

**FINAL DRAINAGE REPORT
FOR
VOLLMER SUBSTATION
EL PASO COUNTY, COLORADO**

JUNE 2019

Prepared For:

MOUNTAIN VIEW ELECTRIC ASSOCIATION

David Waldner
11140 E Woodmen Rd, Peyton, CO 80831
(719) 495-2283

Prepared By:

TERRA NOVA ENGINEERING, INC.

721 S. 23RD STREET
Colorado Springs, CO 80904
(719) 635-6422

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County Job No. #####

**FINAL DRAINAGE REPORT
FOR
VOLLMER SUBSTATION
EL PASO COUNTY, COLORADO**

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CERTIFICATION STATEMENT:

Engineers Statement

This attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the County for drainage reports and said report is in conformity with the master plan of the drainage basin. I accept responsibility for any liability caused by any negligent acts, errors or omissions on my part in preparing this report.

L DUCETT, P.E. 32339

Seal

Developers Statements

I, Mountain View Electric Association, the developer have read and will comply with all of the requirements specified in this drainage report and plan.

Mountain View Electric Association

Business Name

By: _____
Title: _____
Address: _____

El Paso County Approval:

Filed in accordance with the requirements of the Drainage Criteria Manual, Volumes 1 & 2, El Paso County Engineering Criteria Manual and Land Development Code as amended.

Jennifer Irvine,
County Engineer / ECM Administrator

Date

Conditions:

FINAL DRAINAGE REPORT FOR VOLLMER SUBSTATION EL PASO COUNTY, COLORADO

PURPOSE

The purpose of this Final Drainage Report is to identify and analyze the proposed drainage patterns, determine proposed runoff quantities, size drainage structures for conveyance of developed runoff, and present solutions to drainage impacts on-site and off-site resulting from this development. In an effort to protect receiving water and as part of the “four step process to minimize adverse impacts of urbanization” this site was analyzed in the following manner:

1. Reduce Runoff- The new improvements to the site, which consist of adding a gravel yard and access road will be routed to a proposed private sand filter. By capturing these flows in the sand filter the developed runoff will be detained and reduce the quantity of downstream runoff. Additionally, existing native grass areas are being retained that will act as natural grass buffers.
2. Stabilize Drainageways - By reducing the rate of runoff the site is helping to stabilize the downstream waterways. All of the drainageways proposed onsite are grass swales.
3. Provide Water Quality Capture Volume (WQCV)- The sand filter will detain the developed flows, allow a portion to infiltrate, and slowly release the remaining volume, thereby allowing solids and contaminants to settle out and stopping downstream transport.
4. Consider Need for Industrial and Commercial BMPs- As this development will not include outdoor storage or the potential for the introduction of contaminants to the County’s MS4, since it is not an industrial or commercial site, no source controls are proposed or necessary.

GENERAL DESCRIPTION

This Final Drainage Report is an analysis of approximately 4.96 acres of undeveloped land located in the northwest part of El Paso County, approximately 3,600 feet east of the north end of Mohawk Road. This site is being developed by our client as an electrical substation. The development will also include constructing a gravel access road. The site is located in the southeast quarter of Section 34, Township 12 South, Range 65 West of the 6th Principal Meridian currently within El Paso County, Colorado. The site is bounded on all sides by undeveloped open space (rural residential). The site is contained within the Sand Creek Basin.

Soils for this project are delineated by the map in the appendix as Columbine gravelly sandy loam (19), 0 to 3 percent slopes. Soils in the study area are shown as mapped by S.C.S. in the “Soils Survey of El Paso County Area” and contains soils of Hydrologic Group A.

FLOODPLAIN STATEMENT

No portion of this site is within a designated F.E.M.A. floodplain, as determined by Flood Insurance Rate Map No. 08041C0535 G, dated December 7, 2018 (see appendix).

EXISTING DRAINAGE CONDITIONS

The site is currently undeveloped and is open space. The site consists mostly of natural vegetative grass and weeds, with some small areas of bare earth. The site has been broken down into two existing basins, one on the northwest half of the site and the other on the southeast half of the site. An upgradient offsite basin consists of gently sloping plains appears to extend over one mile upgradient of the site. Another offsite basin partially drains into an existing swale that flows onto the site from the east.

Offsite basin OS-1's 138 acres consists primarily of undeveloped open space, with a small number of rural residences. Based on the USGS topo map, runoff sheet flows into several channels and flows south onto the site; however, the detailed topographic survey of the site does not show any channels entering the site on the north side. Based on the survey, runoff ($Q_{10}=20$ cfs) sheet flows onto the site from the north, at Design Point Z. Runoff calculations for this basin were performed using the Soil Conservation Service Hydrograph Method due to the size of the basin.

Offsite basin OS-2's 79 acres consists primarily of undeveloped open space, with a small number of rural residences. Runoff ($Q_5=7.1$ cfs and $Q_{100}=43.7$ cfs) sheet and channel flows to the south and along the east side of the site. A small existing swale will direct some runoff from this basin onto the southeast corner of the site as Design Point Y. The maximum capacity of this existing swale is 36.6 cfs.

Basin EX-A's 2.77 acres consists of undeveloped open space. Runoff ($Q_5=0.9$ cfs and $Q_{100}=6.4$ cfs) sheet flows to the southwest corner of the site, and may channelize during heavier storm events, to Design Point A.

Basin EX-B's 2.16 acres consists of undeveloped open space. Runoff ($Q_5=0.7$ cfs and $Q_{100}=5.0$ cfs) sheet flows to the south edge of the site, before entering an existing shallow onsite swale and flowing a short distance west to Design Point B.

PROPOSED DRAINAGE CONDITIONS

Runoff in the developed conditions will largely follow the historic drainage patterns with the exceptions of diverting upgradient runoff around the proposed yard and adding a sand filter to detain and treat the runoff from the proposed substation yard. For analysis the site has been broken down into six onsite basins (PR-1, PR-2, PR-3, PR-4, PR-5, PR-6) and three offsite basins (PR-7, PR-8, PR-9) for the proposed access road. Additionally, there are two offsite upgradient basins (OS-1 and OS-2). A small berm has been proposed along the north side of the site to prevent upgradient surface runoff from flowing onto the site and the substation yard. Below is a description of the runoff in the developed conditions and how it will be safely routed and treated. See appendix for calculations.

Offsite basin OS-1's 138 acres consists primarily of undeveloped open space, with a small number of rural residences. Based on the USGS topo map, runoff sheet flows into several channels and flows south onto the site; however, the detailed topographic survey of the site does not show any channels entering the site on the north side. Based on the survey, runoff ($Q_{10}=20$ cfs) will sheet flow to the north edge of the site where a proposed berm will stop southerly flow until the runoff reaches the west side of the site and resumes its southerly path, at Design Point Z. Runoff calculations for this basin were performed using the Soil Conservation Service Hydrograph Method due to the size of the basin.

Provide swale/channel.

