APPENDIX D

TOWN OF
BRECKENRIDGE

FACT SHEET
SUBSURFACE INFILTRATION FACILITIES

1.0 Definition

This fact sheet provides design standards for drywells, infiltration trenches, infiltration galleries, and other subsurface infiltration structures used for permanent stormwater treatment facilities in areas with natural high infiltration rates. These types of subgrade infiltration facilities will collectively be known as drywells by this document. Drywells provide either stormwater quality treatment or stormwater detention by collecting surface stormwater runoff, temporarily storing it underground, and then discharging it primarily through infiltration into the surrounding soils. Drywells vary in form and include underground concrete structures, trenches or other excavations filled with granular material.

2.0 Purpose

The purpose of drywells is to provide stormwater quality treatment or stormwater detention through temporary subsurface storage and subsequent infiltration into surrounding soils. Drywells are typically selected for single family homes, small or constrained sites, and steep sites. On sites where space and topography permits, above ground detention and water quality facilities are preferred over drywells for ease of inspection and maintenance.

3.0 Drywell Advantages

1. Utilize the typically highly permeable soils in Breckenridge to provide groundwater recharge
2. Meet the stormwater detention and permanent water quality requirements of Chapter 6
3. Filter contaminants through filtration
4. Utilize site area efficiently
5. Provide environmental benefits by augmenting low flows in streams and reducing the thermal impacts of above ground detention facilities

4.0 Drywell Disadvantages

1. Susceptible to clogging and reduced infiltration rates
2. Difficult to inspect and maintain, increasing the potential for clogging or reduced performance
3. Risk being neglected because they are not readily visible, reducing maintenance frequency
4. Create potential for groundwater contamination issues
5. Require pretreatment to reduce high sediment loads quickly reducing infiltration capacity

5.0 Site Suitability

Drywells are not suitable for all sites where they may have negative impacts to other structures and properties. Drywells will not meet the requirements of Chapter 6 or function adequately for their full life cycle unless the site and the drywell meet certain requirements. Drywells and sites must meet the following criteria to be allowable as detention or stormwater treatment facilities:

1. Area draining to the drywell must be less than one acre.
2. A pretreatment facility is required upstream of the drywell.
3. Existing soils must be hydrological group A or B and infiltration must be at least 1 inch per hour as tested at the proposed elevation of the bottom of the drywell.

4. Drywells must be located at least 10 feet from building foundations or other structures, at least 10 feet from water lines and at least 100 feet from water source wells.
5. Drywells must be located at least 300 feet from an active waterway.
6. Drywells must be located a sufficient distance (at least 25 feet) from wetlands and other sensitive areas to prevent harmful effects.
7. Runoff draining to the drywell must not be contaminated with pollutants other than sediment. Runoff exposed to other pollutants such as oils, fuels, detergents, industrial or agricultural chemicals, etc. may not drain to a drywell.
8. Bottom of drywell shall be at least 3 feet above the seasonally high groundwater as measured by a geotechnical investigation.

6.0 Design

The following design guidelines are typical standards required for drywell design. Special site conditions may lead to additional requirements as determined by the Town Engineer. Each drywell design shall be designed and stamped by a Colorado Licensed Professional Engineer. Drywells serving multiple single family homes are not exempt from the requirements.

7.0 Infiltration Test

Testing shall be conducted by a geotechnical engineer on the site to determine infiltration rates and soil types at the location and depth of the proposed drywells. Infiltration tests shall be conducted at a minimum of every 75 feet for infiltration trenches. The lowest infiltration rate shall be used for design. Drywells for single family home sites may be exempt from an infiltration test; however, soils shall be analyzed from soils reports and other sources to evaluate their suitability to infiltrate runoff. Single family homes may be exempted from the infiltration test requirement if the drywell only receives water from roof drainage and foundation drains.

8.0 Pretreatment

Drywells cannot receive stormwater that has not been pretreated, unless the only source of the stormwater is roof runoff and/or foundation drainage. Pretreatment is required to allow coarse sediment and trash to settle out and prevent premature clogging and failure of drywell. Examples of pretreatment include forebays, concrete manholes with BMP snout and bioskirt, sediment basins, and vegetated buffer strips. Single family home sites are exempt from pretreatment. Single family homes are exempted from the pretreatment requirement if the drywell only receives water from roof drainage and foundation drains.

