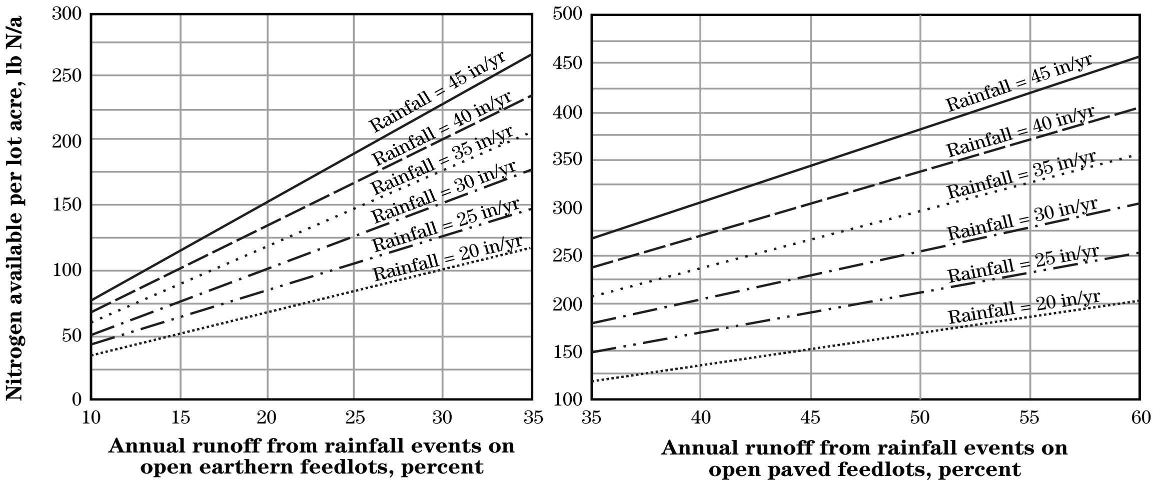


Table 6–1 Method 3 for estimating nitrogen in runoff

Species	Typical nitrogen excretion	N in runoff from open lot [1]	Plant available N [2]
		lb N/finished animal	
Beef finish cattle	55	2.8	0.69
		lb N/finished animal	
Beef – Cow	0.42	0.021	0.0053
Beef – Growing calf	0.29	0.015	0.0036
Dairy – Lactating cow	0.98	0.049	0.012
Dairy – Dry cow	0.50	0.025	0.0063
Dairy – Calf (330 lb)	0.14	0.0070	0.0018
Dairy – Heifer (970 lb)	0.26	0.013	0.0033
Horse – Sedentary (1,100 lb)	0.20	0.010	0.0025
Horse – Intense exercise (1,100 lb)	0.34	0.017	0.043

1 Assumes 5% of excreted N is runoff
2 Assumes 50% of N in runoff is retained after solids separation and 50% of retained N is plant available

Example: Estimate the N in runoff using the three methods for a 2,000 head capacity dirt feedlot located in central Iowa. The feedlot is 11.5 acres in area with an additional 8 acres of roads, drainage ditches, feed storage and preparation areas, and compost site draining into the settling basin. The settling basin's surface area is 123,000 square feet. Annual precipitation is 34 inches. A nearby feedlot has observed an average concentration of 25 pounds total N/acre-inch in runoff samples collected after solids settling. See examples in appendix B for additional information.

Method 1

Total volume to VTA (a-in) = Annual runoff from eedlot and contributing area + (area of settling basin x annual rainfall)

= 240 a-in (from app. B example problem) + (123,000 ft^2 ÷ 43,560 ft^2/a) x 34 in

= 336 a-in/yr

Using a runoff sample from a nearby feedlot (25 lb N/a-in), total N in runoff is:

25 lb N/a-in x 336 a-in = 8,400 lb total N from feedlot per yr

Plant available N (50% of total N) is:

8,400 lb total N x 0.5 = 4,200 lb plant available N/yr

Discussion: Is the concentrations of N in runoff from a nearby feedlot representative of this feedlot? The amount of dilution water from contributing areas can significantly change the N concentration between feedlots. Our example feedlot has significant runoff from the 8 acres of contributing area outside of the feedlot.

Method 2

From figure 6–1 with 23 percent annual runoff[1], 140 pounds of N in runoff per acre of feedlot area from the 11.5 acres of feedlot (assume N runoff from 8 acres additional contributing area is minimal):

140 lb N/a of drainage area x 11.5 a = 1,610 lb N

Method 3

From table 6-1, assuming 5 percent of N is in runoff and 25 percent of that nitrogen will become crop available:

0.69 lb N/finished animal x 4,000 head finished = 2,800 lb plant available N

Discussion: Large volume of dilution water (150 a-in of runoff from roads and other contributing areas and 96 a-in from rainfall on settling basin) make method 1 suspect. No reason was found to reject methods 2 and 3. Select larger estimate of methods 2 and 3 or 2,800 pounds plant available N from feedlot.

1 23% annual runoff estimate is from appendix B, figure B–2 for Earthen open lot runoff (CN=90)

How large will the VTA need to be to capture these nutrients?

If the designer is able to make an appropriate estimate of the pounds of nitrogen that will be applied to the VTA on an annual basis, the minimum size of the VTA can be computed by dividing the nitrogen to be applied to the VTA on an annual basis by the annual nitrogen uptake of the vegetation in the VTA. State or local agronomy guides should be used to determine reasonable crop yields and nitrogen uptake values. In many cases, VTA yield will exceed typical non-irrigated yields in the same locality. In the absence of localized data, use table 6–2 for nitrogen uptake.

For conventional holding ponds and spray irrigation systems, 1 acre of feedlot requires approximately 1 acre of land application area to manage the nitrogen. Similar and possibly slightly larger VTA areas might be needed for a VTA due to a smaller nitrogen volatilization rate during storage and land application. As a result, a land area of between 1 and 1.5 acres VTA per acre of feedlot might be a reasonable starting point for estimating VTA size based upon nitrogen.

How will the nutrient loading of the VTA be timed to match the nutrient uptake of the vegetation?

Timing of the application of the nutrients to a VTA is typically driven by the rainfall and runoff events that carry nutrients to the VTA. In most Corn Belt and High Plains regions, runoff is greatest in spring and early summer which is timed well to the nutrient requirements of most grasses and forages (late spring through fall). Due to the moisture utilization by perennial forages, most excess nitrogen will be stored in the soil during the growing season until it is utilized by the vegetation, minimizing the leaching of nitrogen beyond the root zone.

This may not be a valid assumption where a substantial amount of nutrients are carried to the VTA in early fall if a crop is not continuing to use nutrients. Grass and forages with long growing seasons would be preferable to row crops, such as corn, for utilizing nutrients from early fall runoff events. Late fall and winter application of runoff will add ammonium and some organic nitrogen to the VTA, both of which are immobile in most soils. However, these forms of nitrogen are unlikely to be converted to mobile nitrate nitrogen until the soil warms in the spring. Perennial grasses and forages with long growing seasons should allow removal of mobile nitrate nitrogen during an extended period of the year when nitrogen in this form is available.

Under frozen soil conditions, the ability of a VTA to manage runoff should be reviewed. In many Midwest locations, the fraction of rainfall that exits a dirt lot as runoff is typically very small (for Ames, IA: 10%, <10%, and 15% of monthly rainfall exits as runoff in Jan., Feb., and Mar., respectively). Precipitation is also low during these periods of time (for Ames, IA: 0.76, 0.74, and 2.06 in for Jan., Feb., and Mar., respectively). Frozen soil conditions in a VTA may present minimal environmental risk because of low total runoff from dirt lots during the same period (for Ames, IA:

Table 6–2 Plant nitrogen uptake by forages removed with the harvested part of the crop

Crop	Nitrogen uptake	Crop	Nitrogen uptake
Alfalfa	45 lb/ton	Lespedeza	47 lb/ton
Alfalfa haylage	28 lb/ton	Little bluestem	22 lb/ton
Bahiagrass	25 lb/ton	Orchardgrass	29 lb/ton
Big bluestem	20 lb/ton	Panagolagrass	26 lb/ton
Birdsfoot trefoil	50 lb/ton	Paragrass	16 lb/ton
Bluegrass	58 lb/ton	Red clover	40 lb/ton
Bromegrass	39 lb/ton	Reed canarygrass	27 lb/ton
Clover-grass	30 lb/ton	Ryegrass	33 lb/ton
Dallisgrass	38 lb/ton	Switchgrass	23 lb/ton
Guineagrass	25 lb/ton	Tall fescue	39 lb/ton
Bermudagrass	38 lb/ton	Timothy	24 lb/ton
Indianagrass	20 lb/ton	Wheatgrass	28 lb/ton

0.08, 0.07, and 0.30 in of runoff in Jan., Feb., and Mar., respectively). Runoff from paved lots is significantly higher during winter conditions and may produce a greater risk for frozen soil conditions in a VTA.

Critical assumptions the producer should check

Any design involves several critical assumptions that influence a planner's recommendations for VTA size. To ensure that a design based upon a nitrogen balance will perform as expected, the producer should quiz the planner about the following critical assumptions:

- What estimate was made of nitrogen runoff from the feedlot, nitrogen removal by the solids settling facility, and the crop availability for of nitrogen reaching the VTA? Compare those assumptions with estimates shown.
- What assumptions were made for nitrogen removal by the perennial forage or grass including the planned yield? Do yields match local experience with growing similar forages or grasses?
- What design features were included to maintain relative uniform distribution of nitrogen and water within the VTA?

Draw upon the expertise of a local crop consultant, land grant university extension specialist, or NRCS staff to review the validity of the assumptions made by the planner.

Example: Tall fescue is harvested at 5 ton/a from the VTA on our 2,000 head feedlot. Based upon nutrient removal rates from table 6–2, the amount of land required would be approximately:

Method 2: 1,610 lb N ÷ (39 lb N/ton x 5 ton/a) = 8.3 a

Method 3: 2,800 lb N ÷ (39 lb N/ton x 5 ton/a) = 14 a

VTA sizing by water balance

A water balance is used to design a VTA to minimize release of feedlot runoff nutrients to surface water. It focuses on hydraulic loading rates and limits of a VTA. A water balance approach compares the release rate of runoff from a design storm to the infiltration rate of the soil. Typically, the runoff volume is a function of a 25-year, 24-hour storm event (fig. B–1, app. B), drainage area, and type of surface. Procedures for estimating runoff are illustrated in appendix B.

The water balance procedure described in this section assumes that the runoff release from the solids removal component to the VTA is controlled so that limited runoff is added to the VTA during the storm event. For systems that do not control the release of liquid to the VTA (a settling bench), the intensity of the storm and the more rapid addition of water to the VTA must also be addressed in the design.

The ability of the soil to assimilate the runoff from the storm event is dependent upon three factors:

- The saturated soil infiltration rate (a safety factor for infiltration rate can be included assuming that sheet flow of runoff water does not cover the entire VTA) from the county soil survey.
- The time over which the settling basin is allowed to drain. Typically 30 to 72 hours is allowed for the settling basin to drain to the VTA.
- VTA area

Using these procedures, a ratio of VTA area to drainage area (assuming all precipitation runs off) is reported in table 6–3.

This method does not address deep percolation of runoff water into or below the soil profile. With a VTA/feedlot area ratio of 0.5, and assuming uniform application on the VTA, a 5.5-inch design storm will result in 9 to 11 inches of additional water applied to the VTA (see table B–1 for storm event runoff). If the soil within the crop rooting depth cannot (in most cases will not) assimilate this depth of water, deep percolation may be a concern. A larger VTA may be needed to address this issue.

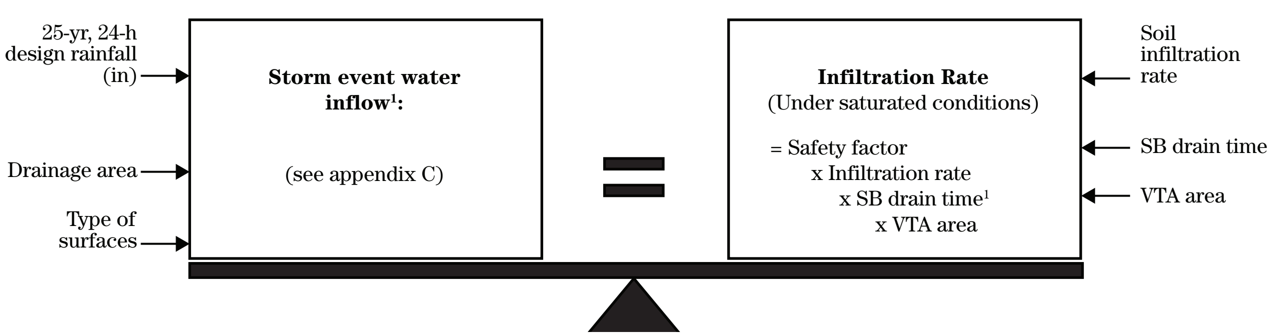
In summary, a water balance can serve as one option for estimating the minimum size requirement for a VTA. This estimate should be compared against an estimate based upon nutrient balance methods. Generally, the nitrogen-based balance will produce the larger VTA design. However, for systems involving additional runoff pre-treatment (solids settling and VIB in advance of VTA), the water balance method may be the more conservative procedure (fig. 6–2). A model for predicting performance using site-specific weather data (ISU VTA Model described in sec. 2) should now be used to estimate performance of the selected VTA size.

Critical assumptions the producer should check

A water balance design involves several critical assumptions that influence a planner's recommendations for VTA size. To assure that a design based upon a water balance will perform as expected, the producer should review with the planner the following critical assumptions:

- What assumptions were made about soil infiltration rate? Was it assumed to remain constant or change during the storm event?