Offsite basin OS-2's 79 acres consists primarily of undeveloped open space, with a small number of rural residences. Runoff ($Q_5=7.1$ cfs and $Q_{100}=43.7$ cfs) sheet and channel flows to the south and along the east side of the site. A small existing swale will direct some runoff from this basin

onto the southeast corner of the site as Design Point Y. The maximum capacity of this existing swale is 36.6 cfs. No modifications to the runoff patterns of this basin have been proposed.

Basin PR-1 (0.42 acres; $Q_5=0.1$ cfs and $Q_{100}=0.7$ cfs) includes the portion of the site north of the proposed substation yard and a section of swale channels runoff around the west side of the substation yard. Drainage in this basin sheet flows into a proposed grass swale before being discharged into Basin PR-5 at Design Point 1.

Basin PR-2 (1.70 acres; $Q_5=1.6$ cfs and $Q_{100}=4.4$ cfs) includes the proposed substation yard and the pond / sand filter area to the south of the yard. The yard and access road will be surfaced with gravel and the pond area will be surfaced with native grasses. Drainage in this basin sheet flows to the south center of the yard and into the pond area and from the access road into the pond area. Once in the pond area, runoff will flow west to the sand filter, and eventually discharge through a culvert at Design Point 3. The sand filter has been sized for water quality control volume only; however, the pond area has been graded to allow for some additional water storage in case of flood conditions.

Basin PR-3 (0.15 acres; $Q_5=0.1$ cfs and $Q_{100}=0.4$ cfs) includes a strip on the east side of the site adjacent to the substation yard. Drainage in this basin sheet flows into a proposed grass swale before being discharged into Basin PR-4 at Design Point 3.

Basin PR-4 (1.43 acres; $Q_5=0.4$ cfs and $Q_{100}=2.4$ cfs) includes the east edge of the site and a large area on the south half of the site. Drainage in this basin sheet flows into an existing natural grass swale (EXS1) before flowing west a short distance and being discharged through a culvert into Basin PR-5 at Design Point 4. The combined flows at Design Point 4 are $Q_5=8.6$ cfs and $Q_{100}=36.6$ cfs. Note: The maximum capacity of this existing swale is 36.6 cfs, which limits the flow at Design Point 4. Any runoff beyond the channel capacity will continue flowing to the south out of the basin. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The majority of this basin has no proposed modifications from the existing conditions.

Basin PR-5 (1.07 acres; $Q_5=0.4$ cfs and $Q_{100}=3.0$ cfs) includes the west side of the site and most of the area to the west of the substation yard. Drainage in this basin sheet flows mostly south before collecting in a natural wide channel at Design Point 5. There is also a small existing swale (EXS1) that enters the south end of basin PR-5 from the east. Note: The maximum capacity of this existing swale EXS1 is 36.6 cfs, which limits the flow entering the basin at Design Point 4. The combined flows at Design Point 5 (from basins OS-2, PR-1, PR-2, PR-3, PR-4, and PR-5) are $Q_5=9.7$ cfs and $Q_{100}=47.5$ cfs. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The majority of this basin has no proposed modifications from the existing conditions.

Basin PR-6 (0.06 acres; $Q_5=0.03$ cfs and $Q_{100}=0.2$ cfs) includes a strip along the southern edge of the site. Drainage in this basin sheet flows south off the site at Design Point 6. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The entirety of this basin has no proposed modifications from the existing conditions.

Basin PR-7 (0.26 acres; $Q_5=0.3$ cfs and $Q_{100}=1.1$ cfs) includes a section of the proposed access road near the south west corner of the site that drains to the north. Drainage in this basin sheet flows to the north at Design Point 7, then collects at a point near the center of the basin, before flowing south under the access road through a culvert.

Basin PR-8 (0.58 acres; $Q_5=0.4$ cfs and $Q_{100}=2.1$ cfs) includes a section of the proposed access road near the south west corner of the site that drains to the south. Drainage in this basin sheet flows to the south at Design Point 8 onto undeveloped land.

Basin PR-9 (3.09 acres; $Q_5=4.1$ cfs and $Q_{100}=13.6$ cfs) includes a section of the proposed access road as it travels away from the site that drains to the south. Drainage in this basin sheet flows to the south at Design Point 9 onto undeveloped land.

Two new grass swales are proposed, both of which are along the edges of the proposed substation yard. The purpose of these swales is to direct runoff away from the proposed substation yard with the proposed flows for both swales being quite low (PRS1 $Q_{100}=0.7$ cfs and PRS2 $Q_{100}=0.4$ cfs).

Details and specs for these proposed swales are included on the Proposed Drainage Map and calculations in the appendix.

Three new culverts are proposed, one as a discharge for the sand filter and pond area, and two for transporting runoff under the proposed access road. Proposed culvert PRC1 discharges the sand filter into basin PR-2. PRC1 is a 18" diameter RCP culvert with a capacity of 14.9 cfs (Design Point 3 $Q_{100}=3.9$ cfs). Typically, this culvert will only be discharging the very low flow rate from the sand filter, but it can also accommodate flows exceeding the 100 year event. The PRC1 design includes outlet protection of 3'x5' type VL 6" riprap.

Proposed culvert PRC2 allows runoff in the existing swale (EXS1) on the south edge of the site to flow beneath the proposed access road and discharges basin PR-4 into basin PR-5. This culvert will also allow flow in EXS1 from the offsite basin OS-2 to cross the site. PRC2 is a 30" diameter RCP culvert with a capacity of 36.8 cfs (Design Point 4 $Q_{100}= 36.6$ cfs). PRC2 was sized to exceed the maximum capacity of the existing swale EXS1 so that any future flow increases into this existing swale would not require an upsizing of this culvert. The PRC2 design includes outlet protection of 8'x22' type VL 9" riprap.

Proposed culvert PRC3 allows runoff to cross the proposed access road and flow to the south. PRC3 consists of 3-1.5'x2.0' reinforced concrete box culverts with a combined capacity of 58.6 cfs ($Q_{100}= 48.6$ cfs). PRC3 was sized to accommodate both the 100 year flows from the site and access road, and the maximum capacity of the existing swale EXS1. The PRC3 design includes outlet protection of 3'x6' type VL 6" riprap.

At Design Point 2 the flow ($Q_5=1.6$ cfs and $Q_{100}=4.4$ cfs) from the proposed substation yard (basin PR-3) is collected in a pond area and treated with a water quality sand filter. The area tributary to the sand filter is 1.70 acres, which is 63% of the 2.7 acres of the site that is being developed. Runoff in the substation yard will sheet flow south to the pond area. Portions of the surrounding access road also sheet flow into the pond area. In the pond area, runoff sheet flows to the west into the sand filter. The sand filter has a water quality storage volume of 0.06 acre-feet (required volume is 0.02 acre-feet) and the pond area has additional storage capacity for flood waters. The

pond area will be surfaced with native grasses, while the sand filter will be surface with filter sand. This sand filter was designed to be partially infiltrating. The sand filter sand surface area is 1,092 square feet and there is a 4-inch diameter underdrain running along the bottom of the sand filter that discharges into an outlet structure. The underdrain pipe will have a cap with a 0.39 inch diameter orifice in the outlet structure to provide the 40-hour water quality drain time. The 2'x2' reinforced outlet structure provides the overflow weir for the sand filter and connects to a 18" diameter RCP culvert that crosses the access road and discharges the runoff into basin PR-2. The outlet structure and culvert have been sized to accommodate 100-year events. If flood waters exceed the discharge capacity and fill the pond area volume, the pond area will overflow on the south and west sides and flow across the access road into basins PR-2 and PR-5. Due to being surrounded by access road, no formal riprap spillway is proposed. The sand filter consists of a 9-inch layer of bedding gravel (and the underdrain) on the bottom, then a 18-inch layer of filter sand, one foot of water quality volume, and one foot of freeboard.