9.0 Depth and Location

Drywells shall be located at least 10 feet from building foundations and 100 feet from water wells. The bottom of each drywell shall be at least 9 feet below the surface or extend to clean cobble rock without fines (minimum rock size greater than 2 inches in diameter) to prevent freezing during winter.

10.0 Design Details

Drywells designs vary widely and include concrete manholes without a bottom and drain holes in the walls, excavated pits backfilled with clean rock, linear trenches backfilled with clean rock, and underground perforated pipes surrounded by a clean aggregate layer. An engineered drywell detail shall be designed and submitted for all installations, including single family homes. Below is a list of design considerations for various drywells:

1. Drywells in areas receiving vehicular traffic shall be HS-20 rated.
2. Drywell manholes shall have 24-inch inlet grates. If grates are located near a roadway or pedestrian area, the grate shall meet AASHTO bicycle and ADA guidelines.
3. Drywell manholes shall be backfilled outside the structure with 1.5-inch to 3-inch crushed and washed stone with a minimum of 40% porosity for a minimum distance of 18 inches.
4. Drywell manholes shall contain perforations with a 1-inch minimum diameter and shall not have a bottom.
5. Trenches shall be backfilled with 1.5-inch to 3-inch crushed and washed stone with a minimum of 40% porosity.
6. Trenches may have filter fabric installed 12 inches below surface to assist with maintenance.
7. Filter fabric shall not be installed at the bottom of drywells.
8. A 6-inch to 12-inch sand layer shall be installed under the bottom of drywells if infiltration rates exceed 4 inches per hour or if the drywell is installed near a sensitive area, such as wetlands, the Blue River, perennial streams, or Cucumber Gulch PMA.
9. Overflow outlets are required to convey flows that exceed the capacity of the drywell. Overflow outlets shall convey runoff to a swale or storm sewer and shall be designed to prevent erosion and damage to neighboring properties.

11.0 Volume

The appropriate WQCV or detention volume shall be calculated using the guidance in Chapter 6. A factory of safety of 1.5 shall be applied to the calculated volume to account for clogging and reductions in the infiltration rate. Drywells shall be designed to infiltrate the entire design volume within 72 hours.

12.0 Maintenance

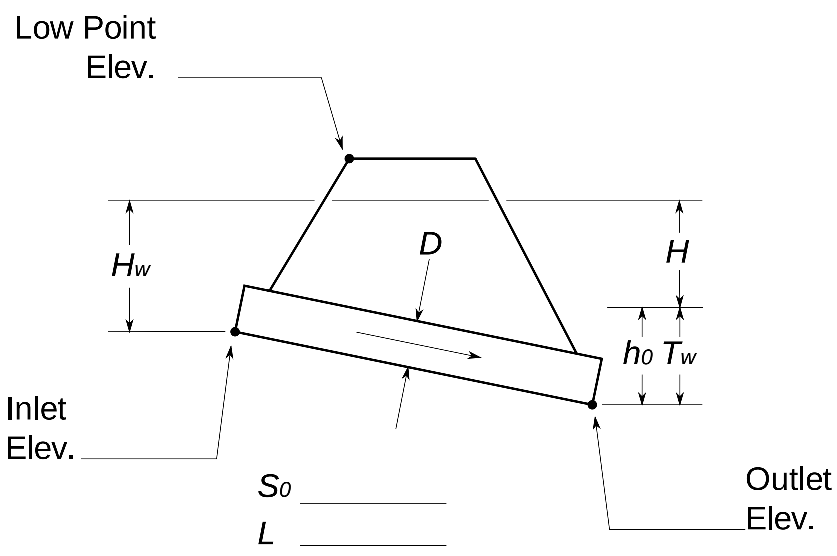
An Operations and Maintenance Plan (O&M Plan) shall be submitted that meets the requirements of Chapter 6. Minimum requirements include:

- Drywells shall not be placed in service until construction is complete and revegetation of the site is established.
- Drywells shall be inspected and maintained annually for sediment and debris.
- Drywells shall be inspected after storms exceeding 1 inch to ensure it is functioning properly and that no water is ponding above the drywell.
- Pretreatment facilities shall be inspected twice annually and sediment and debris shall be removed.
- If a drywell clogs or fails, complete rehabilitation is required to restore storage capacity and infiltration rates.

