MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

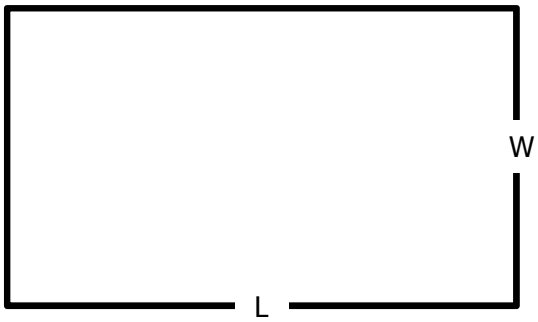
Units of Expression

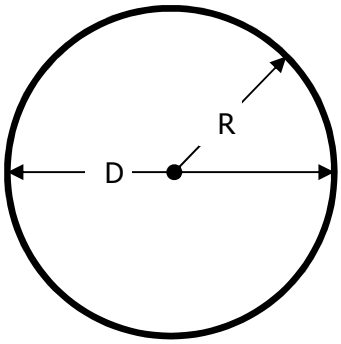
C	=	conversion factor	in	=	inch
D	=	diameter (distance across a circle)	MGD	=	million gallons per day
ft	=	feet	min	=	minute
gal	=	gallon	mph	=	miles per hour
gpd	=	gallons per day	Π	=	pi = 3.14
gph	=	gallons per hour	R	=	radius (half the diameter)
gpm	=	gallons per minute	>	=	greater than
hr	=	hour	<	=	less than

General Conversion Factors

1 acre	=	43,560 ft^2	1 in-acre	=	27,154 gal
1 ft	=	12 inches	1 mile	=	5,280 ft
1 ft^3	=	7.48 gallons	1 hr	=	60 min
1 gal	=	231 in^3			

General Formulas





Area of a rectangle:	Length x Width		
Circumference of a circle:	$2\Pi R$	=	2 x 3.14 x R
Area of a circle:	ΠR^2	=	3.14 x R^2
Irrigation rate:	Volume irrigated ÷ Irrigation area		
OR Irrigation rate:	(Flow ÷ Irrigation area) x Irrigation period		

Please note this document utilizes significant figures.

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

General Reporting Requirements

The Missouri State Operating Permit will contain all applicable reporting and sampling requirements. In general, no-discharge facilities are required to report the following in Table 1:

Table 1. Typical No-Discharge Facility Limitations and Monitoring Requirements

Effluent Parameters	Units	Daily Total	Monthly Total	Measurement Frequency	Sample Type
Irrigation Period	hours	*	*	daily	total
Volume Irrigated	gallons	*	*	daily	total
Irrigation Area	acres	*	*	daily	total
Irrigation Rate	inches	*	*	daily	total

** Monitoring only.*

The operating permit will require monitoring every day that irrigation occurs.

The Missouri State Operating Permit will specify the maximum irrigation rate design limitations. Throughout this document the default maximum irrigation rates below will be compared to the calculated values in the surface wastewater irrigation problems.

Maximum irrigation rates: 0.50 in/hr; 1.0 in/day; 3.0 in/week; 24 in/year

---

Problem 1

Determine the volume irrigated and irrigation rate using pump run time. The irrigation pump is rated at 200 gpm and pumped for two hours equally distributing wastewater over 10 acres in one day.

Solution 1

Irrigation period = 2.0 hours

Irrigation area = 10 acres

Step 1. Determine volume irrigated = Pump Rating (gpm) x C (60 min/hr) x Irrigation Period (hr)

Volume irrigated = 200 gpm x 60 min/hr x 2.0 hr = 24,000 gallons

Step 2. Determine irrigation rate = Volume irrigated (gal) ÷ Irrigation area (acres) ÷ C (27,154 gal/in-acre) ÷ Days of Irrigation (day)

24,000 gallons ÷ 10 acres ÷ 27,154 gal/ (in-acre) = 0.088 in

0.088 in ÷ 1 day = 0.088 in/day [< 1.0 in/day]

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Solution 2 offers another way to solve for the irrigation rate.