HYDROLOGIC CALCULATIONS

Hydrologic calculations were performed using the El Paso County Storm Drainage Design Criteria Manual - Volumes 1 & 2, latest editions. The Rational Method was used to estimate storm water runoff anticipated from design storms with 5-year and 100-year recurrence intervals. The Urban Drainage Criteria Manual was used to calculate the water quality volume.

HYDRAULIC CALCULATIONS

Hydraulic calculations were estimated using the Manning's Formula and the methods described in the El Paso County Storm Drainage Design Criteria Manual – Volumes 1 & 2, latest editions. The pertinent data sheets are included in the appendix of this report.

One existing drainage channel is located onsite, and two proposed drainage channels have been added around the substation yard. Channel flow calculations have been included for both the existing and proposed drainage channels.

Culverts are proposed for the sand filter outfall and at two crossings of the proposed access road. Culvert design calculations have been included in the appendix.

MAINTENANCE

The sand filter is private and therefore must be maintained by the owner (Mountain View Electric Association). The sand filter should be inspected at least twice per year and debris removed as necessary. Once per year, or as necessary to promote drainage, the filter surface should be scarified down to three to five inches. Remove the top three to five inches of filter sand as necessary to allow property drain times (typically every two to five years). After nine inches of filter sand have been removed, replace with nine inches of new filter sand (minimum sand depth is 12 inches).

The sand filters should be cleaned and checked after any significant precipitation event and at least once every three months. The proposed erosion control measures will be repaired and maintained by the property owner or owner's representative as required. Additional information on sand filter maintenance can be found in the El Paso County Drainage Manual – Volume 2.

Access to the sand filter is from the access road on three sides of the sand filter/pond area.

CONSTRUCTION COST OPINION

Public Reimbursable / Non-Reimbursable

Not applicable.

Private Non Reimbursable

1. 18" RCP Culvert	70 LF	\$ 70	\$ 4,900
2. 30" RCP Culvert	55 LF	\$ 105	\$ 5,775
3. 1.5'x2.0' RC Box Culvert	150 LF	\$ 100	\$ 15,000
2. Sand Filter	1 LS	\$ 15,000	<u>\$ 15,000</u>
			Total \$ 40,675

DRAINAGE FEES

The existing site is in the Sand Creek Basin. 2018 Drainage fees due prior to final plat recordation are as follows:

FEE TYPE	% IMP.	PARCEL AREA	MOD.	FEE PER IMP. AC.	SUBTOTAL
DRAINAGE FEES:	17% x	4.96 acres x	75% x	\$18,940 =	<u>\$11,978</u>
TOTAL \$11,978					

SUMMARY

Development of this site will not adversely affect the surrounding developments. Proposed flows, as detailed in this report, will follow the drainage patterns outlined in this report showing how runoff will be safely routed downstream. The sand filter will provide water quality for this site. These water features will need to be periodically maintained by the owner in order to maintain their effectiveness in cleaning the discharge from the site.

PREPARED BY:
TERRA NOVA ENGINEERING, INC.

L Ducett, P.E.
 President
 Jobs/1845.00/drainage/184500 FDR.doc

REFERENCE

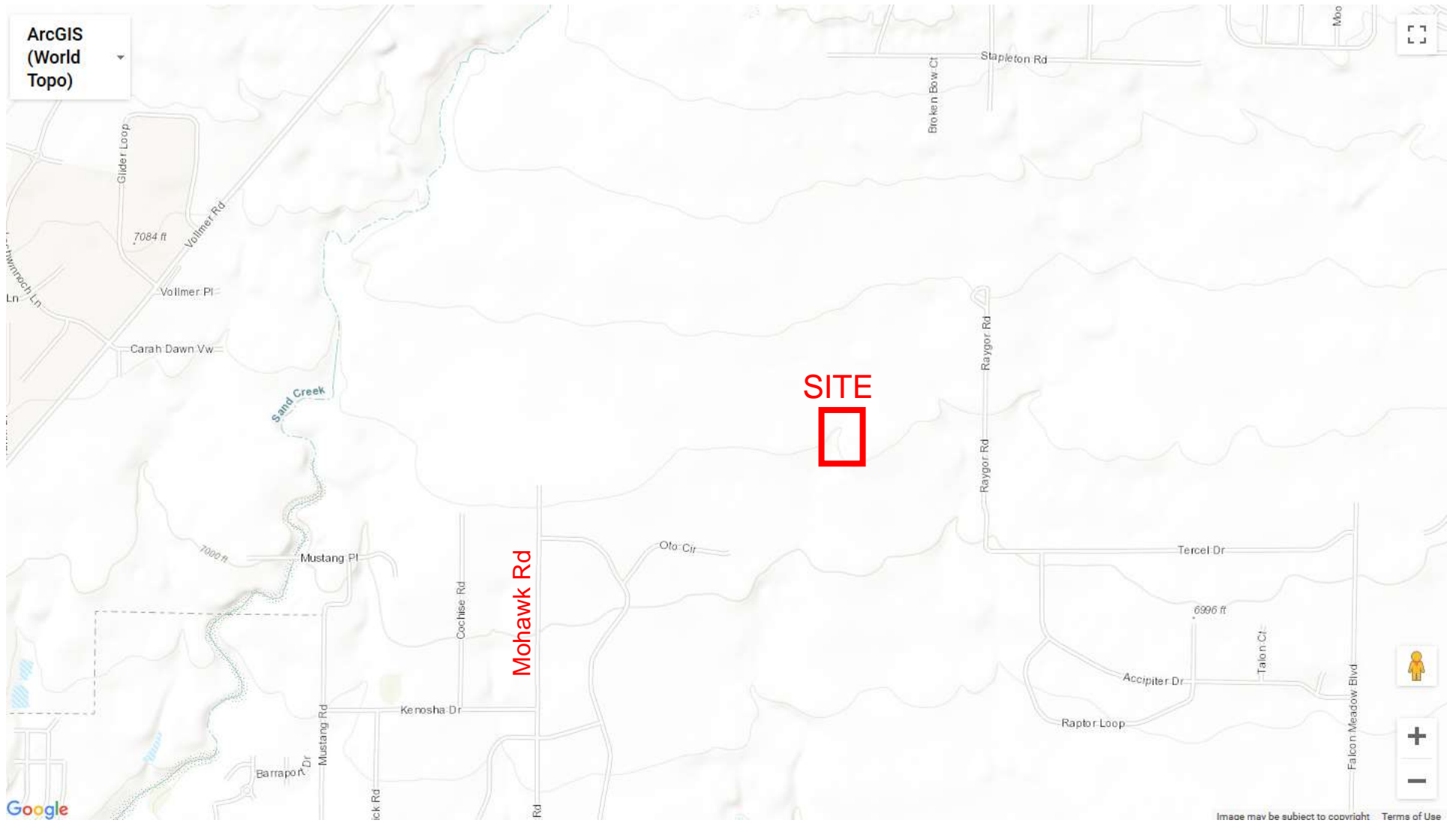
El Paso County Drainage Criteria Manual-Volumes 1 & 2, latest edition