Figure 6–2 Water balance method for VTA



1 Settling basin drain time: Design time for draining 25-yr, 24-h storm from settling basin

Table 6–3 Ratio of VTA area/drainage area for three saturated soil infiltration rates and three settling basin drain times

Design storm event (in)	Infiltration rate (in/h)								
	0.2 in/h settling basin drain time (h)			0.6 in/h settling basin drain time (h)			1.0 in/h settling basin drain time (h)		
	30	48	72	30	48	72	30	48	72
Earthen feedlot surface									
3	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1
3.5	0.8	0.5	0.3	0.3	0.2	0.1	0.2	0.1	0.1
4	1.0	0.6	0.4	0.3	0.2	0.1	0.2	0.1	0.1
4.5	1.1	0.7	0.5	0.4	0.2	0.2	0.2	0.1	0.1
5	1.3	0.8	0.5	0.4	0.3	0.2	0.3	0.2	0.1
5.5	1.5	0.9	0.6	0.5	0.3	0.2	0.3	0.2	0.1
6	1.6	1.0	0.7	0.5	0.3	0.2	0.3	0.2	0.1
6.5	1.8	1.1	0.7	0.6	0.4	0.2	0.4	0.2	0.1
7	1.9	1.2	0.8	0.6	0.4	0.3	0.4	0.2	0.2
Concrete feedlot surface									
3	0.9	0.6	0.4	0.3	0.2	0.1	0.2	0.1	0.1
3.5	1.1	0.7	0.5	0.4	0.2	0.2	0.2	0.1	0.1
4	1.3	0.8	0.5	0.4	0.3	0.2	0.3	0.2	0.1
4.5	1.4	0.9	0.6	0.5	0.3	0.2	0.3	0.2	0.1
5	1.6	1.0	0.7	0.5	0.3	0.2	0.3	0.2	0.1
5.5	1.8	1.1	0.7	0.6	0.4	0.2	0.4	0.2	0.1
6	1.9	1.2	0.8	0.6	0.4	0.3	0.4	0.2	0.2
6.5	2.1	1.3	0.9	0.7	0.4	0.3	0.4	0.3	0.2
7	2.3	1.4	0.9	0.8	0.5	0.3	0.5	0.3	0.2
Medium texture cropland									
3	0.32	0.20	0.13	0.11	0.07	0.04	0.06	0.04	0.03
3.5	0.43	0.27	0.18	0.14	0.09	0.06	0.09	0.05	0.04
4	0.56	0.35	0.23	0.19	0.12	0.08	0.11	0.07	0.05
4.5	0.68	0.43	0.28	0.23	0.14	0.09	0.14	0.09	0.06
5	0.82	0.51	0.34	0.27	0.17	0.11	0.16	0.10	0.07
5.5	0.95	0.60	0.40	0.32	0.20	0.13	0.19	0.12	0.08
6	1.1	0.68	0.46	0.36	0.23	0.15	0.22	0.14	0.09
6.5	1.2	0.77	0.52	0.41	0.26	0.17	0.25	0.15	0.10
7	1.4	0.86	0.58	0.46	0.29	0.19	0.28	0.17	0.12
Medium texture grassland									
3	0.24	0.15	0.10	0.08	0.05	0.03	0.05	0.03	0.02
3.5	0.34	0.21	0.14	0.11	0.07	0.05	0.07	0.04	0.03
4	0.44	0.28	0.18	0.15	0.09	0.06	0.09	0.06	0.04
4.5	0.56	0.35	0.23	0.19	0.12	0.08	0.11	0.07	0.05
5	0.68	0.42	0.28	0.23	0.14	0.09	0.14	0.08	0.06
5.5	0.80	0.50	0.34	0.27	0.17	0.11	0.16	0.10	0.07
6	0.94	0.58	0.39	0.31	0.19	0.13	0.19	0.12	0.08
6.5	1.1	0.67	0.45	0.36	0.22	0.15	0.21	0.13	0.09
7	1.2	0.75	0.50	0.40	0.25	0.17	0.24	0.15	0.10

1 Safety factor of 0.5 was assumed for area of VTA coverage by sheetflow

- Did the infiltration rate consider a shallow water table, if present? Shallow ground water tables will reduce the total infiltration that a site is capable of managing.
- What fraction of the VTA is assumed covered by runoff during a storm event and thus contributing to the total infiltration of runoff? It will be difficult to assure that the entire VTA is uniformly covered with runoff water and thus contributing to runoff infiltration. What design features were included to maintain relative uniform distribution of water within the VTA?

Use the expertise of your local Soil and Water Conservation District or NRCS office to review the validity of the assumptions made by the planner.

Example: Estimate the VTA size for the 2,000 head Central Iowa earthen feedlot (drainage area includes 11.5 acres of feedlot and an additional 8 acres of roads, drainage ditches, feed storage and preparation areas, and compost site) using the water balance. The 25-year, 24-hour design storm is 5.5 inches. The soil survey suggests that the soils at the selected site have an infiltration rate of 0.6 to 2.0 inches per hour. Assume that the settling basin outlet pipe will drain the basin in 48 hours.

From table 6–3, the VTA would need to be:

(0.3 x 11.5 feedlot a) + (0.4 x 8 additional a) = 7 acres

Estimate assumes that additional drainage area would have runoff similar to concrete lot, a conservative assumption.

Estimate also assumes that lower infiltration rate from soil survey will be used.

Discussion: This compares to our earlier estimates of 8 and 14 acres for the VTA based upon two nutrient balance methods. Since the nitrogen balance method suggests a larger VTA size, the vulnerability of local ground water to nitrate leaching may be critical to determining which sizing estimate to accept.

Sheet flow considerations

For VTAs to provide maximum benefit for water quality protection, flow should be uniformly distributed across the treatment area. Uniform flow reduces flow velocity and encourages settling of suspended particles, thus improving treatment efficiency. In addition, uniform flow maximizes infiltration, reducing the potential for a discharge. Dickey and Vanderholm (1981) estimated that it would require flow distances at least 10 times greater for channel flow treatment as compared to treatment from sheet flow through a vegetative filter.

Poor distribution of nutrients is probably the most significant environmental challenge for a VTA. To minimize this problem, the following considerations are essential:

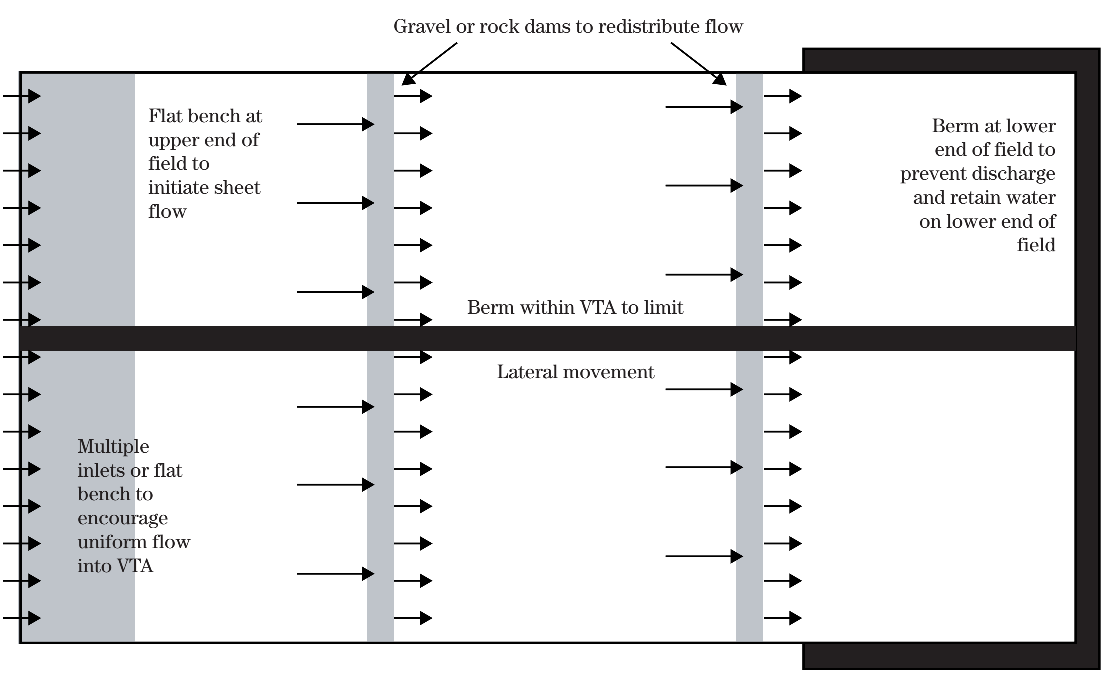
- Uniform distribution of runoff at the entrance
- Flow may converge within the VTA, and in field measures should be considered to redistribute flow within the VTA
- VTA management must monitor and maintain conditions to encourage sheet flow (sec. 8).
- A soil and/or forage nutrient monitoring program is necessary identify potential developing nutrient excess concentrations.

Initial runoff distribution

To maximize VTA performance, it is important that inflow to the system be distributed to initially create shallow sheet flow less than 1 inch deep (by definition) across the entrance to the system (fig. 6–3). To encourage uniform distribution from a settling basin into the VTA, the following options should be considered:

- A concrete distribution lip constructed as part of the settling basin or separately can be used with long, narrow VTAs. It is critical that the lip be at a constant elevation and long enough to span the width of the VTA. The one disadvantage to this approach is the inability to control the flow rate to allow the settling basin to drain over a 30- to 72-hour period.
- Gated irrigation pipe placed on a pre-determined constant contour elevation to allow equal flow at all outlets.
- A flat, land-graded bench can be created over the first 30 to 50 feet of the VTA will encourage uniform spreading of the flow.
- A gravel or rock dam across the upper end of the VTA immediately following the runoff release from the settling basin.
- Multiple pipe outlets from the settling basin can be spaced at 20- to 50-foot intervals with the entrance to each outlet placed at the exact same

Figure 6–3 Options for creating and maintaining sheet flow within a VTA



elevation. Each pipe must be placed on a concrete pad (base of which is below the frost line) to minimize settling. The final height of each inlet must also be adjustable to offset modest irregular settling that cannot be prevented with the concrete pads. The outlet should have a specifically sized orifice designed to produce the 30- to 72-hour settling basin drain period.

In all these cases, the inlet structure (often the outlet from settling basin) should be designed such that periodically the inlet can be re-calibrated to maximize uniform flow distribution. Design and construction for multiple pipe outlets need to include mechanisms for periodic adjustments so each pipe inlet is at a consistent elevation. The gravel and rock structures should be designed and constructed such that they can effectively be re-leveled without significant disturbance to the system. If gated pipe distributes the runoff, uniform distribution can be achieved if pipe flow is operated "full" and gates are adjustable to full pipe flow under most conditions. Placing gated pipe on the contour (constant elevation) is also critical. Screening of debris is also necessary for most inlets to avoid plugging of gates or orifices.

The inlet structure should be such that erosion features will not develop that could reduce the effectiveness of the flow distribution system. Earthen embankments should not be used for flow distribution due to erosion risk. High flow rates at the inlet (a pipe from settling basin) to the VTA should also be avoided because of the erosion potential. A graded flat bench over the first 50 feet of the VTA offers value for erosion control.

Distribution within VTA

The runoff from a feedlot can be introduced to a VTA evenly across the upper end of a VTA and still experience uneven distribution of nutrients over the length of the VTA. The portion of the VTA immediately below the settling basin will be more frequently loaded as a result of smaller storm events producing uneven distribution of nutrients and water. This creates a concern for nitrate leaching to ground water. Three possible solutions to improving distribution over the length of a VTA include:

- The runoff should be distributed to multiple outlets distributed down the length the VTA (one outlet at the headlands and a second halfway between the headlands and the end of the VTA). This option should be used with caution. Outlets not placed at the upper end of the field should include a control valve so they can be shut down during higher intensity storms.
- The runoff could be stored and distributed onto the VTA through sprinkler irrigation or other pressure dosing system such as a pump or siphon to a gated pipe.
- A shallow berm could be built around the lower end of the VTA and excess runoff is stored within the VTA. This does nothing to facilitate flow distribution, although it is useful where concentrated flow occurs despite previous measures and the potential for release from the VTA must be minimized.

Overland flow will tend to converge as it flows through the VTA. Maintenance of sheet flow for more than 200 feet is difficult without some sort of intervention. Level grading of the VTA across its width promotes sheet flow. Spreaders may be constructed as rock or gravel berms or wood and concrete sills. These spreaders should extend above the ground surface only a few inches to allow for flow spreading without extensive ponding of flow. The design and operation and maintenance plan for these spreaders should include provisions for periodic re-leveling.

Constructed spreaders would not need to be as structurally significant as might be required for the inlet distribution system, but they still should be able to remain structurally intact under high flow conditions (fig. 6–3). In addition, periodic maintenance may be required if erosion features would develop in the spreader. As such, the spreaders shall be inspected periodically (not less than annually) to confirm the level and functionality of the spreader.

Since some of the VTA systems may be relatively wide (perpendicular to the direction of predominant flow), limiting the width of the VTA will assist with sheet flow. A maximum width of a VTA should be 200 feet (table 6–4). Wider VTAs should include use of borders or berms parallel to the direction of flow spaced at 200-foot intervals similar to those used in some flood irrigation applications.