TOWN OF BRECKENRIDGE

CULVERT DESIGN FORM

Project:	Consultant:	Date:
Street/Route/Highway:	Engineer:	
Mile Marker:	Other:	



Culvert Data

Size:	n:
Material:	Q_{Full}:
Inlet Style:	V_{Full}:
k_e:	

Outlet Control Equations

(1) $H_w = H + h_0 - LS_0$

(2) For $T_w < D, h_0 = \frac{d_c+D}{2}$ or T_w (whichever is greater)
$T_w > D, h_0 = T_w$

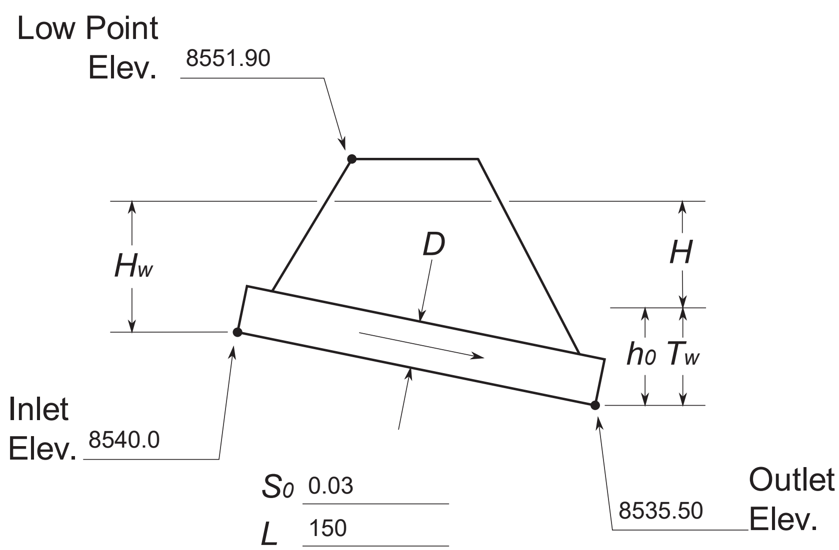
(3) For Box Culvert: $d_c = 0.315\left(\frac{Q}{B}\right)^{2/3}$ (B = width of the box culvert)

Q	Inlet Control		Outlet Control						Design Curve		
					$T_w < D$		$T_w > D$				
	$\frac{H_w}{D}$	H_w	H	T_w	d_c	$h_0 = \frac{d_c + D}{2}$	h_0	H_w	H_w	Control Method	WSEL
Col 1	2	3	4	5	6	7	8	9	10	11	12

TOWN OF BRECKENRIDGE

CULVERT DESIGN FORM EXAMPLE

Project: Example	Consultant: Civil Engineering, Inc.	Date: 6/1/2020
Street/Route/Highway: Main Street	Engineer: Jane Doe, PE	
Mile Marker or Location: 200' south of 1st Avenue	Other: Existing culvert analysis	



Culvert Data

Size: 48" A=12.56 sf	n: 0.015
Material: RCP	Q_{Full}: 135 cfs
Inlet Style: FES	V_{Full}: 10.75 fps
k_e: 0.5	

Outlet Control Equations

(1) $H_w = H + h_0 - LS_0$

(2) For $T_w < D, h_0 = \frac{d_c+D}{2}$ or T_w (whichever is greater)
$T_w > D, h_0 = T_w$

(3) For Box Culvert: $d_c = 0.315\left(\frac{Q}{B}\right)^{2/3}$ (B = width of the box culvert)

Q	Inlet Control		Outlet Control						Design Curve		
					$T_w < D$		$T_w > D$				
	$\frac{H_w}{D}$	H_w	H	T_w	d_c	$h_0 = \frac{d_c + D}{2}$	h_0	H_w	H_w	Control Method	WSEL
Col 1	2	3	4	5	6	7	8	9	10	11	12
100	1.2	4.8	2.1	1.9	3.03	3.52		1.12	4.8	Inlet Control	8544.8
139	1.5	6.0	4.0	2.6	3.51	3.76		3.26	6.0	Inlet Control	8546.0
160	1.7	6.8	5.4	3.0	3.66	3.83		4.73	6.8	Inlet Control	8546.8
186	2.0	8.0	7.5	3.5	3.80	3.90		6.90	8.0	Inlet Control	8548.0
220	2.5	10.0	10.2	4.4			4.4	10.1	10.1	Outlet Control	8550.1