El Paso County Board Resolution No 15-042 (Adoption of Chapter 6 and Section 3.2.1 Chapter 13 of the City of Colorado Springs Drainage Criteria Manual dated May 2014, Hydrology and Full Spectrum Detention)

SCS Soils Map for El Paso County

Federal Emergency Management Agency (FEMA) flood maps

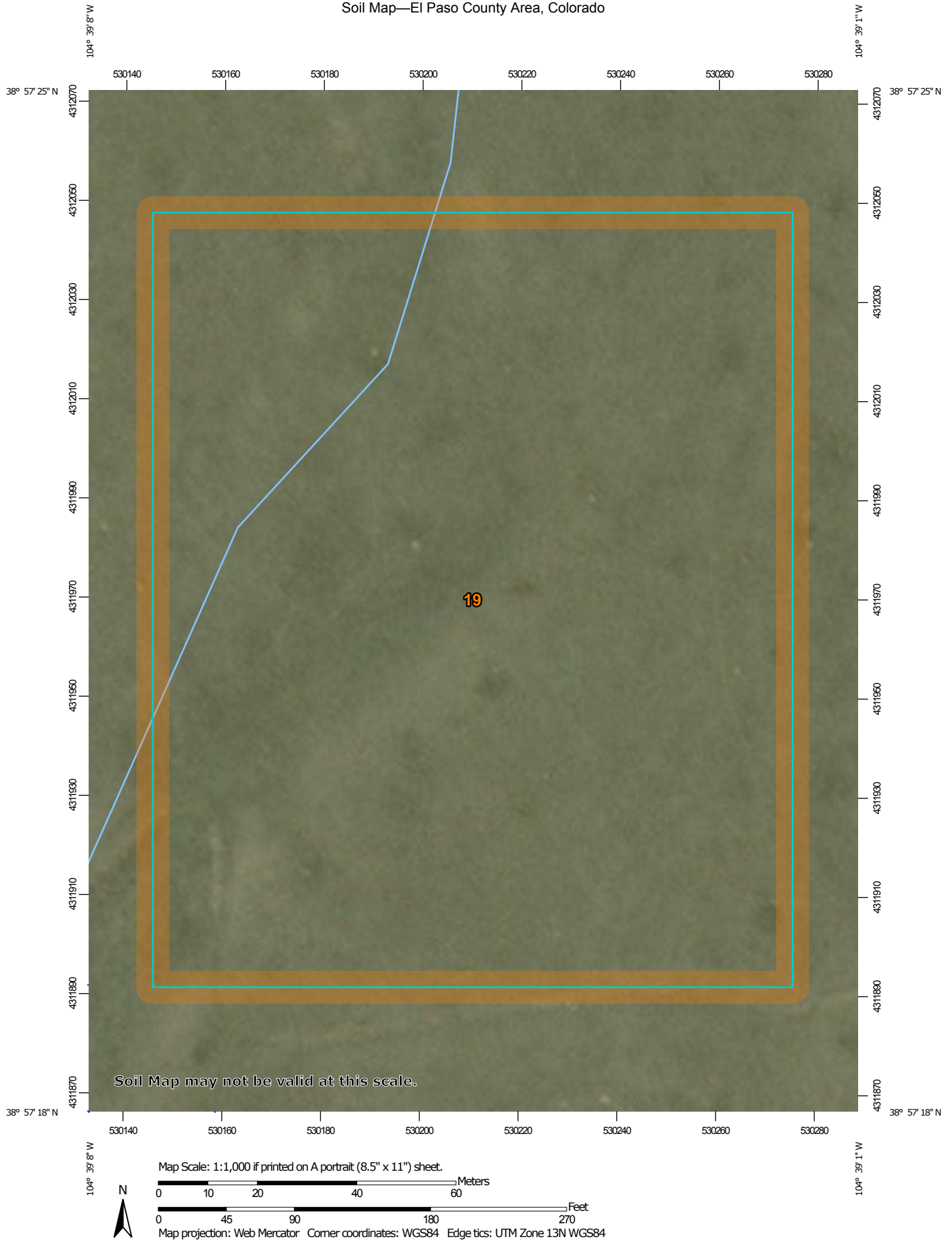
VICINITY MAP



Vollmer Substation Vicinity Map


S.C.S. SOILS MAP

Soil Map—El Paso County Area, Colorado




MAP LEGEND




















Area of Interest (AOI)







-  Area of Interest (AOI)

Soils


-  Soil Map Unit Polygons
-  Soil Map Unit Lines
-  Soil Map Unit Points

Special Point Features






-  Blowout
-  Borrow Pit
-  Clay Spot
-  Closed Depression
-  Gravel Pit
-  Gravelly Spot
-  Landfill
-  Lava Flow
-  Marsh or swamp
-  Mine or Quarry
-  Miscellaneous Water
-  Perennial Water
-  Rock Outcrop
-  Saline Spot
-  Sandy Spot
-  Severely Eroded Spot
-  Sinkhole
-  Slide or Slip
-  Sodic Spot

-  Spoil Area
-  Stony Spot
-  Very Stony Spot
-  Wet Spot
-  Other
-  Special Line Features


Water Features

-  Streams and Canals

Transportation

-  Rails
-  Interstate Highways
-  US Routes
-  Major Roads
-  Local Roads

Background

-  Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: El Paso County Area, Colorado
Survey Area Data: Version 15, Oct 10, 2017

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 22, 2016—Mar 9, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Columbine gravelly sandy loam, 0 to 3 percent slopes	5.0	100.0%
Totals for Area of Interest		5.0	100.0%

El Paso County Area, Colorado

19—Columbine gravelly sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: 367p

Elevation: 6,500 to 7,300 feet

Mean annual precipitation: 14 to 16 inches

Mean annual air temperature: 46 to 50 degrees F

Frost-free period: 125 to 145 days

Farmland classification: Not prime farmland

Map Unit Composition

Columbine and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Columbine

Setting

Landform: Fan terraces, fans, flood plains

Down-slope shape: Linear

Across-slope shape: Linear

Parent material: Alluvium

Typical profile

A - 0 to 14 inches: gravelly sandy loam

C - 14 to 60 inches: very gravelly loamy sand

Properties and qualities

Slope: 0 to 3 percent

Depth to restrictive feature: More than 80 inches

Natural drainage class: Well drained

Runoff class: Very low

Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Available water storage in profile: Very low (about 2.5 inches)