Table 6–4 Level spreader spacing recommended by IA NRCS

Slope (%)	Maximum spacing (ft)
<2	200
2–5	100
>5	50

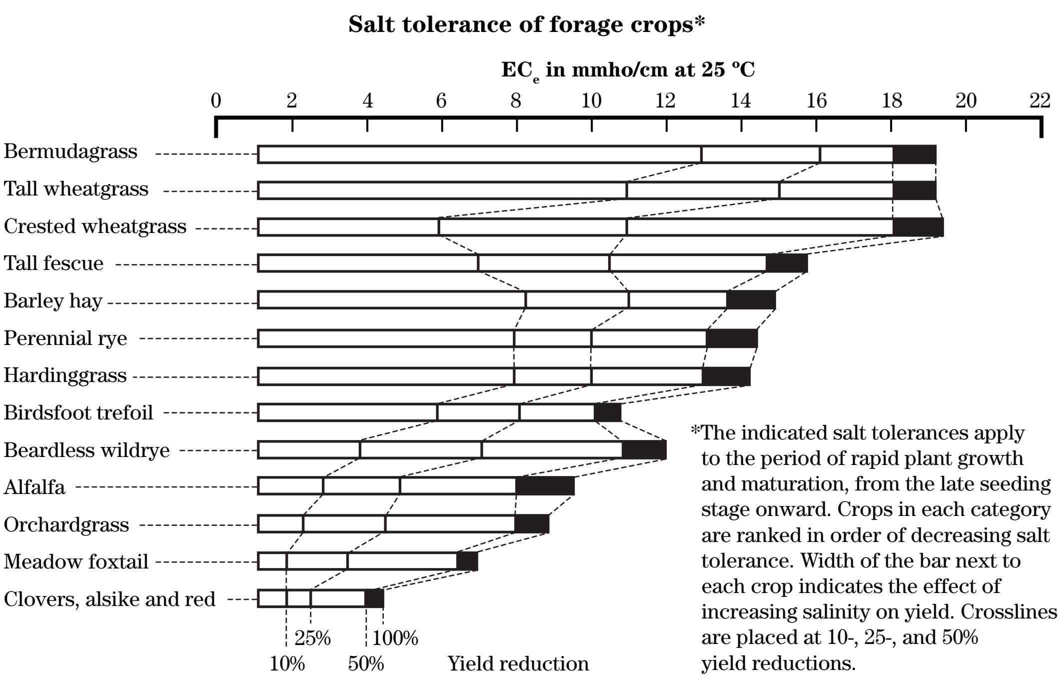
Plant materials selection

Appropriate forages or other crops should be selected based on the following considerations:

- *Tolerance to local climate*—Tolerance to temperature extremes, rainfall, and drought conditions specific to location is a first consideration.
- *Tolerance to flooding and saturated soil conditions* for extended periods—A bermed VTA will collect a diluted runoff from the open lot. Forages or other crops maintained in a bermed VTA will need to withstand flooding and saturated conditions over an extended time period. In addition, a VTA receiving liquid from a settling basin over an extended period (30 to 72 hours) may also deserve special consideration for the plant materials ability to withstand extended periods of saturated soil conditions.
- *Tolerance to salts*—Runoff associated with rainfall events is the primary source of water volume that will be collected by an infiltration basin. Average reported electrical conductivity (EC) levels range from 3.2 millimhos per centimeter (mmho/cm, a standard English measure of electrical conductivity. Some measures are reported in dS/m, which is the metric measurement. The two measures are equal, and no conversion is needed between mmho/cm and dS/m for eastern NE to 8.6 mmho/cm for central CO). Drier climates typically produce the higher average EC levels. Smaller, less intense precipitation events typically produce higher salt concentration in runoff. For example, a central Kansas study observed EC levels ranging from 2 to 13 millimhos per centimeter. Winter runoff is also likely to produce higher EC levels. A Nebraska study suggests EC levels were approximately three times greater for winter runoff as compared to rainstorm runoff.

The research literature has not observed salt tolerance problems in most applications. Dilution of runoff with rainfall falling on the settling basin and VTA plus the leaching of the salts through the soil profile may prevent most concerns. However, selection of an appropriate forage or grass should consider its salt tolerance, and low tolerance plant materials should be avoided. A separate grass or forage species may be preferable for the first 50 feet of the VTA where solids settling and infiltration of runoff will be greatest within the VTA. Figure 6–4 provides an indication of crops tolerance to higher EC levels. Salt tolerance of locally specific crops should be available by contacting your local county cooperative extension program or the local NRCS office.

Figure 6–4 Effect of soil salinity on growth of selected forage crops (Soil Conservation Service, Agricultural Waste Management Field Handbook, ch. 6)



*The indicated salt tolerances apply to the period of rapid plant growth and maturation, from the late seeding stage onward. Crops in each category are ranked in order of decreasing salt tolerance. Width of the bar next to each crop indicates the effect of increasing salinity on yield. Crosslines are placed at 10-, 25-, and 50% yield reductions.

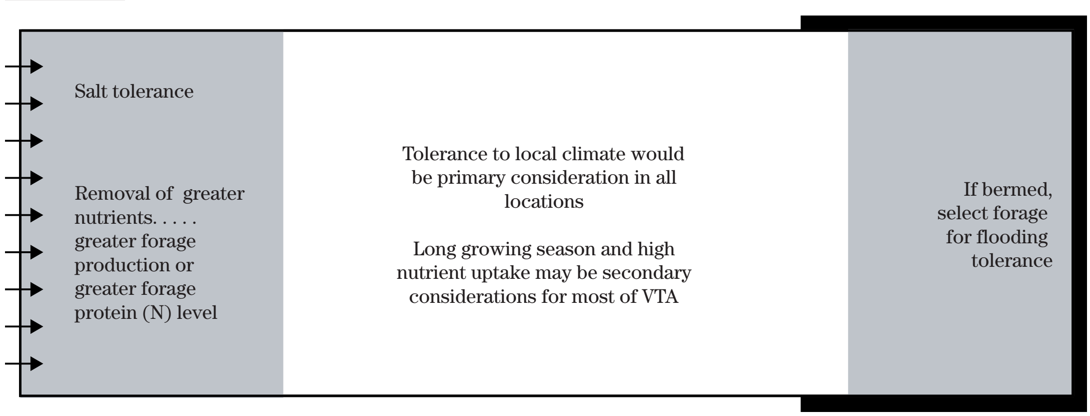
- *Tolerance to ammonia*—Many plants cannot tolerate high concentrations of ammonia. Influent concentrations should be 200 milligrams per liter or less. Typical feedlot runoff may contain higher ammonia concentrations (400–700 mg/L) than the plants can tolerate, although, actual concentrations may vary significantly. Higher concentrations are expected from densely stocked lots, and infrequently scraped lots. If higher ammonia concentrations enter the VTA than the plants can tolerate vegetation will be lost. If high concentrations are anticipated, pre-treat by blending the settling basin effluent with outside clean water to lower the influent concentration. Blending will result in a larger VTA.

In addition to the crop's tolerance to the controlling or limiting conditions discussed previously, a preferred crop for an infiltration basin should have some of the following characteristics:

- *High nutrient uptake*—Forages that harvest high levels of nitrogen are beneficial for infiltration basins. Phosphorus may be of concern. However, open lot runoff tends to be low in phosphorus, especially after moving through a settling basin.
- *Value as animal feed*—VTA forage growth will need to be harvested regularly. It is preferable to select forages that will be of value as an animal feed so as to gain some value for the land committed to a VTA. If harvested forage cannot be used for animal feed, alternative uses (bedding or carbon source for composting) are preferable to stock piling undesirable forage.
- *High evapotranspiration rates*—VTAs can reduce the total water volume if a forage or grass is selected for its high evapotranspiration rates.
- *Long growing season crops* offer advantages for nutrient uptake and evapotranspiration.
- *Perennials*—Infiltration basins should utilize perennial vegetation that provides growing plants from early spring into late fall for maximum nutrient uptake and water evapotranspiration. Grass and forages with long growing seasons would be preferable to row crops, such as corn, for utilizing nutrients from early spring through mid-fall runoff events. Combinations of warm- and cool-season grasses can create a long growing season in many applications. Late fall and winter application of runoff will add ammonium and some organic nitrogen to the VTA, both of which are immobile in most soils. These forms of nitrogen are unlikely to be converted to mobile nitrate nitrogen until the soil warms in the spring. Perennial grasses and forages with long growing seasons should allow removal of mobile nitrate nitrogen during an extended period of the year when nitrogen in this form is available.
- *Large root mass and surface area* provides an environment that encourages microbial activity. Aerobic decompositions of organic solids and mineralization and nitrification of nitrogen in runoff require active biological environments. Plants with large root mass contribute to an active biological environment. Plants that produce large tap roots are undesirable, increasing the potential for preferential flow.
- *Sod-forming grasses* are preferable to bunch-forming grasses as a means to maintaining uniform cover and facilitating sheet flow conditions.

Another intensive vegetation management strategy would be to employ vegetative zones designed similar to those used by some constructed wetlands (fig. 6–5).

Figure 6–5 Considerations for forage selection in different VTA locations



Salt accumulation is typical near the inlet of the runoff to the vegetative area. Planting crops that are salt tolerant near this inlet area would improve sustainability. Also, crops that use greater amounts of nitrogen and phosphorus near this inlet would minimize nutrient build-up. A VTA with a berm to control runoff on the lower end may require plant materials at the lower end that is flood tolerant.

Characteristics of common grasses and forages are summarized in appendix E. Additional suggested resources include:

- USDA Conservation Plants Pocket Guide at *http://plant-materials.nrcs.usda.gov/pubs/mopmcpuidguide.pdf*
- USDA VegSpec Web site at *http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages/HomeVegspec.htm*
- USDA Crop Nutrient Tool, which provides estimates of nutrient removal by crops, based upon nutrient percentages that reflect national averages. It can be found at *http://npk.nrcs.usda.gov/*

Slope considerations

Preferred slopes for effective VTA function are dependent on several factors such as soil infiltration rate and vegetation type and condition. Additionally, the primary function of the VTA, whether plant uptake, soil infiltration or vegetative filtration, should also be considered for determining the appropriate slope. Research for VTAs has been conducted on a range of topographic slopes from 0.25 to 10 percent. According to the EPA Process Design Manual for Land Treatment of Municipal Wastewater 1982, VTAs have been effectively used on slopes of less than 1 percent and up to 12 percent with the optimum range being 2 to 8 percent. Some reports have suggested that slopes less than 3 percent can produce ponding and poor distribution. However, it is the collective judgment of the authors that slopes between 1 and 5 percent are recommended with special considerations given to slopes outside this range.

Minimum slope—While attempting to maximize contact time, special precautions should be taken for lower slopes, generally less than 1 percent, to ensure that ponding and/or front end nutrient loading does not occur. Saturated soil conditions are not conducive to rigorous vegetative growth, which is necessary for effectively treating feedlot runoff. Without feedlot runoff moving down slope, the upper reach of the VTA has the potential of becoming overloaded with nutrients and possible contaminants. Excessive nutrient loadings would also negatively affect vegetative growth. Additional monitoring or soil sampling may be necessary in the upper reaches of the VTA to ensure proper functionality.

Maximum slop—Slopes greater than 5 percent have a greater likelihood of channelized and possibly gullying conditions uniform vegetative cover is established prior to using the VTA. Additional efforts to redistribute flow such as additional in-field spreaders (see table 6–4) or application of terraced VTA must be considered for steeper slopes. Reduced performance and potential failure of a VTA is possible due to erosion and/or reduced utilization of nutrients and contaminants. Greater slopes may also require larger treatment areas for equivalent performance.

Additional options for reducing VTA runoff release

Several options can be employed to reduce potential for an unplanned release from a VTA. Systems designed to reduce this risk are described in section 3. Some additional VTA design strategies can also be used to reduce discharge. A brief description for each of these is listed below.

Runoff volume reduction—Current regulations require CAFOs to collect any runoff originating from the unroofed animal confinement (feedlot, exercise lots, or loafing areas), the feed storage and preparation area, and on-site manure storage or composting areas. It is important to divert clean runoff coming from crop production areas, roadways (not used for animal traffic), or roofed buildings (animal housing, feed storage, equipment storage) to reduce the runoff volume collected. Reducing runoff volume will directly impact the risk of a discharge from the VTA.

Storage prior to VTA—Storage size (typically the settling basin) impacts the risk of a discharge. Reducing the size of the temporary runoff storage facility increases the potential for untreated runoff to pass over the vegetated area and be released from the VTA. A smaller storage volume prior to the VTA will require a VTA with a larger area to minimize releases. A storage volume capable of handling a 25-year, 24-hour storm is important to minimizing an uncontrolled discharge.

Controlling discharge to VTA—Timing of the release of liquids from a settling basin to the VTA is critical to reducing discharges from the VTA. During chronic rainy periods, the VTA soil profile is saturated lending itself to solute transport to ground water and discharges from the VTA. Two management options exist for reducing these risks. Controlling the release of runoff from the settling basin until after the storm event (active producer management of release) reduces the surface water risk. This also requires close management of the release during chronic wet periods to prevent overflows from the settling basin. High rate discharges from the settling basin are possible if an actively managed system is not closely observed in a chronic wet period.

A passively managed release strategy is based upon a carefully designed release rate for liquids in the settling basin. Extended periods for releasing the collected runoff from the settling basin to the VTA minimizes the addition of contaminated runoff to the VTA during the storm event and extends the opportunity for infiltration into the soil after the storm event. A release time of 30 hours is considered a minimum for the designed storage volume with a 72-hour design period being preferred. This approach minimizes the risk to the basin structure. Both options are discussed in greater details in sections 3 and 8.

Both the actively and passively designed release of liquids from the settling basin should include a fail-safe method for releasing liquids under storm events that exceed the basin's design capacity (an emergency spillway).

Contact time—Strategies that increase infiltration also improve contact time between potential contaminants in the runoff and the soil biological components, which aid in remediation. Soil biological components include plant roots, rodents, worms, insects, and microorganisms. One of the most important biological components for utilizing nutrients contained in feedlot runoff is the symbiotic zone surrounding plant roots called the rhizosphere. Generally, pore spaces in this rhizosphere are small, and as a result, nutrient transport is diffusion dependent. Increasing contact time of runoff nutrients in the rhizosphere will improve transport into these small pore spaces. Improving nutrient movement (extending periods for infiltration and matching VTA area to expected nutrients in runoff) into the rhizosphere will effectively increase nutrient utilization by the microorganisms and plant systems.

Containment dikes—Installing containment dikes around the vegetative area reduce or eliminate untreated discharge to the environment. These dikes increase contact time of the runoff water with the vegetation and reduce the effect of convergent flow paths short-circuiting through the treatment area. These are most effective on relatively flat slopes of two percent or less.

VTA management—Multiple management options should be considered in operation of a VTA. Section 8 discusses those management options.

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Section 8 Management Guidelines for Vegetative Treatment Systems

Section 8 Management Guidelines for Vegetative Treatment Systems

Contents

Section 8 Management Guidelines for Vegetative Treatment Systems

Topics

- Vegetation management for a VTS
- Environmental management for a VTS
- Standard operating procedures
- Records for monitoring performance

Purpose

Just as with any conventional manure or runoff management system, proper management of alternative treatment systems is critical to their proper functioning and longevity. After the appropriate plant species are established in the VTA or VIB, there are a number of operation and maintenance activities essential to their proper function. The following critical management issues should be addressed:

- Management of vegetation (soil fertility and harvesting)
- Management of environmental risks (tracking nutrient concentration, maintaining sheet flow, and controlling release of runoff into the VTA)
- Establishment of standard operating procedures for critical management tasks
- Implementation of a record keeping system for documenting performance of overall VTS

The purpose of this section is to discuss implementation of the critical management practices. The overall management requirements of VTSs will vary with individual components and their specific design selected for the overall system. For example, a solids settling area designed with sufficient volume to hold a year's accumulation of solids may only require infrequent inspections and yearly cleaning. Other choices may require more active manager participation—an actively managed outlet from the solids setting basin to the VTA may require the manager to check VTA soil moisture levels and basin liquid levels after each storm event when timing liquid release.