Solution 2

Step 1. Determine flow = Pump Rating (gpm) x C (60 min/hr)

Flow = 200 gpm x 60 min/hr = 12,000 gph

Step 2. Determine irrigation rate = (Flow (gph) ÷ C (7.48 gal/ft^3)) ÷ (Irrigation area (acres) x C (43,560 ft^2/acre)) x C (12 in/ft) x Irrigation period (hr) ÷ Days of Irrigation (day)

(12,000 gph ÷ 7.48 gal/ft^3) ÷ (10 acres x 43,560 ft^2/acre) x 12 in/ft = 0.044 in/hr [< 0.50 in/hr]

0.044 in/hr x 2.0 hr ÷ 1 day = <u>0.088 in/day</u> [< 1.0 in/day]

Problem 2

Determine the volume of wastewater irrigated using a rain gauge where the method of irrigation evenly distributed wastewater over five acres of land. In one-day irrigation for three hours, the rain gauge reads four tenths inches.

Solution

Irrigation period = <u>3.0 hours</u>

Irrigation area = <u>5.0 acres</u>

Step 1. Determine irrigation rate = Rain Gauge Depth (in) ÷ Irrigation Period (hr) ÷ Days of Irrigation (day)

Irrigation rate = 0.40 in ÷ 3.0 hours = 0.133 in/hr [< 0.50 in/hr]

Irrigation rate = 0.133 in/hr x 3.0 hours ÷ 1 day = <u>0.40 in/day</u> [< 1.0 in/day]

Step 2. Determine volume irrigated = (Rain Gauge Depth (in) ÷ C (12 in/ft)) x (Irrigation area (acres) x C (43,560 ft^2/acre)) x C (7.48 gal/ft^3)

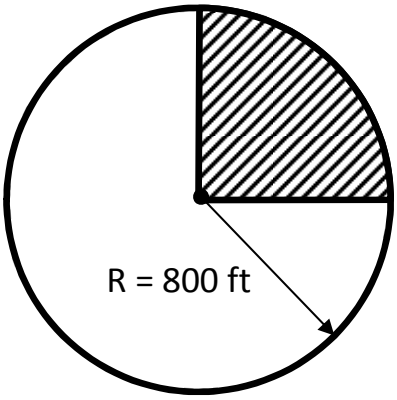
Volume irrigated = (0.40 in ÷ 12 in/ft) x (5.0 acres x 43,560 ft^2/acre) x 7.48gal/ft^3 = <u>54,000 gallons</u>

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 3

Determine the volume of wastewater irrigated, wetted irrigation area, and irrigation rate. A center pivot with a length of 800 feet irrigates for one hour per day at 300 gpm. The center pivot rotates a quarter of the circumference (¼ rotation = 0.25).



Solution

Irrigation period = 1.0 hour

Step 1. Determine flow = Pump Rating (gpm) x C (60 min/hr)

Flow = 300 gpm x 60 min/hr = 18,000 gph

Step 2. Determine volume irrigated = Flow (gph) x Irrigation Period (hr)

Volume irrigated = 18,000 gph x 1.0 hr = 18,000 gallons

Step 3. Determine total area of the center pivot = ΠR^2; the center pivot length = radius

Total area of center pivot = 3.14 x $(800\ ft)^2$ = 2,009,600 ft^2

Step 4. Determine irrigation area = Total area of center pivot (ft^2) x Number of rotations

Irrigation area = 2,009,600 ft^2 x 0.25 = 502,400 ft^2

Irrigation area = 502,400 ft^2 ÷ 43,560 ft^2/acre = 12 acres

Step 5. Determine irrigation rate = ((Flow (gph) ÷ C (7.48 gal/ft^3)) ÷ Irrigation area (ft^2)) x C (12 in/ft) x Irrigation period (hr) ÷ Days of Irrigation (day)

((18,000 gph ÷ 7.48 gal/ft^3) ÷ 502,400 ft^2) x 12 in/ft = 0.058 in/hr [< 0.50 in/hr]