TOWN OF BRECKENRIDGE

TREATMENT TRAIN EXAMPLE CALCULATION

A series of treatment facilities is planned to provide permanent stormwater treatment to a low-density residential development. The development drains to a small parking lot that drains over a level spreader and across a grass buffer 10 ft wide and 20 ft long. The grass buffer transitions to a full grassed swale section with a width of 5 ft and length of 250 ft. The swale discharges into a bioretention facility 20 ft wide and 50 ft long. The bioretention discharges directly to a storm sewer. The design water quality flow rate is the 2-year peak flow rate and was calculated based on the procedures in Section 6.3 and 6.4 and determined to be 7 cfs. Evaluate the treatment train to determine the percent of TSS removed by the treatment train to ensure it is at least 80%. Use the procedures in Chapter 4 of *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality* (EPA,1986).

Step 1: Determine the starting TSS concentration for the development by land use. Some jurisdictions require a static maximum effluent concentration, such as 30 mg/L, while the Town requires only a percent removal. If a static concentration is required, a starting concentration is also required. Since the Town requires a percent reduction, **the starting concentration may be set to 100 mg/L as a proxy for percent concentration**. Once the "concentration" reaches 20 mg/L, it can be assumed that 80% has been removed.

Step 2: Calculate the settling velocity for the minimum particle size of interest. A spherical particle with a diameter of 60 microns may be assumed. The settling velocity occurs when the net force acting on the particle becomes zero and the weight of the object is balanced by the drag and buoyancy forces, yielding the equation:

$$W = F_b + D \qquad \text{or} \qquad \frac{\pi}{6}d^3\rho_s g = \frac{\pi}{6}d^3\rho g + \frac{1}{2}C_d\rho {V_s}^2 A$$

W = Weight of the particle

F_b = Buoyancy force

D = Drag force

d = diameter of the particle (mm)

ρ_S = density of the particle

ρ = density of the fluid

g = acceleration due to gravity = 32.2 ft/s^2

Cd = drag coefficient

V_S = settling velocity of the particle (ft/s)

A = projected area of the sphere = ¼ πd^2

Substituting in the projected area of the sphere and solving for the settling velocity yields the following equation

$$V_s = \sqrt{\frac{4gd}{3C_d}\left(\frac{\rho_S-\rho}{\rho}\right)}$$

Additionally, substituting in the projected area of the sphere and the expression for the coefficient of drag, $C_d = \frac{24}{Re} = \frac{24}{\nu}\rho dV$, the expression becomes

$$V_s = \frac{1}{18}\frac{gd^2}{\nu}(\rho_s - \rho)$$

v = Viscosity of water = 1.664x10⁵ ft²/s @40 degrees F

Density can be expressed in terms of specific gravity. Because the specific gravity of water is close to 1 g/cm³, the final expression for settling velocity becomes

$$V_s = \frac{1}{18}\frac{gd^2}{v}(SG_s - 1)$$

SG_S = Specific gravity of the particle = 2.65

Finally, the settling velocity can be calculated. A water temperature of 40 degrees Fahrenheit is assumed, having a viscosity of $1.664\text{x}10^5$ ft^2/s. The specific gravity of the particle is assumed to be 2.65. The settling velocity of a 60-micron particle is 0.0059 fps.

$$V_s = \frac{1}{18}\frac{32.2\frac{ft}{s^2}*(0.06mm)^2}{1.664*10^5\frac{ft^2}{s}}(2.65 - 1) = 0.0059fps$$

Step 3: Calculate the surface area for the first facility. The surface area of the grass buffer swale is calculated with a simple area equation $l * w = 20ft * 10ft = 200sf$. The area of the grass buffer is 200 sf.

Step 4: Determine the turbulence factor. The turbulence factor accounts for decreased performance from turbulence and short circuiting. For this example, a conservative turbulence factor of n=1 is assumed for the grass buffer and grass swale as flow will move continuously through these facilities and not pond as it will in the bioretention facility. A value of n=3 is assumed for the bioretention facility as flow is captured, detained, and released slowly, decreasing the likelihood of turbulence or short circuiting in that system.