Interpretive groups

Land capability classification (irrigated): 4e

Land capability classification (nonirrigated): 6e

Hydrologic Soil Group: A

Ecological site: Gravelly Foothill (R049BY214CO)

Hydric soil rating: No

Minor Components

Fluvaquentic haplaquolls

Percent of map unit:

Landform: Swales

Hydric soil rating: Yes

Other soils

Percent of map unit:

Hydric soil rating: No

Pleasant

Percent of map unit:

Landform: Depressions

Hydric soil rating: Yes

Data Source Information

Soil Survey Area: El Paso County Area, Colorado

Survey Area Data: Version 15, Oct 10, 2017

FEMA FIRM MAP

HYDROLOGIC CALCULATIONS

VOLLMER SUBSTATION
(Area Runoff Coefficient Summary)

EXISTING CONDITIONS

		<i>DEVELOPED</i>			<i>UNDEVELOPED</i>			<i>WEIGHTED</i>	
BASIN	TOTAL AREA	AREA	C₅	C₁₀₀	AREA	C₅	C₁₀₀	C₅	C₁₀₀
	<i>(Acres)</i>	<i>(Acres)</i>			<i>(Acres)</i>				
<i>OS-2</i>	79.00	0.00	0.30	0.50	79.00	0.09	0.36	0.09	0.36
<i>EX-A</i>	2.77	0.00	0.30	0.50	2.77	0.09	0.36	0.09	0.36
<i>EX-B</i>	2.16	0.00	0.30	0.50	2.16	0.09	0.36	0.09	0.36

Calculated by: DLF
Date: 9/17/2018
Checked by: LD

VOLLMER SUBSTATION
(Area Runoff Coefficient Summary)

DEVELOPED CONDITIONS

		<i>DEVELOPED</i>			<i>UNDEVELOPED</i>			<i>WEIGHTED</i>	
BASIN	TOTAL AREA	AREA	C ₅	C ₁₀₀	AREA	C ₅	C ₁₀₀	C ₅	C ₁₀₀
	(Acres)	(Acres)			(Acres)				
<i>OS-2</i>	79.00	0.00	0.30	0.50	79.00	0.09	0.36	0.09	0.36
<i>PR-1</i>	0.42	0.00	0.30	0.50	0.42	0.09	0.36	0.09	0.36
<i>PR-2</i>	1.70	1.70	0.30	0.50	0.00	0.09	0.36	0.30	0.50
<i>PR-3</i>	0.15	0.02	0.30	0.50	0.13	0.09	0.36	0.12	0.38
<i>PR-4</i>	1.43	0.16	0.30	0.50	1.27	0.09	0.36	0.11	0.38
<i>PR-5</i>	1.07	0.00	0.30	0.50	1.07	0.09	0.36	0.09	0.36
<i>PR-6</i>	0.06	0.00	0.30	0.50	0.06	0.09	0.36	0.09	0.36
<i>PR-7</i>	0.26	0.15	0.30	0.50	0.11	0.09	0.36	0.21	0.44
<i>PR-8</i>	0.58	0.15	0.30	0.50	0.43	0.09	0.36	0.14	0.40
<i>PR-9</i>	3.09	2.46	0.30	0.50	0.63	0.09	0.36	0.26	0.47

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

VOLLMER SUBSTATION AREA DRAINAGE SUMMARY

EXISTING CONDITIONS

		WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T _i	INTENSITY		TOTAL FLOWS	
BASIN	AREA TOTAL (Acres)	C ₅	C ₁₀₀	C ₅	Length	Height	T _C	Length	Slope	Velocity	T _t	TOTAL	I ₅	I ₁₀₀	Q ₅	Q ₁₀₀
		* For Calcs See Runoff Summary										(min)	(in/hr)	(in/hr)		
OS-2	79.00	0.09	0.36	0.09	300	9.4	21.9	5500	3.1%	0.9	104.1	126.0	1.0	1.5	7.1	43.7
EX-A	2.77	0.09	0.36	0.09	300	9.0	22.2	0	3.0%	0.9	0.0	22.2	2.9	4.8	0.7	4.8
EX-B	2.16	0.09	0.36	0.09	300	9.0	22.2	0	3.0%	0.9	0.0	22.2	2.9	4.8	0.6	3.7

DEVELOPED CONDITIONS

		WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T _i	INTENSITY		TOTAL FLOWS	
BASIN	AREA TOTAL (Acres)	C ₅	C ₁₀₀	C ₅	Length (ft)	Height (ft)	T _C (min)	Length (ft)	Slope (%)	Velocity (fps)	T _i (min)	TOTAL (min)	I ₅ (in/hr)	I ₁₀₀ (in/hr)	Q ₅ (c.f.s.)	Q ₁₀₀ (c.f.s.)
		* For Calcs See Runoff Summary														
OS-2	79.00	0.09	0.36	0.09	300	9.4	21.9	5500	3.1%	0.9	104.1	126.0	1.0	1.5	7.1	43.7
PR-1	0.42	0.09	0.36	0.09	40	5.0	5.0	425	0.5%	0.4	20.0	25.1	2.7	4.5	0.1	0.7
PR-2	1.70	0.30	0.50	0.30	180	2.0	19.0	0	0.0%	1.1	0.0	19.0	3.1	5.2	1.6	4.4
PR-3	0.15	0.12	0.38	0.12	20	4.0	3.0	250	0.8%	0.4	9.3	12.3	3.8	6.5	0.1	0.4
PR-4	1.43	0.11	0.38	0.11	180	7.0	15.4	280	0.8%	0.4	10.4	25.8	2.7	4.4	0.4	2.4
PR-5	1.07	0.09	0.36	0.09	100	14.0	7.7	0	0.0%	0.4	0.0	7.7	4.4	7.8	0.4	3.0
PR-6	0.06	0.09	0.36	0.09	30	2.0	5.4	0	0.0%	1.1	0.0	5.4	4.9	8.9	0.03	0.2
PR-7	0.26	0.21	0.44	0.21	30	2.0	4.7	0	0.0%	1.1	0.0	4.7	5.1	9.2	0.3	1.1
PR-8	0.58	0.14	0.40	0.14	30	2.0	5.1	0	0.0%	1.1	0.0	5.1	5.0	9.0	0.4	2.1
PR-9	3.09	0.26	0.47	0.26	30	2.0	4.5	0	0.0%	1.1	0.0	4.5	5.1	9.3	4.1	13.6

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

***VOLLMER SUBSTATION
AREA DRAINAGE SUMMARY***

EXISTING AND DEVELOPED CONDITIONS

Site: Vollmer Substation
Basin: OS-2
Basin Area: 138 ac or 0.216 sq mi
Method: Soil Conservation Service Hydrograph
Hydrologic Soil Group: A, good condition
CN= 39
Tc= 21.9 min
L= 13.1 min
P10-2= 2.3"
P100-2= 3.6"
S= 15.6"
Ia= 3.1"
Q10= 0.05"
Q100= 0.01"
D= 2.9 min, using D=5 min (minimum value)
Tp= 16 min or 0.26 hr
Qp10= 20 cfs
Qp100= 4.0 cfs