Both the producer and the regulatory agency (CAFO application) should be actively engaged in planning the management program as design alternatives are being evaluated. Once the level of essential management inputs are identified, VTS designs can be finalized, standard operating procedures assembled, and appropriate record keeping identified for the producer to meet these management expectations.

Vegetation management

Vegetation is the critical component in the success of a VTA. Selection of appropriate vegetation for application to a VTA and VIB is discussed in sections 6 and 7, respectively. Vegetation is established in VIB to produce and maintain a soil condition that promotes infiltration and removes and transforms nutrients. In the VTA, the vegetation slows movement of water to improve settling out of sediments, nutrients, and other contaminants; promotes infiltration; encourages chemical transformations; maintains soil permeability; and provides forage for animal use. The roots also provide a substrate for a highly active microbial zone that breaks down organic material, utilizes nutrients, and destroys pathogens. Proper vegetation management is essential for a high-performing VIB or VTA.

Soil fertility for optimum growth

Two distinct issues should be considered in selecting a soil-sampling program: maintaining optimum crop growth and environmental protection. A general discussion of soil-sampling issues for management of a VTA or VIB follows. A later section describes the soil sampling needed to monitor environmental performance. State-specific soil-sampling recommendations are typically available from your land grant university or other accepted resources.

A key to healthy vegetation is the proper fertility status. Usually, because of the nutrient enriched nature of the runoff entering the vegetated areas, lack of nutrients is not a problem. What can become a problem is an imbalance of nutrients, resulting in poor crop growth that could compromise the effectiveness of the vegetation. To monitor the fertility status of the VIB and VTA, a regular soil-testing program should be a part of the operation and maintenance plan.

For the purposes of soil nutrient monitoring, sample the top 8 to 10 inches of the soil. A deep soil sample (preferably to a depth of 36 in) is necessary if residual soil nitrogen, measured as nitrate-nitrogen, is to be monitored. Collect sufficient samples to give a good representation of the area. Cooperative extension programs at land grant universities may provide recommended sampling procedures. Because greater nutrient settling and runoff infiltration is expected near the inlet end of both a VIB and VTA, collect separate soil samples from the first 50 feet from the inlet area and separate samples from the rest of the VTA. Figure 8–1 illustrates one way of subdividing a VTA. A separate set of samples is taken in each sub-area (A, B, and possibly C), because the soil nutrient status may be different as you move farther from the point where runoff enters the VTA.

Analyze shallow soil samples for plant available phosphorus and potassium, important micronutrients, pH, soil electrical conductivity, and salts (sodium, calcium, and magnesium). Deep soil samples should be analyzed for nitrate-nitrogen. Based upon the results of the soils report, some management changes may be necessary (table 8–1). Only a fraction of the nitrogen and phosphorus (5% or less) excreted by the animals travels with runoff. About half of that in the runoff will be removed by a well-designed solids separation component. For the nitrogen that is transported to the VTA or VIB (primarily as ammonium-nitrogen), there also will be additional losses from denitrification and volatilization.

A greater percentage of the total potassium in the system will reach the VTA or VIB than either nitrogen or phosphorus. Potassium is soluble, so it will stay in solution as runoff leaves the pens and lots. Only a small percentage stays with the solids that settle out in the settling basin. The salt level in VTA and VIB soils should be monitored. Salts may accumulate in the root zone during periods of small rain and runoff events that do not saturate the soil and leach salts. Check soil electrical conductivity as part of a soil-sampling program, and discuss the results with your crop consultant. See the vegetation discussion in sections 6 or 7 for additional information on the salinity tolerance of different species.

The frequency of soil sampling will vary depending on the purpose. To track general fertility status, follow the land grant university, NRCS, or local conservation district's guidelines for forage or grass species fertility

Figure 8–1 Suggested soil sampling locations

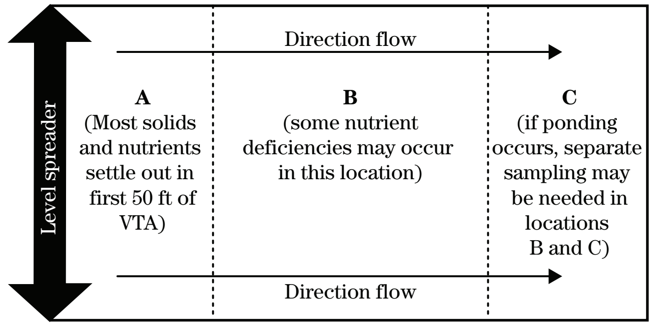

Table 8–1 Possible actions to be taken in response to soil sample test results

Soil sampling test result	Possible action to be taken
Soil P levels	
Low or medium soil test P	Follow land grant university recommendation for fertilizing VTA
High or very high soil test P levels	Is runoff from VTA occurring frequently? If no, continue to monitor frequency of runoff events If yes: • Increase the frequency of soil sampling to once every 2 years • Reduce the nutrient loading rate to the VTA, either by reducing outflow from the solids removal area or by increasing the efficiency of pretreatment solids removal • Over-seed or introduce legumes into the VTA to increase harvest of P from the VTA forage • Treat VTA with P-adsorbing material (iron or aluminum) • Stop use of the VTA until harvesting lowers the soil test
Increasing soil test P levels	Increasing soil test P levels indicate an emerging concern. Follow recommendations for high or very high soil test P levels
Soil nitrate levels	
Low or medium soil nitrate levels	Follow land grant university recommendation for fertilizing VTA
High soil nitrate levels	Increase forage removal by possibly changing harvesting frequency. Check nitrate concentrations of forage Consider alternative grasses or forages that remove greater amounts of nitrogen Consider controlled drainage to modify soil moisture in root zone
Soil potassium levels	
Low or medium soil test K levels	Follow land grant university recommendation for fertilizing VTA
High or very high soil test K levels	If harvested forage is used for livestock feed, monitoring forage K levels, and visit with nutritionist about need for modifying use of forage in diet
Soil micro-nutrient levels	
Low or medium soil test levels.	Follow land grant university recommendation for fertilizing VTA
High or toxic soil test levels	Stop use of VTA if soil analyses show unacceptable levels of heavy metals Other micro-nutrients should be monitored
Soil electrical conductivity	
High soil EC	Irrigate VTA with fresh water Provide drainage to leach away excess salts Divide the VTA into two sections so that one section can be rested except during high intensity or large storms. Resting a VTA section will allow rainfall to move salts out of the root zone

needs. If no guidelines exist, soil sample at least once every 3 years. Deep soil sampling for nitrate nitrogen may be beneficial near the VTA inlets on an annual basis. When samples are taken on subsequent occasions, try to take samples close to the same location each time. This ensures that any differences that show up are a result in the actual nutrient status of the site and not due to a soil difference.

Harvesting a VTA

Another requirement for maintaining a healthy stand of vegetation is periodic mowing and removal of the crop. VTAs and VIBs should be harvested at least once a year so that the nutrients contained in the plant material are removed from the treatment area. Depending on the plant species used in the VTA or VIB, more frequent harvesting may promote a more vigorous stand of vegetation, greater utilization and removal of nutrients, and higher quality feed. Frequent mowing promotes thicker sod and controls weeds.

When harvesting, leave a minimum stubble height of 3 inches to ensure the required stem density and stiffness to maintain sheet flow through the VTA. Some species, particularly warm-season prairie grasses, require a taller stubble height to be left to maintain plant vigor and stand density. For all species, the last harvest in the fall should be early enough to allow sufficient regrowth prior to dormancy for proper functioning during the winter.

Sometimes there are toxic levels of some salts and ions, (NH_4^+) in the runoff from concentrated livestock areas. These can have a major deleterious effect on the vegetation. If this occurs, pre-treat (usually by dilution) the outflow from the solids removal area to reduce toxic levels. The key here is to maintain vigorous crop growth and density to maximize nutrient uptake and disperse overland flow.

In the ideal world, harvest a VTA or VIB when soil moisture conditions will not produce tire tracks or ruts. Tire tracks that are parallel to the direction of runoff flow create channel flow and substantially reduce the effectiveness of a vegetative system. If harvesting equipment or other field traffic presents a risk for creating tire tracks, the equipment should travel perpendicular to the flow of water.

Management of soil moisture in VTA

Soil moisture plays an important role in the functioning of a VTA. Soil water is essential for plant growth and high level of activities by microorganisms. If soil moisture is deficient, the plants and microbes are not functioning to their potential and the benefits of a VTA are not realized. In dry climates, supplemental irrigation may be required to maintain an actively growing VTA. Historic weather data, soil moisture indicators, and visual observations can assist in supplying adequate soil moisture.

Soil moisture content is critical for the transformation of many contaminants that will be passed through the VTA. The nitrification of ammonia occurs when aerobic bacteria have ample soil oxygen to convert the ammonia to nitrate nitrogen. Without oxygen, the saturated soil conditions are conducive to anaerobic bacteria that convert nitrate nitrogen to atmospheric nitrogen gases. In this case, nitrogen is lost from the system and potential greenhouse gases are formed. Saturated soils also can change the availability and solubility of phosphorus. Soil minerals, like iron, tend to release the stable, fixed phosphorous making it more susceptible to translocation by water moving through the soil profile. Saturated soils also promote downward movement of draining water that can cause excess leaching.

Saturated soils compact easily. If machinery or livestock are used to harvest the forage in a VTA, dry, firm soil conditions are required to prevent compaction or rutting. Wheel tracks and hoof traffic can cause disruption in the surface flow down the VTA, concentrating flow and reducing infiltration.

Two management measures should be considered to alleviate saturated soil conditions. First, the surface topography should be smooth and uniform to promote sheet-like flow. This will slow the flow through the VTA, encourage uniform infiltration, and prevent depressions and wet spots. Second, soil profile moisture can be managed with subsurface drainage. Tile drains beneath VTAs must be controlled. Tile drain outlets can become sources of contaminants. Drains must be managed to allow excess soil moisture to be removed from the soil profile, but not allow for a conduit of leached nutrients, salts, and pathogens. Installing tiles at the appropriate depth and location will off set some of these risks. Being able to regulate flow (drain during rainy season, closed during dry season) will promote plant root growth and crop uptake, plus provide favorable conditions for soil biology. Effluent can be discharged into a vegetated area or routed back into the VTA. Drainage water should be monitored for elevated levels of contaminants. Local NRCS resources should be used in determining appropriate local use of subsurface drainage.

Weed and brush control

Weeds, brush, and other pests should be controlled in the VTA to ensure proper functioning. Periodic mowing, at least frequent enough to prevent seed formation, is an effective weed control measure. Harvesting the VTA forage on a prescribed schedule will usually control weeds. Herbicides are another alternative for controlling weeds. Precautions are needed in selecting the proper registered products, applying proper rates, and being knowledgeable of grazing and forage harvest restrictions. A healthy stand of vegetation, absent of any bare spots, will prevent weed encroachment. All bare spots should be reseeded.

Grazing is not commonly recommended for harvesting of VTA vegetation. Grazing removes very few nutrients from a VTA and is not a good alternative to mechanical harvesting of forage. However, occasional grazing can assist with weed control. Grazing needs to be controlled, both in timing and extent. Livestock should not be allowed when soils in the VTA are moisture saturated. Footprints can compact the soil surface and reduce infiltration. Foot traffic can also damage crowns and roots of vegetation. Care should be taken to remove cattle when proper grazing height of vegetation is reached.

Environmental management

The nutrients nitrogen and phosphorus represent a primary environmental risk associated with open lot runoff. Nitrogen in a nitrate form represents a risk to ground water and possibly drinking water supply. Nitrogen in an ammonium form can be toxic to aquatic life, contributing to fish kills. Both phosphorus and nitrogen can contribute to eutrophication (algae blooms and large swings in dissolved oxygen levels) of surface waters. Pathogens in animal manures can produce a human health risk for recreational and drinking water uses of our water resources. Management strategies designed to limit these risks and monitoring programs to document proper management implementation are essential for a VTS.

Soil sampling for environmental protection

The second soil sampling purpose is to monitor environmental performance of the VTA. There are two separate concerns: nitrogen leaching below the root zone and phosphorus accumulation. *Monitoring for increasing soil phosphorus will provide a forewarning of water quality problems originating from the VTA, enabling proactive instead of reactive management changes.*

If the nitrogen entering the VTS exceeds vegetation removal, the excess nitrogen that is converted to nitrate can move beyond the root zone under saturated soil conditions. Rainfall on the VTA and runoff from the open lot creates the opportunity for leaching nitrate past the root zone. Since plants can no longer use nitrate leached beyond the root zone, it will eventually reach tile lines or ground water.

For environmental protection, a deep sampling regime can provide a snapshot of root zone nitrate levels and the potential for future movement. Samples should be taken within the root zone and analyzed for nitrate-nitrogen content. Most of the plants that are suitable for the VTA have the majority of their roots in the top 36 inches, so the soil samples should be taken below the surface in 1-foot intervals.

For additional information on nitrogen management within a VTA, forage nitrate monitoring may provide some insights about potential excess nitrate levels in the VTA. Check with your land grant university as to the availability of recommendations for forage nitrate levels that may suggest excess soil nitrate levels. *Forage nitrate should be measured for any harvested* *material that will be fed to livestock, especially ruminants, because high nitrates can be toxic.*

Soil sampling for assessing environmental risk associated with phosphorus can be measured with surface soil samples described previously for managing a vegetative system for optimum growth. As phosphorus enters the soil, it readily precipitates out of solution and it is readily adsorbed as calcium, iron, and aluminum phosphates. It typically accumulates near the surface of the soil. If the amount removed by harvesting vegetation is less than the amount entering the VTA or VIB, the soil exchange matrix can eventually become saturated.

Excess soil phosphorus levels can have two effects. High phosphorus levels will commonly remain near the soil surface of fine textured soils such as silt loam or silty clay loam soils (higher adsorption capacity). Excess phosphorus in course textured soils, like sands and loamy sands lack adsorption capacity and allow phosphorus to migrate further into the soil profile. Excess phosphorus accumulation in the top 2 inches of soil will desorb as dissolved phosphorus when runoff water passes over these soils and transport phosphorus off site with soil erosion. Movement of phosphorus with soil erosion should not be a significant concern for well-maintained VTAs. A standard soil sample used for optimum growth (0–8-in sample) can provide an indication of potential environmental risk due to excess phosphorus. An occasional separate soil sample of the top 2 inches of soil layer analyzed for available phosphorus will detect stratification of phosphorus in the soil surface.