Step 5: Calculate the fraction of removal due to sedimentation for the grass buffer and determine the effluent concentration.

The fraction of removal due to sedimentation is calculated using equation 2

$$R = 1 - \left[1 + \frac{1}{n} * \frac{V_s}{Q/_A}\right]^{-n} = 1 - \left[1 + \frac{1}{1} * \frac{(0.0059\,fps)}{7\,cfs/_{200\,sf}}\right]^{-1} = 14.5\%$$

R = fraction of solids removed

n = Turbulence factor

Q/A = rate of applied flow divided by surface area of the treatment facility

The effluent concentration out of the grass buffer is calculated as

$$100\frac{mg}{L} - \left(100\frac{mg}{L} * 14.5\%\right) = 85.5\frac{mg}{L}$$

The percent removed has not reached 80%, therefore more treatment is required. Steps 3 through 5 are repeated to determine the final effluent concentration downstream of the treatment train. The next facility in the treatment train is the grass swale.

Grass Swale:

$\text{A} = 250ft * 5ft = 1250sf$

$$R = 1 - \left[1 + \frac{1}{1} * \frac{(0.0059\,fps)}{7\,cfs/_{1250\,sf)}}\right]^{-1} = 51.4\%$$

The starting concentration for each treatment facility in the treatment train is the effluent concentration of the previous upstream treatment. In this case, it is the effluent concentration of the grass swale, 85.5 mg/L.

$$85.5\frac{mg}{L} - \left(85.5\frac{mg}{L} * 51.4\%\right) = 41.5\frac{mg}{L}$$

The effluent concentration out of the grass swale is 41.5 mg/L. The final treatment facility is bioretention and the influent concentration into the bioretention facility is 41.5 mg/L.

Bioretention Facility:

$$\mathrm{A} = 50ft * 20ft = 1000sf$$

$$R = 1 - \left[1 + \frac{1}{3} * \frac{(0.0059\,fps)}{7\,cfs/_{1000\,sf)}}\right]^{-3} = 52.6\%$$

$$41.5\frac{mg}{L} - \left(41.5\frac{mg}{L} * 52.6\%\right) = 19.7\frac{mg}{L}$$

The final effluent concentration out of the treatment train is 19.7 mg/L, which in our example corresponds to 80.3% removal, which is greater than the Town's criteria of 80% removal of the 60 micron particle from the peak runoff rate from the 2-year return period storm over the area being treated.

A spreadsheet is a very helpful tool in evaluating a treatment train. However, as the settling velocity equation is rather complex, it is recommended that the spreadsheet results for this equation be tested with calculations completed on a calculator before the entire spreadsheet is developed and relied upon for accurate results. The spreadsheet below is for this example.

Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality (EPA440/5-87-001, Sept, 1986)

What is Removal Efficiency of a Treatment Train?

What is desired removal rate? **80% of 60 μm (0.06 mm) per criteria**

Submerged Weight - Drag = Settling Velocity

Equilibrium Equation: $C_d[\pi d^3/4][\rho V_s^2/2]=(\pi d^3/6)(\rho_s-\rho)g$

This assumes a Reynold's number < 0.5

Settling Velocity, $V_s = 1/18[(d^2g/\nu)(SG-1)]$

Assume SG=2.65

Viscosity of water, ν is 1.664×10^5 ft^2/s @ **40°**

Settling Velocity, $V_s = 1.774 \times 10^{-5} d^2$ for **40°** where d is in feet and V_s is in fps.

Settling Velocity, $V_s = 1.648 d^2$ for **40°** where d is in mm and V_s is in fps.

Fraction of particles removed, $R = 1 - [1 + (1/n)(V_s/Q/A)]^{-n}$ where V_s is settling velocity and n indicates turbulence

Example System										
Location	Inflow (cfs)	Area (sf)	Q/A	n	d (mm)	V_s (fps)	Initial Load (%)	Removal Rate	Final Load (%)	Total Removed
Buffer Swale	7.0	200	0.035	1	0.060	0.0059	100	14.5%	85.5	
Grass Swale	7.0	1250	0.006	1	0.060	0.0059	85.5	51.4%	41.5	
Bioretention	7.0	1000	0.007	3	0.060	0.0059	41.5	52.6%	19.7	**80.3%**