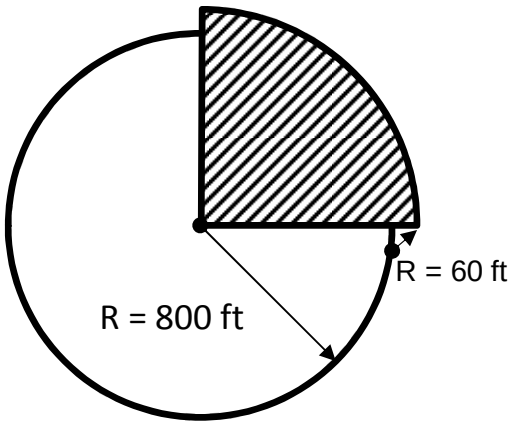
0.058 in/hr x 1.0 hr ÷ 1 day = 0.058 in/day [< 1.0 in/day]

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 4

Determine the volume of wastewater irrigated, wetted irrigation area, and irrigation rate. A center pivot with a length of 800 feet irrigates for one hour per day at 300 gpm. The center pivot also has an end gun with a radius of 60 feet. The center pivot rotates a quarter of the circumference (¼ rotation = 0.25).



Solution

Irrigation period = <u>1.0 hour</u>

Step 1. Determine flow = Pump Rating (gpm) x C (60 min/hr)

Flow = 300 gpm x 60 min/hr = 18,000 gph

Step 2. Determine volume irrigated = Flow (gph) x Irrigation Period (hr)

Volume irrigated = 18,000 gph x 1.0 hr = <u>18,000 gallons</u>

Step 3. Determine the total radius of wetted area = Radius of center pivot + Radius of end gun

Total radius = 800 ft + 60 ft = 860 ft

Step 4. Determine total area of the center pivot plus end gun = ΠR^2

Total area = 3.14 x $(860\ ft)^2$ = 2,322,344 ft^2

Step 5. Determine irrigation area = Total area (ft^2) x Number of rotations

Irrigation area = 2,322,344 ft^2 x 0.25 = 580,586 ft^2

Irrigation area = 580,586 ft^2 ÷ 43,560 ft^2/acre = <u>13 acres</u>

Step 6. Determine irrigation rate = ((Flow (gph) ÷ C (7.48 gal/ft^3)) ÷ Irrigation area (ft^2)) x C (12 in/ft) x Irrigation period (hr) ÷ Days of Irrigation (day)

((18,000 gph ÷ 7.48 gal/ft^3) ÷ 580,586 ft^2) x 12 in/ft = 0.050 in/hr [< 0.50 in/hr]

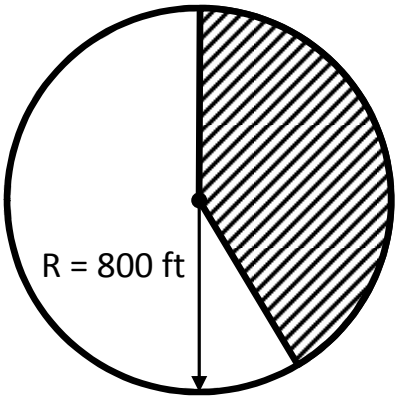
0.050 in/hr x 1.0 hr ÷ 1 day = <u>0.050 in/day</u> [< 1.0 in/day]

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 5

Determine the volume of wastewater irrigated, wetted irrigation area, and irrigation rate. A center pivot with a length of 800 feet irrigates for two hours per day at 300 gpm. The center pivot travels a distance of 2,000 feet of the circumference.



Solution

Irrigation period = 2.0 hours

Step 1. Determine flow = Pump Rating (gpm) x C (60 min/hr)

Flow = 300 gpm x 60 min/hr = 18,000 gph

Step 2. Determine volume irrigated = Flow (gph) x Irrigation Period (hr)

Volume irrigated = 18,000 gph x 2.0 hr = 36,000 gallons

Step 3. Determine circumference of center pivot = $2\Pi R$

Circumference = 2 x 3.14 x 800 ft = 5,024 ft

Step 4. Determine percent travel of center pivot = (Distance traveled (ft) ÷ Circumference (ft)) x 100%

Percent travel = (2,000 ft ÷ 5,024 ft) x 100% = 39.8%

Step 5. Determine total area of the center pivot = ΠR^2

Total area of center pivot = 3.14 x $(800\ ft)^2$ = 2,009,600 ft^2

Step 6. Determine irrigation area = Total area of center pivot (ft^2) x (Percent travel ÷ 100%)