Course textured sandy loam or loamy sand soils (lower adsorption capacity) tend to become saturated with phosphorus more quickly allowing phosphorus movement deeper into the soil profile. This is unlikely to become an environmental concern unless the VTA is located over a shallow water table or subsurface drainage. Previously described 0- to 8-inch and 0- to 36-inch soil samples should be valuable for reviewing this risk.

If soil phosphorus test levels become excessive, the need for changes in management depends on the amount of runoff water (and associated dissolved phosphorus) exiting a VTA. A properly designed and managed VTA may rarely experience runoff with the exception of the most intense storms. Thus higher soil phosphorus levels will have little impact on surface water quality. Poor design or management may produce greater runoff and require greater attention to a need for modifying management with increasing soil phosphorus levels.

If VTA runoff is common and soil test levels reach a high or very high range for crop production, some management techniques need to be implemented (table 8–1). These can include harvest and removal of vegetation biomass, better management of solids in sediment basin, or removal and mixing of topsoil layers in the VTA. If soil test analysis shows soil test levels are extremely elevated (three times the high soil test level) the soils become a source of runoff and remedial management is necessary including end of the VTA use.

Sheet flow maintenance

For VTAs to provide maximum water quality protection, the overland flow should be as uniformly distributed as possible across the treatment area. Uniform flow minimizes localized areas of higher flow velocity and encourages greater particulate removal. In addition, since a portion of the runoff entering the VTA will infiltrate, maximizing uniform flow will allow for a greater portion of the VTA to contribute to the infiltration of runoff. Concentrated flow within the VTA reduces infiltration. A thorough discussion of options for encouraging sheet flow is reviewed in section 6 on VTA design. The literature review in section 9 summarizes the research experiences detailing the critical importance for maintaining sheet flow.

Sheet flow is not an issue with a VIB. VIBs are designed to pond water resulting from runoff from most storms. A flat or very low slope is important to creating a uniform depth of liquid within a VIB. However, other issues discussed below are relevant only to a VTA.

Inlets from the solids removal component to the VTA may require annual re-leveling to ensure initial even distribution of feedlot runoff to the VTA. Irrigation pipe distribution systems may need to be repositioned on the contour and pipe gates adjusted. Flow rates from irrigation pipe gates should be adjusted to encourage full pipe flow during most runoff events. Achievement of this goal should be checked seasonally. For concrete structures with weir plates for controlling flow, the elevation of all weir plates should be checked and matched on a periodic basis. The gravel and rock structures used to redistribute flow at the upper end of a VTA should be re-leveled and structural integrity checked. Piped outlets from the settling basin should be adjustable and periodically matched for a consistent elevation. Most distribution systems will require screening of debris to prevent plugging of outlets. Debris screens and other points of potential debris accumulation should be checked after each significant rainfall event.

Overland flow always tends to converge as it flows through the VTA. Spreaders should be installed at regular intervals and other VTA design features included as discussed in section 6 to redistribute any concentrated flow within the VTA. Maintaining reasonably uniform flow through the length of a VTA will require regular VTA inspection and

- Maintenance of in-field spreaders
- Removal of solids accumulation near runoff inlets to a VTA
- Repair to areas of erosion or wheel tracks
- Reestablishment of vegetation in areas where it has been killed
- Repair of eroded areas in berms

Any equipment operations (mowing, baling) that take place in the VTA should be done when soil conditions are such that tracks or ruts, which can disrupt sheet flow, are not formed. Grazing should be avoided, as livestock hoof action can disrupt sheet flow.

Passive versus active management of liquid release

The risk of a discharge from a VTA is significantly greater if feedlot runoff enters the VTA simultaneously with rainfall directly falling on the VTA. The infiltration rate of the soil can be overwhelmed with the two simultaneous sources of water. Delay release of runoff liquids until after the storm or limit the release of runoff during the storm to reduce the potential of a discharge of feedlot runoff with pollutants from the feedlot. Three primary options for managing the release of liquids from a solids removal component to the vegetative component are possible. The latter two are designed to minimize the potential for a discharge from the vegetative component.

- *Unrestricted runoff release*—The outlet of the settling basin is not restricted, possibly because of limited or no storage capacity in the solids settling component. Runoff release is designed to match the peak flow rate of liquids into the settling basin when the basin is nearly full.
- *Active settling basin liquid release*—The outlet of the settling basin can be physically controlled. The manager determines the best timing for the release of basin liquids, presumably when the VTA soil conditions are most appropriate. This approach requires that the settling basin has sufficient capacity to handle a 25-year, 24-hour storm, as well as some additional capacity for normal runoff for some possible storage period (a few days to possibly months). The resulting settling basin volume is very similar to that of a standard holding pond. Its frequency of discharging will be essentially no different from the conventional basin and irrigation system. Many advantages of a VTA system including reduced cost, modest storage, and less risk of management errors are no longer realized with a system based upon active settling basin liquid release. However, the risk of a release from the VTA has been significantly reduced.
- *Passive settling basin liquid release*—The outlet of the settling basin can be controlled to deliver liquid slowly over a 36- to 72-hour period. The settling basin will need to be sized to handle a 25-year, 24-hour storm. Additional volume to store normal rainfall runoff would not be necessary since liquids would be released over a short period of time (<72 h). A passive system also does not rely upon the observation and decision making of a manager thus reducing potential problems due to infrequent inspections or poor management. Common advantages of a VTA system including reduced cost and modest storage will not be realized with a passive settling basin liquid release. However, as with active release systems, the risk of a release is substantially reduced. Design information for controlling liquid release from passive systems is presented in section 5.

Active versus passive management of flow from a solids settling component to a VTA is described in section 5.

Solids harvesting

Manure and other solids in the system must be managed to ensure the proper function of the treatment components. Solids should be harvested from earthen lots at least once after each pen of cattle is marketed (approximately twice a year) and every 180 days for dairy. More frequent solids removal will have value for animal management and odor and dust control and may have some value to reducing solids in runoff.

The maximum solids volume in a settling basin should be clearly identified (marked on a level gage) and solids should be removed in advance of solids accumulation to that point. As a minimum, the solids settling basin should be cleaned out once a year. The solids should be removed frequently from settling benches and siltation fences to maintain their effectiveness, possibly after each major runoff event.

Proper feedlot surface maintenance and solids settling should prevent the buildup of solids in a VTA. If solids begin to accumulate in a VTA, they can damage forage and contribute to channel flow. If solids accumulation within the VTA is observed, first attempt to reduce this problem with improved management of the feedlot surface and settling basin. If solids remain a concern in the VTA, a light tillage operation should redistribute the solids while allowing some grass to survive. If solids accumulation is a severe problem, a more aggressive tillage operation may be necessary followed by replanting of grass.

Vegetation inspection

The health and vigor of vegetation within a VTA or VIB should be checked regularly for potential developing problems. Some common concerns that can be monitored visually include:

- Indications of fertility deficiencies as identified by crop color
- Indications of ponding or solids accumulation causing loss or thinning of forage
- Indications of undesirable plant species
- Indications of high areas where infiltration is not occurring (plants may show signs of low fertility or drought)
- Indications of burrowing animals that would bypass infiltration role of soils

Form 3 of appendix F provides a sample inspection form for inspecting vegetation within a plant treatment system.

Standard operating procedures

When created for a specific, clear reason, written operating procedures save time and reduce the chances of mistakes. These procedures are generally referred to as a standard operating procedure (SOP). For some operation and maintenance, a written procedure may be advantageous if one or more of the following applies:

- The NPDES permit targets specific management expectations.
- The procedure is a condition of an environmental permit compliance.
- The procedure is difficult to commit to memory or is not done frequently enough to commit to memory.
- More than one person will be doing the procedure, and/or it must be done the same way each time.
- There could be serious environmental or safety consequences if the procedure is done incorrectly.
- In the manager's absence, someone else may need to do the procedure (vacations).
- New employees are regularly asked to complete a procedure.

A good SOP is written in simple language (including those languages native to all employees) that everyone can understand, includes all the steps involved in the procedure (even simple or obvious steps should be included, especially if they could have environmental consequences if skipped), is signed and dated, is reviewed, and is revised as needed by the responsible person.

Some key topics to be addressed by SOP for a vegetated treatment system include:

- VTA or VIB soil sampling procedure
- Solids removal from settling basin or other solids collection structure
- Runoff sampling procedures
- Forage harvesting procedures
- Liquid release from solids settling basin or storage (if release is actively controlled)
- Visual inspections for discharges following rainfall events
- Visual inspection of VTS components

- Mass nitrogen and phosphorus balance calculations on a VTA or VIB
- Other management procedures specifically identified within the NPDES permit

Records for monitoring performance

Sample records for VTA systems are provided in appendix F. A discussion of key issues to be addressed by these records follows.

CAFO regulation compliance

The NPDES permit issued to an individual CAFO will define the specific record keeping requirements and should be the final reference for establishing a recordkeeping and reporting program. Table 8–2 summarizes the three primary principles that should be addressed by a recordkeeping program for a conventional and a VTA system. State permitting authorities have the option of expanding the record and reporting requirements beyond those discussed in this section.

Of primary concern are the records and reporting requirements associated with a discharge event. Conventional runoff control systems must demonstrate their ability to limit surface water discharges resulting from a 25-year, 24-hour storm event or less. Larger storm events and possibly chronic (extended) wet periods can produce allowable discharges only if records demonstrate the quantity and timing of rainfall events and proper management of the manure management system prior to and during such events. Records commonly used to document attainment of this objective by a CAFO using a conventional system are summarized in table 8–2.

Alternative technologies such as a VTA system must perform at least as well as the conventional technology. Records will be necessary to verify the same precipitation and management related information. Table 8–2 summarizes a suggested set of records for documenting proper management of a VTA. Suggested records to document a VTA performance are included in appendix F for VTAs.

Releases of water from VTA **must** be observed, sampled, and reported to the permitting authority. To determine when a release occurs, a small reception basin with a spillway should be constructed at the outlet of the last component of the VTS. This small reception basin should be designed to provide a visual means of identifying when a discharge has occurred and a location for collecting a representative sample for later analysis of solids, nutrients, and fecal coliform concentration. An open livestock watering tank buried at ground level at the outlet may serve this purpose.

Table 8–2 Record expectations for a CAFO using a conventional or VTA system. *Suggested records for non-CAFOs are italicized.* [1]

Performance monitoring principle	Recommended records (reports) for a conventional system	Recommended records (reports) for a VTA system (see app. F for sample records)
1) What are the precipitation events that lead to the discharge? If a single storm event or a chronic rainfall period greater than the 25-year, 24-hour storm is the cause of a discharge, then the permitting authority will likely consider such a discharge as an acceptable discharge	– Daily onsite precipitation records	– Daily onsite precipitation records
2) Was good management practiced prior to a discharge? Producers must document key indicators of good (or poor) management	– Animal inventory – Pond liquid level – Pumping start and stop time and dates – Amount pumped – Daily visual inspections of water lines – Runoff effluent nutrient analysis – Weekly inspections of storm water collection/diversion components, runoff storage components, and pond depth readings	– Animal inventory – VTA inspection and maintenance for uniform flow – Crop harvest date and yield – Timing of solids harvest from solids settling system – Daily visual inspections of water lines – Runoff effluent nutrient analysis – Weekly inspections of storm water collection/diversion components – If a settling basin includes storage, follow recommendations for conventional system – VTA and VIB soil samples
3) When does a discharge occur? Any discharge from the runoff holding pond (or last stage of the VTA system) must be reported to the permitting authority within 24 hours by phone and 7 days by written report	– Livestock manure or related process water discharge report (Form 1 or equivalent) – Lab sample report on concentration of solids, nutrients, pH, and fecal coliform in discharge	– Discharge from VTA occurring as feedlot runoff is being applied to VTA (Form 1 or equivalent) [2] – Lab sample report on concentration of solids, nutrients, pH, and fecal coliform in discharge [2]

1 State permitting authorities may add additional requirements to the NPDES program for individual states. The CAFO's NPDES permit will define the specific record and reporting requirements with which the CAFO must comply.

2 Individual permitting authorities will define which releases of runoff from a VTA will qualify as a discharge and require reporting within 24 hours. Ask the permitting authority for this information. The producer also is encouraged to collect and analyze samples from releases from a VTA and create a history as to what releases are primarily clean water and what release contain feedlot runoff.

Example

Standard Operating Procedure (SOP) for
Sampling Open Lot Runoff Nutrient Concentration

Developed by: John Q Owner ___ Revised by: ___

Date: September 1, 2004 ___ Date Revised: ___

Filing Location: Clear Creek Feedlot business office

Posting Location: SOP manuals in feedlot office, employee break room, and all feedlot pickups

Purpose: Procedure ensures that runoff is regularly and accurately sampled for concentration of nutrients, solids, and potential contaminants.

Steps

1. Take samples in June and October.
2. Get rubber gloves, dipping can (coffee can on 8 ft pole), and a clean 5-gallon sampling bucket from the scale shed. Put the gloves on.
3. Collect 10 surface samples from perimeter of solids settling basin immediately following a rainfall event of 0.5 or more inches. Pour samples into 5-gallon bucket.
4. Stir the 5-gallon bucket sample in the bucket. Continue to stir until all the sample is mixed completely.
5. Get a clean quart plastic bottle from scale house. Fill the jar leaving 1-inch empty headspace.
6. Add lid and seal lid to jar with electrical tape.
7. Add a large mailing label to the jar. Record the farm name, your initials, and the date on the mailing label using a permanent marker.
8. Empty the remaining runoff from the bucket into settling basin.
9. Dispose of the gloves in the trash can and wash/disinfect hands thoroughly.
10. Take the sample to the office manager for immediate freezing or refrigeration.