Calculated by: DLF
Date: 9/17/2018
Checked by: LD

VOLLMER SUBSTATION

PROPOSED SURFACE ROUTING SUMMARY

<i>Design Point(s)</i>	<i>Contributing Basins</i>	<i>Area Ac</i>	<i>Flow</i>		
			<i>Q₅</i>	<i>Q₁₀</i>	<i>Q₁₀₀</i>
Z	OS-1	138.00	---	20	---
Y	OS-2	79.00	7.1	---	36.6*
1	PR-1	0.42	0.1	---	0.7
2	PR-2	1.70	1.6	---	4.4
3	PR-3	0.15	0.1	---	0.4
4	PR-3, PR-4, OS-2	81.00	8.6	---	36.6*
5	PR-1, PR-2, PR-3, PR-4, PR-5, OS-2	84.00	9.7	---	47.5*
6	PR-6	0.06	0.03	---	0.2
7	PR-7	0.26	0.3	---	1.1
8	PR-8	0.58	0.4	---	2.1
9	PR-9	3.09	4.1	---	13.6

* Note: the existing swale EXS1 has a max capacity of 36.6 cfs.

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

Table 6-6. Runoff Coefficients for Rational Method
(Source: UDFCD 2001)

Land Use or Surface Characteristics	Percent Impervious	Runoff Coefficients											
		2-year		5-year		10-year		25-year		50-year		100-year	
		HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D
Business													
Commercial Areas	95	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.87	0.87	0.88	0.88	0.89
Neighborhood Areas	70	0.45	0.49	0.49	0.53	0.53	0.57	0.58	0.62	0.60	0.65	0.62	0.68
Residential													
1/8 Acre or less	65	0.41	0.45	0.45	0.49	0.49	0.54	0.54	0.59	0.57	0.62	0.59	0.65
1/4 Acre	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
1/3 Acre	30	0.18	0.22	0.25	0.30	0.32	0.38	0.39	0.47	0.43	0.52	0.47	0.57
1/2 Acre	25	0.15	0.20	0.22	0.28	0.30	0.36	0.37	0.46	0.41	0.51	0.46	0.56
1 Acre	20	0.12	0.17	0.20	0.26	0.27	0.34	0.35	0.44	0.40	0.50	0.44	0.55
Industrial													
Light Areas	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Heavy Areas	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Parks and Cemeteries	7	0.05	0.09	0.12	0.19	0.20	0.29	0.30	0.40	0.34	0.46	0.39	0.52
Playgrounds	13	0.07	0.13	0.16	0.23	0.24	0.31	0.32	0.42	0.37	0.48	0.41	0.54
Railroad Yard Areas	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
Undeveloped Areas													
Historic Flow Analysis-- Greenbelts, Agriculture	2	0.03	0.05	0.09	0.16	0.17	0.26	0.26	0.38	0.31	0.45	0.36	0.51
Pasture/Meadow	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Forest	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Exposed Rock	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Offsite Flow Analysis (when landuse is undefined)	45	0.26	0.31	0.32	0.37	0.38	0.44	0.44	0.51	0.48	0.55	0.51	0.59
Streets													
Paved	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Gravel	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Drive and Walks	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Roofs	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Lawns	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50

3.2 Time of Concentration

One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the hydraulically most remote part of the drainage area under consideration to the design point. However, in practice, the time of concentration can be an empirical value that results in reasonable and acceptable peak flow calculations.

For urban areas, the time of concentration (t_c) consists of an initial time or overland flow time (t_i) plus the travel time (t_t) in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. For non-urban areas, the time of concentration consists of an overland flow time (t_i) plus the time of travel in a concentrated form, such as a swale or drainageway. The travel portion (t_t) of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainageway. Initial time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow. The time of concentration is represented by Equation 6-7 for both urban and non-urban areas.

HYDRAULIC CALCULATIONS

MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

Location: EXS1 - South edge of property line - Capacity

By: Dane Frank

Date: 8/27/2018

Chk By:

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

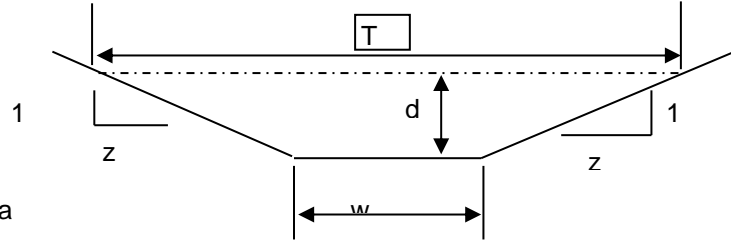
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 22
z (sideslope)= 48
b (btm width, ft)= 0
d (depth, ft)= 1.2
S (slope, ft/ft) 0.008
n low = 0.13
n high = 0.13

Clear Data
Entry Cells

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	T =	
1.2	50.40	84.04	0.60	0.7270711	36.6444	0.727071	36.6444	Dm =	84
				Sc low =	0.2919	Sc high =	0.2919		0.600
s _c = critical slope ft / ft									
T = top width of the stream				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
d _m = a/T = mean depth of flow				0.2043	0.3795	0.2043	0.3795		

s_c = critical slope ft / ft

T = top width of the stream

$d_m = a/T$ = mean depth of flow

Created by: Mike O'Shea

MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

By: Dane Frank

Chk By:

Location: PRS1 - North edge of PR Yard - Q5 = 0.1 cfs

Date: 8/27/2018

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

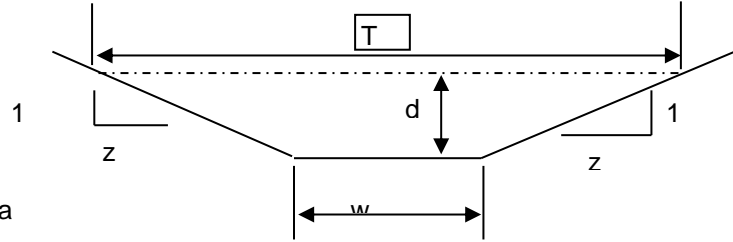
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4
z (sideslope)= 4
b (btm width, ft)= 0
d (depth, ft)= 0.33
S (slope, ft/ft) 0.005
n low = 0.13
n high = 0.13

Clear Data
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.33	0.44	2.72	0.16	0.23827597	0.10379	0.238276	0.10379	T = 2.64
				Sc low = 0.4671		Sc high = 0.4671		Dm = 0.165
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.3270	0.6072	0.3270	0.6072	

s_c = critical slope ft / ft

T = top width of the stream

d_m = a/T = mean depth of flow

Created by: Mike O'Shea

MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation **Location:** PRS1 - North edge of PR Yard - Q100 = 0.7 cfs
By: Dane Frank **Date:** 8/27/2018
Chk By: **Date:** version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