Irrigation area = 2,009,600 ft^2 x (0.398) = 799,820.8 ft^2

Irrigation area = 799,820.8ft^2 ÷ 43,560 ft^2/acre = 18 acres

Step 7. Determine irrigation rate = ((Flow (gph) ÷ C (7.48 gal/ft^3)) ÷ Irrigation area (ft^2)) x C (12 in/ft) x Irrigation period (hr) ÷ Days of Irrigation (day)

((18,000 gph ÷ 7.48 gal/ft^3) ÷ 799,820.8 ft^2) x 12 in/ft = 0.036 in/hr [< 0.50 in/hr]

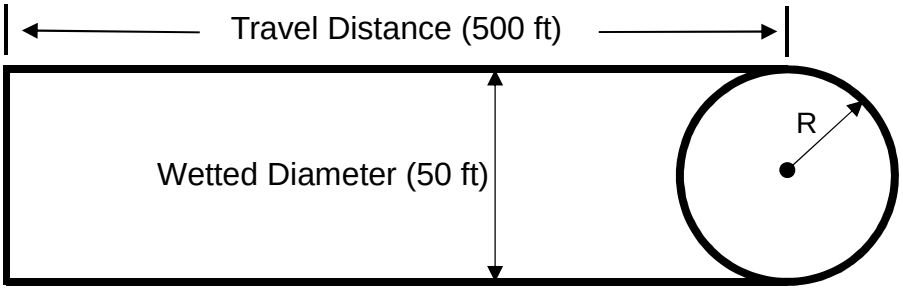
0.036 in/hr x 2.0 hr ÷ 1 day = 0.072 in/day [< 1.0 in/day]

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 6

Determine the volume of wastewater irrigated, wetted irrigation area, and irrigation rate. A traveling gun or drag hose has a pump rate of 100 gpm, a wetted diameter of 50 feet, and travels a total distance of 500 feet in one day at a speed of 0.10 miles per hour.



Solution

Step 1. Determine irrigation period = Travel distance (ft) ÷ C (5,280 ft/mile) ÷ Speed (mi/hr)

Irrigation period = 500 ft ÷ 5,280 ft/mile ÷ 0.10 mi/hr = <u>0.95 hour</u>

Step 2. Determine flow = Pump Rating (gpm) x C (60 min/hr)

Flow = 100 gpm x 60 min/hr = 6,000 gph

Step 3. Determine volume irrigated = Flow (gph) x Irrigation Period (hr)

Volume irrigated = 6,000 gph x 0.95 hr = <u>5,700 gallons</u>

Step 4. Determine radius of the traveling gun = Wetted diameter (ft) ÷ 2

Radius = 50 ft ÷ 2 = 25 ft

Step 5. Determine irrigation area = (Wetted diameter (ft) x Travel distance (ft)) + ½(ΠR^2)

Irrigation area = (50 ft x 500 ft) + ((3.14 x (25 ft)^2) ÷ 2) = 25,981.25 ft^2

Irrigation area = 25,981.25 ft^2 ÷ 43,560 ft^2/acre = <u>0.60 acre</u>

Step 6. Determine irrigation rate = (Flow (gph) ÷ C (7.48 gal/ft^3)) ÷ Irrigation area (ft^2) x C (12 in/ft)) x Irrigation period (hr) ÷ Days of Irrigation (day)

((6,000 gph ÷ 7.48 gal/ft^3) ÷ 25,981.25 ft^2) x 12 in/ft = 0.37 in/hr [< 0.50 in/hr]

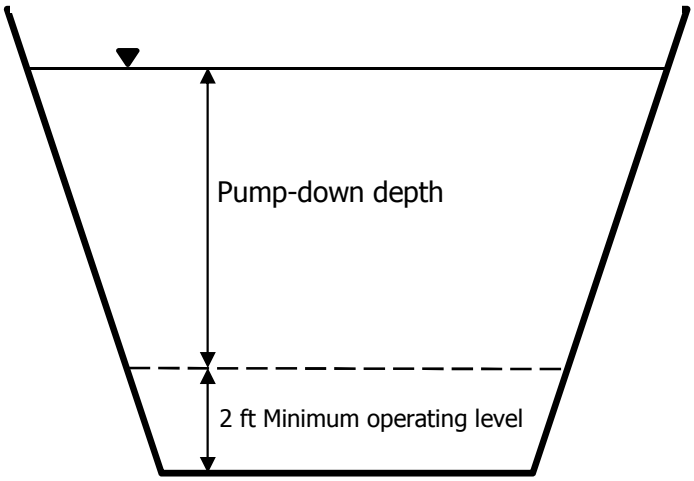
0.37 in/hr x 0.95 hr ÷ 1 day = <u>0.35 in/day</u> [< 1.0 in/day]