Farm Personnel Training Needs

Employee	Training Topic	Date Completed	Dates Update
John Q. Owner	Sampling SOP and mailing to lab	Sept. 1, 2003	
Mary Rider	Sampling SOP	Sept. 4, 2003	9/04
Jim Crewchief	Sampling SOP	Sept. 4, 2003	
Chris Office	Mailing sample to lab	Sept. 10, 2003	

Standard Operating Procedure (SOP) for

____

Developed by: __________________________ Revised by: _________________________________

Date: ________________________________ Date Revised:______________________________

Filing Location: ____

Posting Location: ______

Purpose: ____

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Steps:

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Farm Personnel Training Needs

Employee	Training Topic	Date Completed	Dates Update

Individual permitting authorities will define which releases of runoff from a VTA will qualify as a discharge and require reporting within 24 hours. **Ask the permitting authority for clarification on reportable discharges.** The producer also is encouraged to collect and analyze samples from releases from a VTA and create a history as to which releases are primarily clean water and which releases contain feedlot runoff. The presence of ammonium, volatile solids, or salts may provide some indication of presence or absence of feedlot runoff in the sample. A comparison sample from a field receiving no manure or feedlot runoff would be helpful in identifying if significant runoff pollutants from the feedlot are escaping the VTA.

Many of these records are essential for proper management of a VTA for all sizes of AFOs (not specifically CAFOs). Regular inspections and records for the VTA site and related components are essential for ensuring proper nutrient management and distributed flow of runoff over the VTA. Records detailing liquid levels in the settling basin and precipitation are essential for avoiding classification of an animal-feeding operation as a CAFO as a result of a discharge.

Ground water protection

Some states may regulate performance of animal production systems relative to their impact on ground water. For VTA systems, excess nitrogen application creates the potential for leaching of nitrate below a crop's root zone and is the primary opportunity for impact on ground water by a VTA. This issue is likely to be of greatest concern in the first 50 feet of a VTA. Possible indicators of ground water risk might include:

- End of growing season deep soil nitrate testing (24 to 36 in). This is only a fair measure because larger rainfall event can flush nitrate beyond sampling depth
- Crop nitrate levels
- Crop nitrogen removal (only estimates removal of nitrogen, not nitrogen additions to field):

$$\text{N removal (lb)} = \frac{\text{Tons of harvested crop} \times \text{\% crop protein} \times 20}{6.25}$$

Records to document at least one of these three indicators of nitrogen utilization by the cropping system (and minimal nitrate leaching) are recommended for situations were ground water contamination is regulated or a priority neighborhood or regional issue.

Vegetation management

Table 8–2 contains a suggested set of records to document efforts to maintain a well-performing vegetation system.

Example:

In section 6, sizing calculations for a 2,000 head feedlot suggested the need for a VTA between 8 and 14 acres based upon the assumptions made the design phase. A 12-acre VTA was installed. In 2004, 4.5 tons per acre of tall fescue was harvested with an average protein content of 12.5 percent. Check the nitrogen balance for the VTA.

$$\text{N removal (lb)} = \frac{4.5 \text{ ton/a} \times 12 \text{ a} \times 0.125 \times 2{,}000 \text{ lb/ton}}{6.25} = 2{,}200 \text{ lbN/a}$$

Discussion: This value compares favorably with the two estimates of nitrogen in feedlot runoff in section 6 (1,600 and 2,800 lb N/yr) and the literature value from section 9 (table 9–4) of 0.68 lb N in runoff per finished animal (2,700 lb total N/yr, about half of which is crop available). Because of challenges with uniform distribution of nitrogen, deep soil sampling should be initiated near the runoff inlet into the VTA.

Record	Headlands (50 ft after effluent inlet)	Remainder of VTA
Soil nutrient profile		
Shallow (top 2 in) soil sample for P and pH	X	X[1]
• Plow layer sample for soil organic matter P, K, EC, and pH	X	X[1]
• Deep soil sample for nitrates (top 3 ft)	X	X[1, 2]
Crop production		
• Harvest timing and conditions	For entire VTA	
• Quantity of forage harvested	For entire VTA	
• Forage protein	For entire VTA	
• Forage nitrate	X	X
• Forage potassium (animal health)	For entire VTA	
• Pesticide application timing, rate, and product	For entire VTA	

1 Remainder of VTA may be divided into one or more zones.
2 Risk will be greatest in upper end of VTA. Sampling may not be warranted until headlands nitrate-nitrogen levels are observed to be high.

Appendix B How Much Runoff Will Come from the Feedlot?

Single storm event

The volume of runoff from a feedlot for a single storm event is commonly estimated using the NRCS Curve Number method. This method is commonly use to estimate the storage volumes required for design storm events such as a 25-year, 24-hour storm (fig. B–1). It is described in the NRCS National Engineering Handbook, Part 630, Chapter 10. For the purpose of estimating the volume of storm runoff from a feedlot, the following equation is solved for Q:

$$Q = \frac{\left[P - 0.2\left(\left(\frac{1000}{CN_1}\right) - 10\right)\right]^2}{P + 0.8\left\{\left(\frac{1000}{CN_1}\right) - 10\right\}} \qquad (1)$$

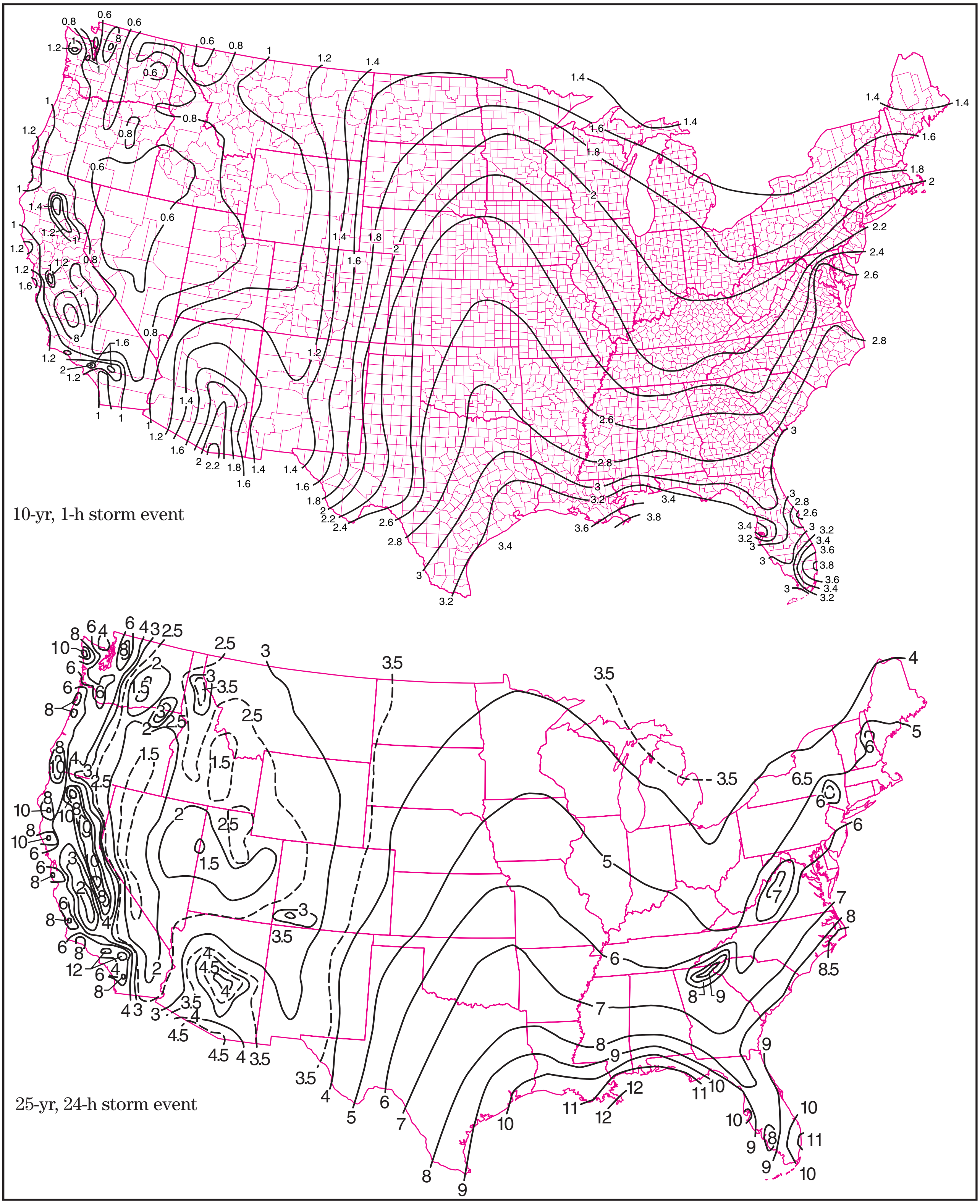
where:
Q = volume of runoff (in)
P = rainfall (in)
CN_1 = NRCS 1-day curve number

A CN_1 of 89 or 90 is commonly used for an unpaved feedlot, and a CN_1 of 97 or 98 is commonly used for a paved feedlot. The volume of rainfall for this application is usually the volume of a 25-year, 24-hour or a 10-year, 1-hour (fig. B–1) storm event. Estimates of runoff for four different surfaces are illustrated in table B–1.

Table B–1 Volume of runoff in inches associated with an individual storm event for four surfaces based upon equation 1

Rainfall event (in)	Surfaces			
	Concrete lot or compacted surface (CN_1 = 98)	Earthen feedlot surface (CN_1 = 90)	Medium texture cropland (CN_1 = 75)	Medium texture grassland (CN_1 = 70)
2.0	1.8	1.1	0.4	0.2
2.5	2.3	1.5	0.7	0.5
3.0	2.8	2.0	1.0	0.7
3.5	3.3	2.4	1.3	1.0
4.0	3.8	2.9	1.7	1.3
4.5	4.3	3.4	2.1	1.7
5.0	4.8	3.9	2.4	2.0
5.5	5.3	4.4	2.9	2.4
6.0	5.8	4.8	3.3	2.8
6.5	6.3	5.3	3.7	3.2
7.0	6.8	5.8	4.1	3.6
7.5	7.3	6.3	4.6	4.0
8.0	7.8	6.8	5.0	4.5

Figure B–1 Precipitation (in) resulting from a single storm event



Monthly runoff

Monthly runoff is of used to estimate the storage requirements between periods of land application (storage period). Monthly runoff may be estimated using the thirty day curve number (CN_{30}). Using this method the CN_1 is converted to a CN_{30} using the following equation:

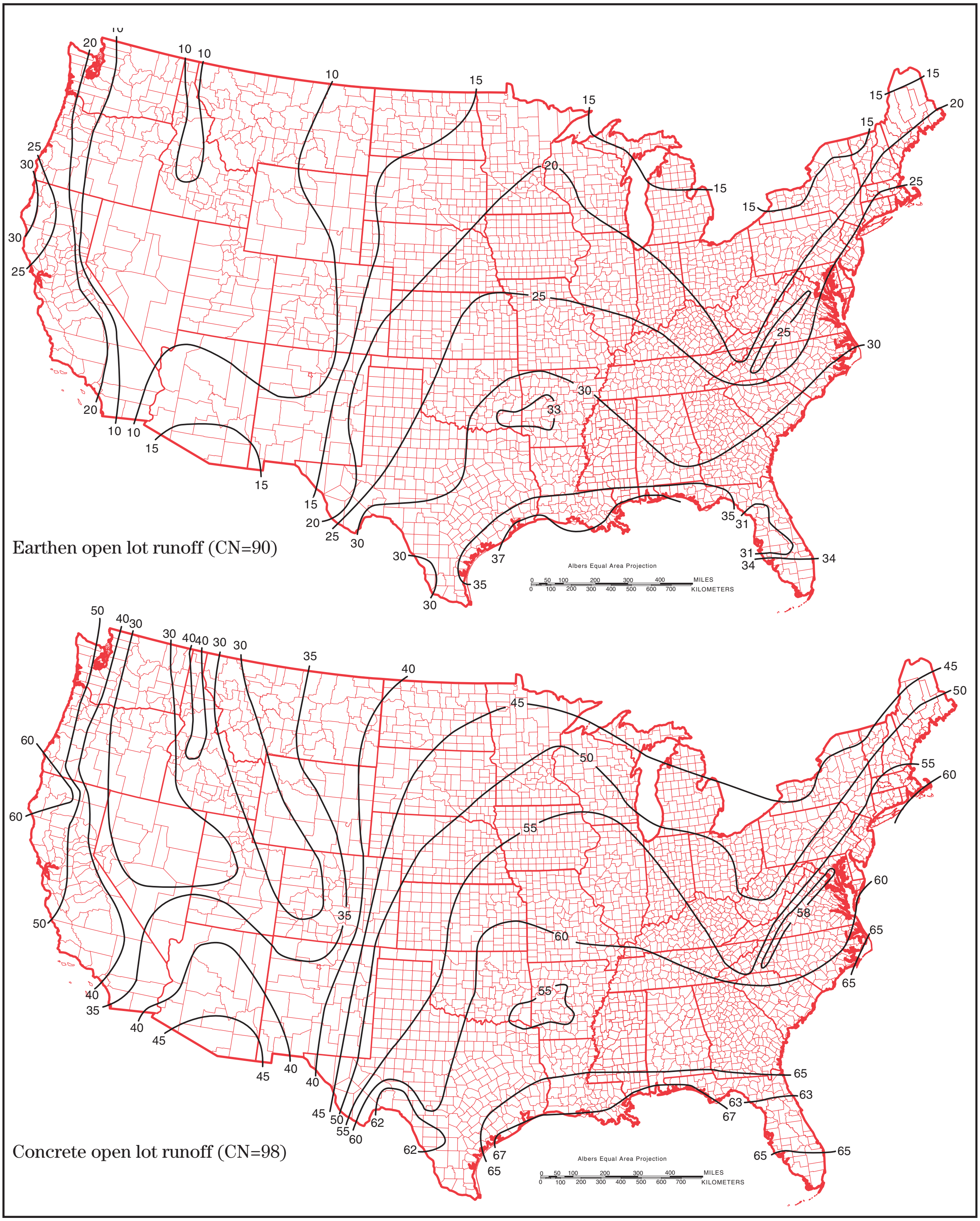
$$CN_{30} = CN_1 - \left\{ CN_1 - \left[\left(\frac{CN_1^{2.365}}{631.79} \right) - 15) \right] \right\} \log 30 \qquad (2)$$

A CN_{30} for an unpaved feedlot is commonly 73 to 76, and a CN_{30} for a paved feedlot is commonly 95 to 98. The monthly runoff from a feedlot is computed by substituting CN_{30} for CN_1 in equation 1. In this application, P would be the average rainfall for a given month. If a storage period is required for the months of December through March to avoid winter application, then a CN_{30} is calculated and used with monthly precipitation values to estimate runoff for each of the 4 months. The summation runoff for the 4 months would represent the volume required for the storage period. The volumes computed using CN_{30} is typically high when compared with actual data. They work better on smaller watersheds than on larger watersheds. National maps showing average monthly runoff percentages are also available from chapter 10 of the NRCS Agricultural Waste Management Field Handbook (see *http://www.wcc.nrcs.usda.gov/awm/awmfh.html*).