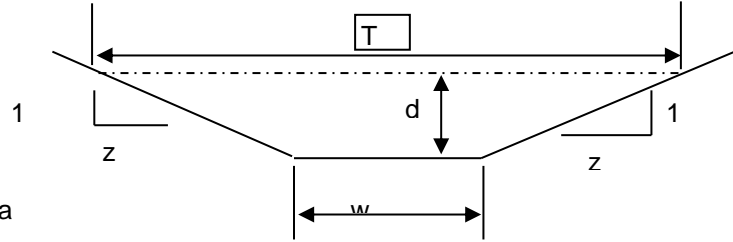
$$R = A/P$$

A = cross sectional area

P = wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4
z (sideslope)= 4
b (btm width, ft)= 0
d (depth, ft)= 0.68
S (slope, ft/ft) 0.005
n low = 0.13
n high = 0.13

Clear Data
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.68	1.85	5.61	0.33	0.38585195	0.71367	0.385852	0.71367	T = 5.44
				Sc low = 0.3671		Sc high = 0.3671		Dm = 0.340
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.2570	0.4772	0.2570	0.4772	

s_c = critical slope ft / ft

T = top width of the stream

$d_m = a/T$ = mean depth of flow

Created by: Mike O'Shea

MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

Location: PRS2 - East edge of PR Yard - Q5 = 0.1 cfs

By: Dane Frank

Date: 8/27/2018

Chk By:

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

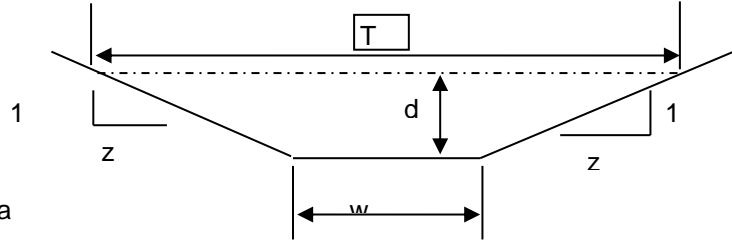
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4
z (sideslope)= 4
b (btm width, ft)= 0
d (depth, ft)= 0.3
S (slope, ft/ft) 0.008
n low = 0.13
n high = 0.13

Clear Data
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		T =	Dm =
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
0.3	0.36	2.47	0.15	0.2828419	0.10182	0.282842	0.10182	2.4	0.150
				Sc low =	0.4822	Sc high =	0.4822		
s _c = critical slope ft / ft									
T = top width of the stream				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
d _m = a/T = mean depth of flow				0.3375	0.6268	0.3375	0.6268		

s_c = critical slope ft / ft

T = top width of the stream

d_m = a/T = mean depth of flow

Created by: Mike O'Shea

MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

By: Dane Frank

Chk By:

Location: PRS2 - East edge of PR Yard - Q100 = 0.4 cfs

Date: 8/27/2018

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

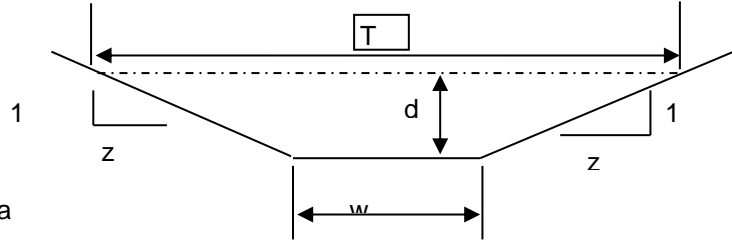
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4
z (sideslope)= 4
b (btm width, ft)= 0
d (depth, ft)= 0.51
S (slope, ft/ft) 0.008
n low = 0.13
n high = 0.13

Clear Data
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.51	1.04	4.21	0.25	0.40288773	0.41916	0.402888	0.41916	T = 4.08
				Sc low = 0.4040		Sc high = 0.4040		Dm = 0.255
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.2828	0.5252	0.2828	0.5252	

s_c = critical slope ft / ft

T = top width of the stream

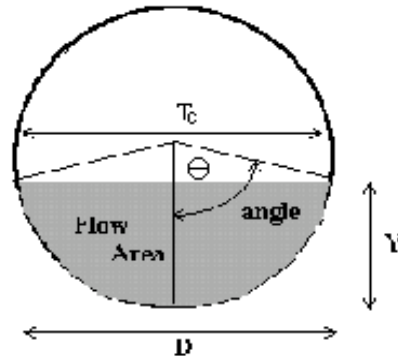
d_m = a/T = mean depth of flow

Created by: Mike O'Shea

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC1 - Sand Filter Discharge - 5 Yr**



Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0200	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	18.00	inches
Design discharge	$Q =$	1.60	cfs

Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	1.77	sq ft
Full-flow wetted perimeter	$P_f =$	4.71	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	14.90	cfs

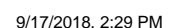
Calculation of Normal Flow Condition

Half Central Angle ($0 < \theta < 3.14$)	$\theta =$	0.98	radians
Flow area	$A_n =$	0.29	sq ft
Top width	$T_n =$	1.25	ft
Wetted perimeter	$P_n =$	1.47	ft
Flow depth	$Y_n =$	0.33	ft
Flow velocity	$V_n =$	5.50	fps
Discharge	$Q_n =$	1.60	cfs
Percent Full Flow	$\text{Flow} =$	10.7%	of full flow
Normal Depth Froude Number	$Fr_n =$	2.01	supercritical