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 7

Determine the minimum volume of wastewater that will need to be irrigated during the course of a wet year to keep the lagoon from discharging and to achieve pump-down requirements set in the operating permit. This operating permit contains a special condition which requires the irrigation system to be capable of irrigating the annual design flow during an irrigation period of 100 days or less per year. Also, determine the minimum irrigation area required based on an irrigation rate of 24 in/year. The operating permit provides the following design basis of the lagoon:



Design population equivalent is 467.
Design flow is 50,000 gallons per day (Design flow plus 10-year rainfall minus evaporation, does not account for inflow and infiltration).
Average design flow is 46,700 gallons per day (dry weather flows).

Solution

Step 1. Determine the minimum volume to irrigate based on the design flow plus 1-in-10 year rainfall minus evaporation (not including inflow and infiltration) = 1-in-10 year design flow (gpd) x 365 days

Minimum volume = 50,000 gpd x 365 days = <u>18,250,000 gallons during the wettest year in 10</u>

Step 2. Determine the minimum volume to irrigate in 100 days = Minimum volume (gal) ÷ 100 days

Minimum irrigation volume in 100 days = 18,250,000 gal ÷ 100 days = <u>182,500 gpd</u>

To meet the operating permit condition, the wastewater treatment facility will need to irrigate a minimum of 182,500 gpd on average for a period of 100 days.

Step 3. Determine the minimum irrigation area = Minimum volume (gal) ÷ C (7.48 gal/ft^3) ÷ Irrigation rate (in/year) x C (12 in/ft) x C (43,560 ft^2/acre)

Minimum irrigation area = 18,250,000 gal ÷ 7.48 gal/ft^3 ÷ 24 in/year x 12 in/ft = 1,219,920 ft^2

1,219,920 ft^2 ÷ 43,560 ft^2/acre = <u>28 acres</u>

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

No-Discharge Operator Math

Problem 8

Determine the volume of wastewater irrigated, irrigation area, and irrigation rate of a subsurface drip soil dispersal system. The emitters are spaced two feet on center with a total length of 1,000 feet of drip line. The drip system disperses wastewater for eight hours in one day. The distance between drip lines (also known as the wetted width) is two feet. The emitters have a flow rate of 0.020 gph each. The qualified individual who prepared the soils report suggested an irrigation rate of 0.050 gpd/ft^2.

Solution

Irrigation period = 8.0 hours

Step 1. Determine number of emitters = Length of drip line (ft) ÷ Emitter spacing (ft)

Number of emitters = 1,000 ft ÷ 2.0 ft = 500 emitters

Step 2. Determine total flow = Number of emitters x Emitter flow (gph)

Total flow = 500 emitters x 0.020 gph = 10 gph

Step 3. Determine volume irrigated = Total flow (gph) x Irrigation period (hr)

Volume irrigated = 10 gph x 8.0 hr = 80 gallons

Step 4. Determine irrigation area = Length (ft) x Width (ft)

Irrigation area = 1,000 ft x 2.0 ft = 2,000 ft^2

Irrigation area = 2,000 ft^2 ÷ 43,560 ft^2/acre = 0.046 acre

Step 5. Determine irrigation rate = Volume irrigated (gal) ÷ Irrigation area (ft^2) ÷ Days of Irrigation (day)

80 gal ÷ 2,000 ft^2 = 0.040 gal/ft^2

0.040 gal/ft^2 ÷ 1 day = 0.040 gpd/ft^2 [< 0.050 gpd/ft^2]

For more information

Missouri Department of Natural Resources
Water Protection Program
P.O. Box 176
Jefferson City, MO 65102-0176
800-361-4827 or 573-751-1300
dnr.mo.gov/env/wpp/