Annual runoff

Annual totals for feedlot surfaces are summarized in figure B–2. Annual runoff values might be used in planning nutrient runoff from feedlot for sizing of a land application area (sec. 6) or other planning roles.

Figure B–2 Annual runoff from open lots as a percent of mean annual precipitation (NRCS Agricultural Waste Management Field Handbook, ch. 10 (*http://www.wcc.nrcs.usda.gov/awm/awmfh.html*))



Example—Calculation of runoff

Determine the runoff for a 2,000 head capacity dirt feedlot (finishing 4,000 head of cattle per year) located in central Iowa. The feedlot is 11.5 acres in area an additional 8 acres of roads, drainage ditches, feed storage and preparation areas, and compost site drains into the settling basin. Annual precipitation is assumed to be 34 inches.

10-year, 1-hour storm runoff: 2.3 inches of rainfall (from fig. B–1) which produces 1.4 and 2.1 inches of runoff from feedlot (table B–1, CN=90) and additional drainage area (assumed to be primarily compacted surfaces, thus selecting CN=98 from table B–1), respectively. This single event would produce:

$$= (1.4 \text{ in} \times 11.5 \text{ feedlot a}) + (2.1 \text{ in} \times 8 \text{ additional a})$$
$$= 33 \text{ a-in of runoff}$$

25-year, 24-hour storm runoff: 5.5 inches of rainfall (from fig. B–1) which produces 4.4 and 5.3 inches of runoff from feedlot (table B–1, CN=90) and additional drainage area (assumed to be primarily compacted surfaces, thus selecting CN=98 from table B–1), respectively. This single event would produce:

$$= (4.4 \text{ in} \times 11.5 \text{ feedlot a}) + (5.3 \text{ in} \times 8 \text{ additional a})$$
$$= 93 \text{ a-in of runoff}$$

Monthly runoff: Estimate runoff for the month of June when average precipitation is 3.5 inches. The CN_{30} value is estimated using equation 2 as follows:

$$\text{Feedlot: } CN_{30} = 90 - \left\{ 90 - \left[\frac{\left(90^{2.365}\right)}{631.79} \right] - 15 \right\} \log 30 = 77$$

$$\text{Additional area: } CN_{30} = 98 - \left\{ 98 - \left[\frac{\left(98^{2.365}\right)}{631.79} \right] - 15 \right\} \log 30 = 95$$

Monthly runoff is calculated from equation 1 as follows:

$$\text{Feedlot: } Q = \frac{\left\{ 3.5 - 0.2 \left[\left(\frac{1,000}{77} \right) - 10 \right] \right\}^2}{\left\{ 3.5 + 0.8 \left[\left(\frac{1,000}{77} \right) - 10 \right] \right\}} = 1.4 \text{ in}$$

$$\text{Additional area: } Q = \frac{\left\{ 3.5 - 0.2 \left[\left(\frac{1,000}{95} \right) - 10 \right] \right\}^2}{\left\{ 3.5 + 0.8 \left[\left(\frac{1,000}{95} \right) - 10 \right] \right\}} = 2.9 \text{ in}$$

Average June open lot runoff is:

$$= (1.4 \text{ in} \times 11.5 \text{ feedlot acres}) + (2.9 \text{ in} \times 8 \text{ additional acres})$$
$$= 39 \text{ a-in of runoff}$$

Example—Continued

Monthly runoff maps are found in chapter 10 of the NRCS Agricultural Waste Management Field Handbook.

Annual Runoff: Annual runoff from the feedlot is estimated to be:

$$\text{Annual runoff} = \text{Annual precipitation} \times \% \text{ runoff} \times \frac{\text{area}}{100}$$

(fig. B–3) (fig. B–2)

For feedlot, annual runoff is:

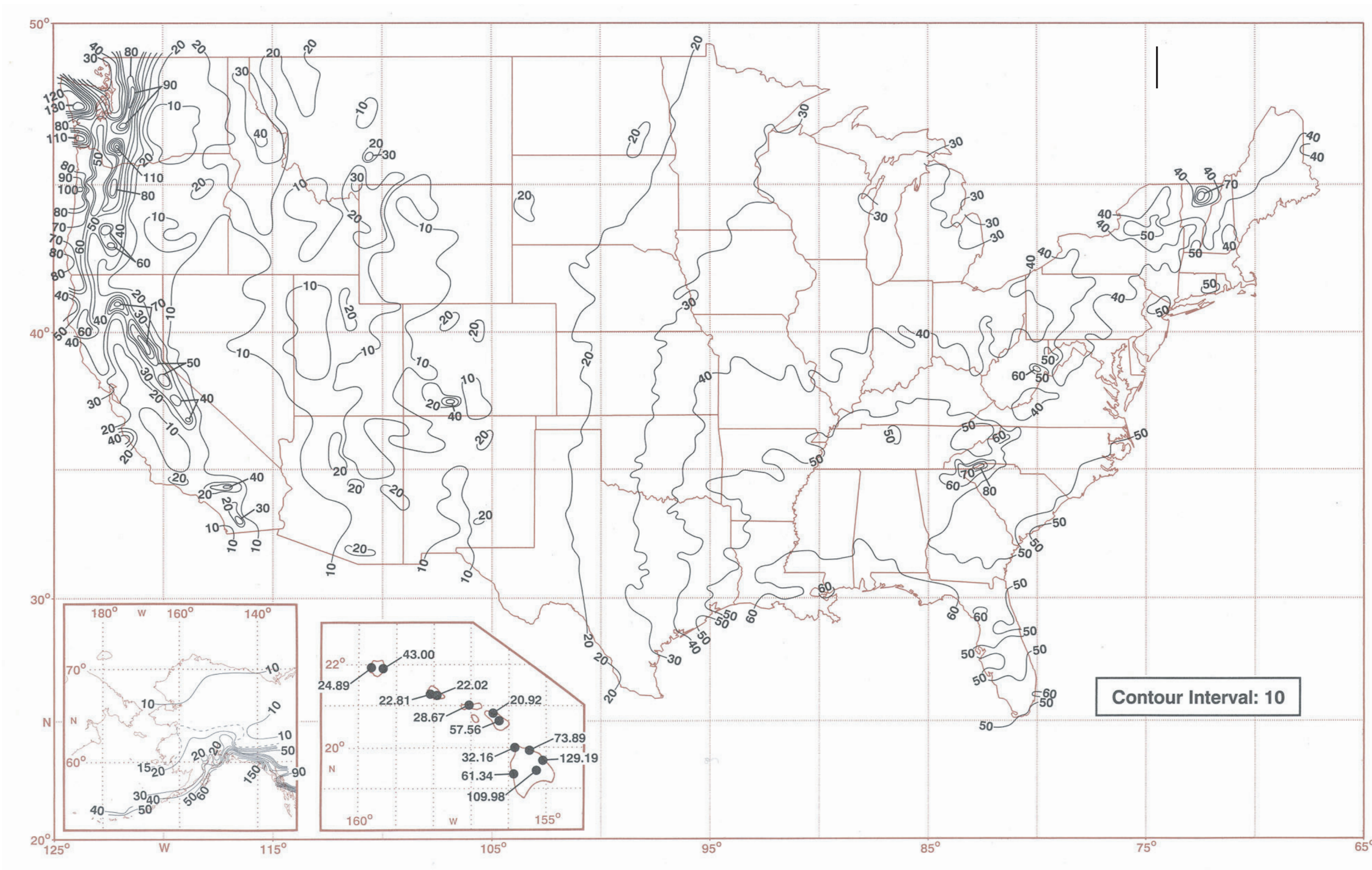
$$= 34 \text{ in} \times 23 \times \frac{11.5 \text{ a}}{100}$$
$$= 90 \text{ a-in}$$

For additional contributing area (roads, drainage ditches, feed storage and preparation areas, and compost site), it is assumed that the concrete open lot runoff value in figure B–2 is a reasonable (and likely a conservative) approximation of runoff:

$$= 34 \text{ in} \times 55 \times \frac{8 \text{ a}}{100}$$
$$= 150 \text{ a-in}$$

Total annual runoff should not exceed 240 acre-inches (sum of feedlot and contributing area estimates).

Figure B–3 Mean annual precipitation (inches) for 1961 to 1990 (National Climate and Data Center, *http://www.ncdc.noaa.gov/img/documentlibrary/clim81supp3/precipnormal_lowres.jpg)*



Appendix C Example Sizing of Settling Basin

Problem

Design a settling basin for a 2,000 head dirt feedlot located in central Iowa. The outflow of the basin will be to a VTA. The feedlot is 11.5 acres in area an additional 8 acres of roads, drainage ditches, feed storage and preparation areas, and compost site drains into the settling basin. The basin will be cleaned once a year in late summer. The site restricts basin depth to 4 feet. There will be a sloped screen and a perforated riser pipe with an orifice plate at the basin outlet. Basin must have a detention time of at least 1 hour. Basin capacity of equivalent runoff from a 25-year, 24-hour storm will also be assumed necessary because liquid release will be spread over a 72-hour period for this storm event. Sizing procedures are described in section 5.

Solution

1. Rainfall volume for a 25-year, 24-hour storm in central Iowa (fig. B–1) is 5.5 inches. Rainfall volume for a 10-year, 1-hour storm in central Iowa (fig. B–1) is 2.4 inches.

2. Peak flow rate off lot

$$= 19.5 \text{ a} \times 43{,}560 \text{ ft}^2/\text{a} \times \frac{2.4 \text{ in/h}}{43{,}200}$$
$$= 47 \text{ ft}^3/\text{s}$$

3. Use settling rate of 4 feet per hour.

4. Basin surface area

$$= \frac{(47 \times 3{,}600 \text{ s/h})}{4}$$
$$= 42{,}300 \text{ ft}^2$$

5. Liquid storage depth $= 4 \text{ ft/h} \times 1 \text{ h}$
   $= 4$ ft. maximum depth
   Select actual storage depth of 2.75 feet liquid depth and 0.25 feet freeboard depth for solids storage.

6. Liquid volume

$$= 2.75 \text{ ft} \times 42{,}300 \text{ ft}^2$$
$$= 116{,}000 \text{ ft}^3$$

(Provides about a 40-min detention time)

Liquid volume = 93 acre-inch or 338,000 cubic foot (based from 25-yr, 24-hr storm as calculated in app. B example). Select larger of two volumes or 338,000 cubic foot for settling basin storage volume.

Recalculate basin surface area holding depth constant:

Basin surface area

$$= \frac{338{,}000 \text{ ft}^3}{2.75 \text{ ft liquid depth}}$$
$$= 123{,}000 \text{ ft}^2$$

7. Solids storage volume

$$= 0.5 \text{ a-in/a} \times 11.5 \text{ a} \times 1.0 \text{ yr} \times \frac{43{,}560 \text{ ft}^2\text{/a}}{12 \text{ in/ft}}$$
$$= 21{,}000 \text{ ft}^3$$

8. Solids storage depth

$$= \frac{21{,}000 \text{ ft}^3}{123{,}000 \text{ ft}^2}$$
$$= 0.2 \text{ ft}$$

(Slightly less solids storage will be required than 0.25 ft allowed in step 5…no design change will be made at this time.)

9. Overall basin depth

$$= 2.75 + 0.25$$
$$= 3 \text{ ft}$$

10. Screen area

$$= \frac{(2.2 \times 60 \text{ s/min})}{(0.6 \times 2.5 \text{ ft/min})}$$
$$= 88 \text{ ft}^2$$

Screen length

$$= \frac{88 \text{ ft}^2}{3 \text{ ft}}$$
$$= 32 \text{ ft}$$

11. Minimum basin length

$$= 3 \text{ ft} \times \frac{12}{1} \text{ ramp ratio} + 32$$
$$= 68 \text{ ft}$$

(based on screen length and ramp…actual basin length will be much longer)

12. Assume basin average width of 59 feet (50 ft wide bottom and 3 to 1 slope sidewalls for 3 ft depth basin).

Basin length

$$= \frac{123{,}000 \text{ ft}^2}{59 \text{ ft}}$$
$$= 2{,}100 \text{ ft}$$

13. a. Average flow rate from basin

Outlet flow rate

$$= \frac{338{,}000 \text{ ft}^2}{(72 \text{ hr} \times 3{,}600 \text{ s/h})}$$
$$= 1.3 \text{ ft}^3\text{/s for a 72 hour release rate into VTA}$$

b. Assume that two riser pipes will be used (0.65 ft^3/s per pipe). Orifice diameter from table 5–2 for a 0.65 cubic foot per second flow and a 2.75 foot head is between 3.75 (0.62 ft^3/s), and 4 inches (0.71 ft^3/s). Select the 3.75-inch orifice with a flow rate of 0.62 cubic foot per second.

c. Open area for riser pipe is estimated from table 5–3 to be 6 square inch per foot for a flow rate of 0.62 cubic foot per second.

d. Select 7.5 inches per foot allowing for 25 percent greater open area per foot of riser than that shown in table 5–3 for orifice flow rate. This is done to ensure orifice diameter controls discharge.

14. Assuming separate mainlines for each riser, a 1 percent mainline pipe slope, and a flow rate of 0.62 cubic foot per second for each line, an 8 inches mainline pipe is required according to figure 5–6.

15. The minimum riser pipe size selected should be the largest of the following three possibilities:

(1) The diameter of the mainline or offset line if used, (8 in) determined in step 14,

(2) 2 inches larger than the selected orifice diameter (3.75 + 2 = 5.75 in), or

(3) The diameter from table 5–4 for the design flow rate of 0.62 cubic foot per second (3.6 in).

Select a riser diameter of 8 inches. If each 8-inch riser were equipped with two slots of 1 foot by 4 inches per linear foot of riser, the 7.5 square inch per linear foot requirement would be satisfied. Thus, two 8-inch riser pipes with 3.75-inch orifice plates would be recommended. Each riser would have 8-inch mainline conveying water to the VTA.

Appendix E Tolerance Factors

Table E–1 is a listing of a several tolerance factors for forages and legumes to various soil and moisture conditions as assembled by a team from the University of Montana and USDA NRCS. For information on additional crop tolerance factors not listed in this table log onto:

http://www.animalrangeextension.montana.edu/Aticles/Forage/Main-species.htm

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Table E–1 Tolerance factors

Species	pH tolerance	Salt tolerance	Moisture range	Tolerance to water table	Tolerance to early spring flooding	Drought tolerance
Forages						
Big bluegrass	2,3		12–22	4		2
Kentucky bluegrass	2,3		14–22	2		2
Smooth bromegrass	2,3	2	12+	3	35–56	2
Meadow bromegrass	2,3	2	14+	3		2
Reed canarygrass	1,2,3	2	15+	1	35–56	2
Tall fescue	1,2,3,4	1	16+	2		2
Creeping foxtail	2,3,4	2	18+	1		3
Meadow foxtail	2,3		18+	1	21–42	3
Green needlegrass	3		18–22	4		1
Orchardgrass	2,3	2	15+	3		2
Timothy	2,3		15+	2	21–56	3
Beardless wheatgrass	3		12–18	3		1
Bluebunch wheatgrass	3		10–18	4		1
Crested wheatgrass, fairway	3	1	10–18	4		1
Crested wheatgrass, standard	3	1	11–18	4		1
Intermediate wheatgrass	2,3	1	13–22	3	21–28	2
Pubescent wheatgrass	2,3	1	12–20	3		2
Siberian wheatgrass	3		10–18	4		1
Slender wheatgrass	2,3,4	1	12–20	3	35–56	1
Tall wheatgrass	3,4	1	14+	2	35–56	1
Thickspike wheatgrass	3	2	10–18	3		1
Western wheatgrass	3,4	1	12+	2		1
Russian wildrye	3,4	1	10–18	3	21–35	1
Altai wildrye	3,4	1	12–18	3	2	1
Legumes						
Alfalfa	2,3	2	12+	3	7–14	2
Red clover	1,2,3	3	16+	3		3
Alsike clover	1,2,3	3	16+	2	7–14	3
Ladino or white clover	1,2,3	3	16+	2		3
Dutch clover	1,2,3	3	14+	2		2
Sainfoin	3		12–20	4		2
Sweetclover, yellow or white	2,3	2	10+	3	7–14	1
Birdsfoot trefoil	1,2,3	2	14+	2		2
Cicer milkvetch	2,3	2	14+	2		2

pH tolerance

Soil pH levels:
1 = < 5.5 pH: Tolerant to strong acid conditions.
2 = 5.6 – 6.5 pH: Tolerant to weak acid conditions.
3 = 6.6 – 8.4 pH: Tolerant to neutral to moderately alkaline conditions.
4 = >8.5 pH: Tolerant to strongly alkaline conditions.

Salt tolerance

Salt tolerance is the relative capacity of a forage to produce satisfactory yield or cover on a salty site. Saline soils are usually a mixture of some of the chloride, sulfate or bicarbonate salts of calcium, magnesium, and sodium. The total concentration of ions in the soil-water solution influences plant response more than the specific salt composition. For most purposes, soil salinity levels can be determined using the electrical conductivity (EC) of the soil solution.

1 = Good salt tolerance
2 = Fair salt tolerance
3 = Poor salt tolerance

Salt tolerance in forage species is complex, and information on many species is lacking. Once established, most forages can tolerate fairly high levels of salinity. Caution is urged to carefully select species based on utilization needs for conservation practices, many species are available; however, for grazing or hay, salinity can affect production, palatability, and concentration of nutrients and minerals. Further, soils that are high in exchangeable sodium (sodic soils) present special problems in addition to those attributed to total salinity. High levels of exchangeable sodium break down organic matter and cause soil particles to disperse, resulting in small pores. Poor aeration, water movement, and root growth are associated with these changes in soil structure (black alkali soils). Leaching of sodium and application of soil amendments can improve soil structure.

Moisture range to which species is well adapted

Plant response to moisture is subject to many variables: elevation, exposure, total heat units, season when greatest amount of moisture is received, and runoff losses to name a few. Moisture, as used here, includes all sources: annual precipitation, natural flooding, and irrigation. Some species may do well in rows under lower moisture than shown since this makes the available moisture more effective.

In defining a moisture range for a species, the lower limit is the minimum at which the species gives satisfactory production in solid stand. The upper limit is the amount beyond which the species will not utilize additional moisture. If no upper limit is given, it means it does well under maximum precipitation experienced in forage producing areas in Montana or under irrigated conditions. Ratings are expressed as inches of moisture.

Tolerance to water table

1 = Species will grow on sites with soil-water at or above field capacity, will grow when the water is ponded on the surface for several weeks at a time, and will grow under marshy conditions.

2 = Species will grow on sites with the soil-water at or above field capacity for most of growing season. It does not grow well when water is ponded on the surface for more than a few days at a time.

3 = Species will grow on sites with the soil-water at or above field capacity for several weeks in early spring. It will not grow well on soils where the water is ponded on the surface during the growing season.

4 = Species will grow on well-drained sites without a water table.

Tolerance to early spring flooding

Ratings are given in days for several species (McKenzie, R.E., Vol. 31, 1951, Sci. Agric. pp. 358-367). Based on observations, estimates of flooding tolerance of mature plants have been made for other species. To distinguish between these and the research data these estimates are shown as follows:

Exc. = (excellent) more than 49 days
Good = 14 to 49 days
Poor = less than 14 days

Very little information is available on tolerance to summer flooding. It is known that plants are far less tolerant to flooding with warm water and even less to still, warm water.

Drought tolerance

This rates the ability of a species or strain to survive prolonged periods of dry weather. It rates survival during periodic severe drought but not relative yield in an arid climate. Ratings assume the species is well adapted to the soil site, is being utilized each year, and is under good management.

1 = High
2 = Medium
3 = Low

Appendix F Records for VTA Systems

Form 1: Livestock Manure and Effluent Discharge Notification

Caution: Individual permitting authorities will define which releases of runofff from a VTA will qualify as a discharge and require reporting within 24 hours. This question should be raised for clarification with permitting authority. The information requested in this form should also be verified with the individual permitting authority or preferred alternative record used by the permitting authority substituted for this record.

Name: ____
Permitted Operation Name

Owner/Manager: ____

Address: ____
P.O. Box/Street Address

____
City, State, and Zip Code

Legal Description of Operation

________, of ________, _____________N, ___________ ☐ E or ☐ W, ____________________ County
1/4 1/4 Section Township Range

Do you have an **NPDES** permit? ________ Yes ________ No **If** yes, Permit No. ______________________

Do you have a **State** Permit? ________ Yes ________ No **If** yes, Permit No. ______________________

Complete the following:

1. List reason(s) for discharge (i.e., power failure, large storm or chronic wet period, leak or break in the water supply system, component failure of the waste control facility; and/or releases during land application due to equipment failure, accidents or irrigation equipment failure):

   ____

   ____

2. The discharge flowed into ____
   (ditch, drainage way, stream name)

3. Did the discharge flow directly into surface water (stream, river, drainage ditch, lake, wetland) or did the discharge flow over cropland prior to discharging to surface water? ______________________

4. The approximate width and depth of the surface water (which the discharge entered):
   ______________________ (width in feet) and ______________________ (depth in feet)

5. The discharge started on (date and time): Please indicate if this was the actual time or if this was when the discharge was discovered.

   ____

   ____

6. The discharge ended on (date and time): Please indicate if this was the actual or the estimated time

   ____

   ____

(continued on next page)

Form 1: Livestock Manure and Effluent Discharge Notification (continued)

7. Average flow of the discharge was: ____(gallons/minute)

8. Estimated total volume of discharge (ft^3): ______________________________________(L x W x D)

9. List any damage to the waste control facility: ____

____

____

10. Describe factors and conditions that were used to minimize the adverse effects to the environment from the discharge:

____

____

____

Additional Information

1. You may submit rainfall, land application, and system storage records for up to a 12-month period prior to the discharge event to demonstrate the need for the discharge.

2. Samples of discharge are required for all NPDES permitted animal feeding operations. The following characteristics should be analyzed. Sample locations, at a minimum, must include point of discharge, upstream, downstream and the mix zone (where the discharge mises with surface water). Provide a map with collection sites marked.

   a) Five-day Biochemical Oxygen Demand (BOD^5)
   b) total ammonium-nitrogen
   c) nitrate-nitrite nitrogen
   d) pH (field measurement)
   e) temperature of the effluent and receiving stream (field measurement)
   f) total phosphorus
   g) total suspended solids
   h) Escherichia coli or fecal coliform

3. Was sample kept cool with ice or frozen during time between sample was taken and delivery to lab?
   ______ Yes ______ No

I HEREBY CERTIFY THAT THE INFORMATION SUBMITTED HEREIN IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

X____

Signature of authorized representative Date

Form 2: Record of Precipitation, Land Application, and Liquid Levels

Purpose: A record of precipitation, land application events, and liquid levels is required for all permitted storage facilities for containing storm related runoff from open lot production systems.

Month and Year: ________________ **Settling Basin ID:** ________________ **VTA Site ID:** ________________

Day	Precipitation	Vegetative Treatment Area					
		Hour pumping or release started	Hour pumping or release stopped	Flow rate (gpm)	Total volume released or pumped	Check if discharge from VTA[1]	Settling basin or pond liquid level[2]
1	in.			gpm	gal.		ft.
2	in.			gpm	gal.		ft.
3	in.			gpm	gal.		ft.
4	in.			gpm	gal.		ft.
5	in.			gpm	gal.		ft.
6	in.			gpm	gal.		ft.
7	in.			gpm	gal.		ft.
8	in.			gpm	gal.		ft.
9	in.			gpm	gal.		ft.
10	in.			gpm	gal.		ft.
11	in.			gpm	gal.		ft.
12	in.			gpm	gal.		ft.
13	in.			gpm	gal.		ft.
14	in.			gpm	gal.		ft.
15	in.			gpm	gal.		ft.
16	in.			gpm	gal.		ft.
17	in.			gpm	gal.		ft.
18	in.			gpm	gal.		ft.
19	in.			gpm	gal.		ft.
20	in.			gpm	gal.		ft.
21	in.			gpm	gal.		ft.
22	in.			gpm	gal.		ft.
23	in.			gpm	gal.		ft.
24	in.			gpm	gal.		ft.
25	in.			gpm	gal.		ft.
26	in.			gpm	gal.		ft.
27	in.			gpm	gal.		ft.
28	in.			gpm	gal.		ft.
29	in.			gpm	gal.		ft.
30	in.			gpm	gal.		ft.
31	in.			gpm	gal.		ft.

1. This column should be checked if pump out or VTA discharge is directed to surface waters, wetlands, ditch or drainage connecting to surface waters. Regulatory authority should be notified by phone within 24 hours.
2. Liquid level is measured from: _____low point at top of berm, dam, or spillway; _____bottom of storage; _____must pump level mark on liquid level indicator.

Measure to the nearest one foot increment.

Form 3: Vegetated Treatment System Inspection Checklist

Checks in shaded boxes suggest potential problem or risk.

Farm:____ Facility ID: ____ Year: ______________________

Date								
Inspected by (initials)								

Solids settling component observations

	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Comments
Signs of berm/dam damage due to:																	
Burrowing animals?																	
Presence of trees or large weeds?																	
Erosion, gullies or poorly established sod?																	
Is solids accumulation excessive?																	
For settling basins, is maximum solids storage clearing marked and visible?																	
Are gravity drained outlets free of obstructions?																	
Security: Are gravity drain valves or pump power supplies locked/secure from tampering?																	

Vegetated Treatment Area (VTA)

	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Comments
Do VTA inlets appear to evenly distribute flow?:																	
Are VTA inlets free of obstructions and debris?																	
Are there signs of erosion/damage to field border?																	
Signs of channel or non-uniform flow?																	
Presence of wheel ruts or gullies?																	
Presence of eroded areas?																	
Infield spreader erosion/maintenance needs?																	
Signs of ponding within VTA?																	
Signs of high areas which runoff does not reach?																	
Does forage need to be harvested?																	
Are there signs of fertility deficiencies?																	
Are there signs of undesirable plant species?																	
Is there a good stand of forage in first 50 ft?																	
Is there a good stand of forage in rest of)?																	

Form 3: Vegetated Treatment System Inspection Checklist (continued)

Checks in shaded boxes suggest potential problem or risk.

Date																
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**

Vegetative Infiltration Basin (VIB)

																	Comments
Signs of berm/dam damage due to:																	
Burrowing animals?																	
Presence of trees or large weeds?																	
Erosion, gullies, or poorly established sod?																	
Is water flowing from all drainage tile runs?																	
Is there a good stand of forage in first 1/3 of VIB?																	
Is there a good stand of forage in last 2/3 of VIB?																	
Does water drain from VIB within three days?																	
Does water spread evenly over VIB?																	

Clean Water Diversion

Signs of berm/dam damage due to:																	
Burrowing animals?																	
Presence of trees or large weeds?																	
Erosion, gullies, or poorly established sod?																	
Are perimeter drains plugged or blocked?																	
Is roof water entering storage?																	
Is field runoff entering storage?																	
Are diversions/waterways maintained?																	

Visual Appearance and Safety

Is site neat and recently mowed?																	
Are mortality or afterbirth observed?																	
Are medical consumables observed?																	
Is area fenced and properly marked?																	

Form 4: VTA System Maintenance Record

Date	Component or equipment	Maintenance performed	Worker initials

Form 5: VTA Documentation of Nutrient Management

Review Ground Water Protection and Soil Sampling discussion in Chapter 8

Farm Owner: ______________________________ **VTA ID:** ____________________ **Crop:** ______________________

Sample date	Nitrogen management monitoring options[1]						Shallow soil test results							
	Option 1: Soil nitrate level (ppm) and sample depth (inches)		Option 2: Forage nitrate level (ppm)	Option 3: Crop nitrogen removal			Soil organic matter		Soil residual P		Soil EC (mmhos/cm)		Soil pH	
	First 50 ft	Rest of VTA		Tons harvested	Percent protein	lbs. N[2] removal	First 50’	Rest of VTA	First 50’	Rest of VTA	First 50’	Rest of VTA	First 50’	Rest of VTA

[1] Only one of these three indicators of nitrogen management is recommended unless risk to ground water is high.
[2] lbs N removed = tons harvested x % protein x 20/6.25.