Calculation of Critical Flow Condition

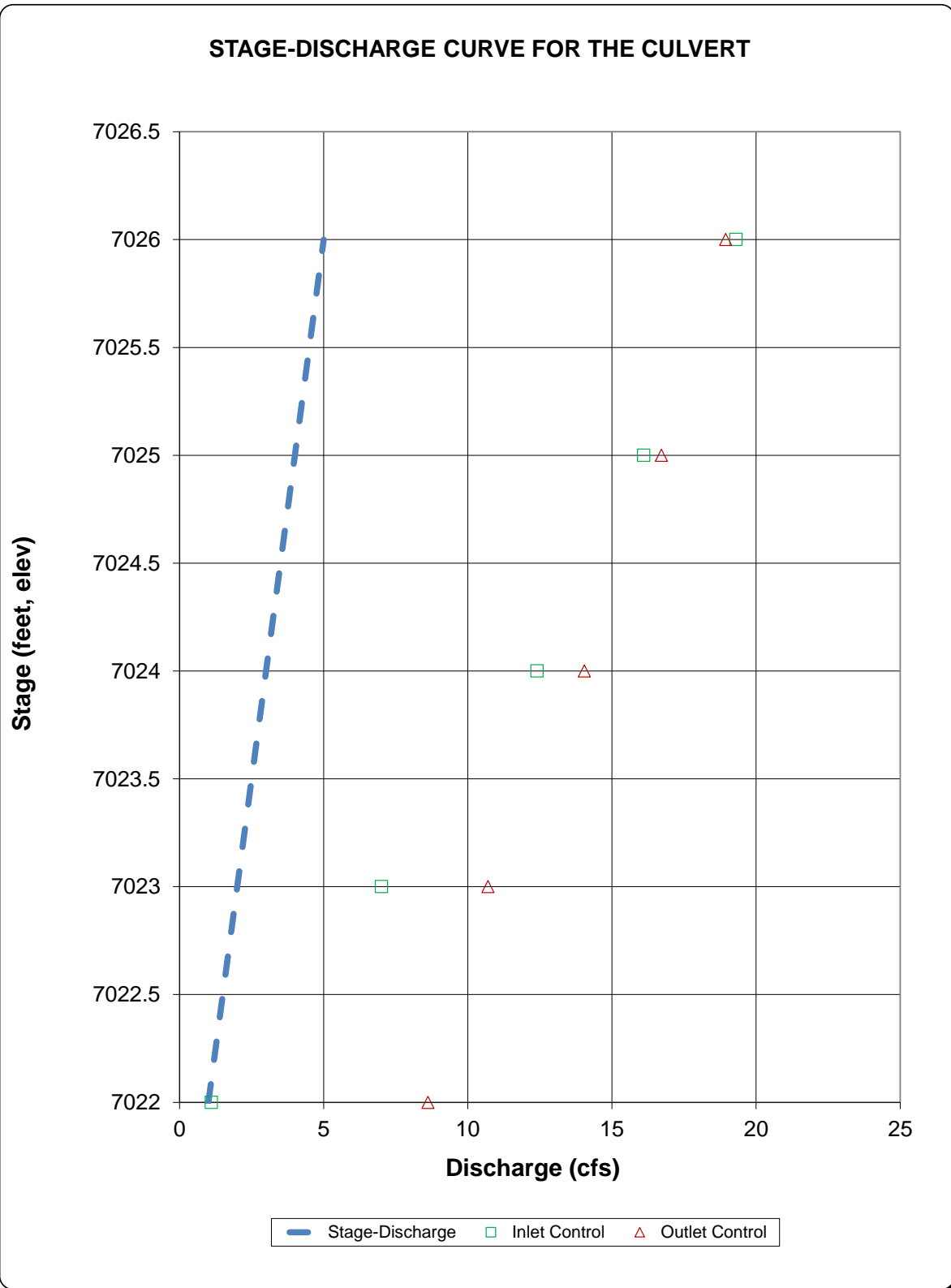
Half Central Angle ($0 < \theta_c < 3.14$)	$\theta_c =$	1.20	radians
Critical flow area	$A_c =$	0.48	sq ft
Critical top width	$T_c =$	1.40	ft
Critical flow depth	$Y_c =$	0.48	ft
Critical flow velocity	$V_c =$	3.33	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC1 - Sand Filter Discharge - 5 Yr**
 Status:



CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

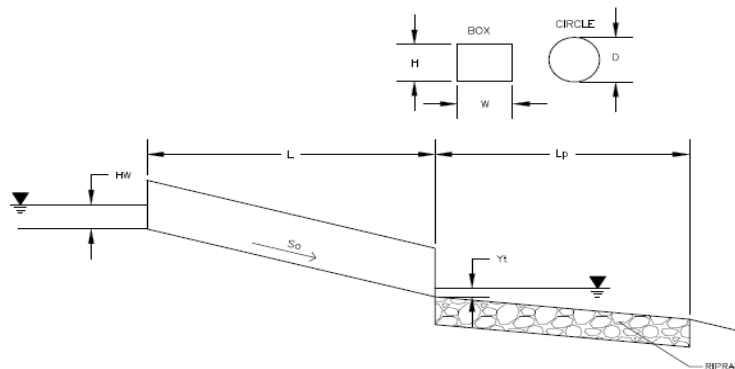
Project: Voolmer Substation
Basin ID: PRC1 - Sand Filter Discharge - 5 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC1 - Sand Filter Discharge - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using D_a to calculate protection type.

Design Information (Input):

Design Discharge

Q = 1.6 cfs

Circular Culvert:

Barrel Diameter in Inches

D = 18 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7021.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7020.1 ft

Culvert Length

L = 70 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t =

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 0.60 ft

Flow Area at Max Channel Velocity

A_t = 0.32 ft²

Culvert Cross Sectional Area Available

A = 1.77 ft²

Entrance Loss Coefficient

k_e = 0.50

Friction Loss Coefficient

k_f = 1.27

Sum of All Losses Coefficients

k_s = 2.77

Culvert Normal Depth

Y_n = 0.33 ft

Culvert Critical Depth

Y_c = 0.48 ft

Tailwater Depth for Design

d = 0.99 ft

Adjusted Diameter **OR** Adjusted Rise

D_a = 0.92 ft

Expansion Factor

$1/(2*\tan(\Theta))$ = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/D^{2.5}$ = 0.58 ft^{0.5}/s

Froude Number

Fr = 2.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/D = 0.66

Supercritical!

Inlet Control Headwater

HW_i = 0.66 ft

Outlet Control Headwater

HW_o = -0.38

Design Headwater Elevation

HW = 7,022.16 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.44

Minimum Theoretical Riprap Size

d_{50} = 1 in

Nominal Riprap Size

d_{50} = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 5 ft

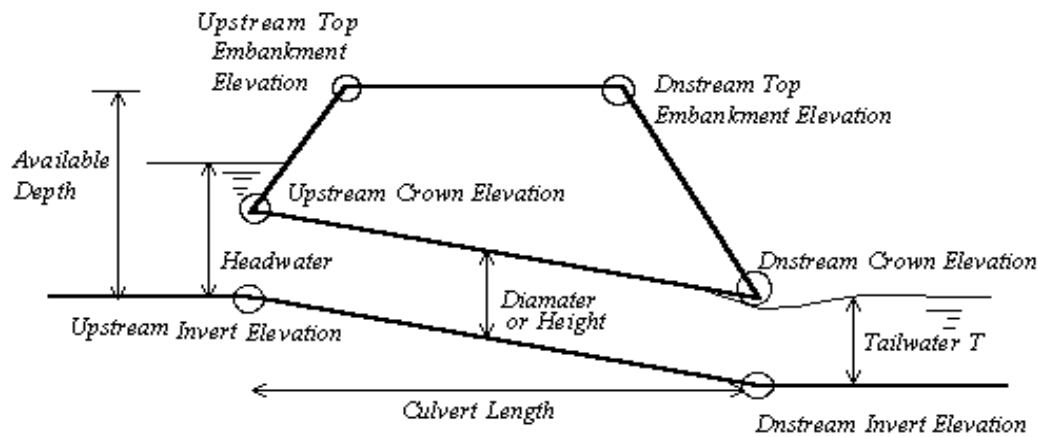
Width of Protection

T = 3 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC1 - Sand Filter Discharge - 5 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	70.00	ft
Barrel Invert Slope	So =	0.0200	ft/ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Top Embankment Elevation	EDT =	7026.00	ft
Upstream Top Embankment Elevation	EUT =	7026.00	ft
Design Headwater Depth (not elev.)	Hw =	0.66	ft
Tailwater Depth (not elev.)	Yt =	0.99	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	4.50	ft
Design Hw/D ratio	Hw/D =	0.44	

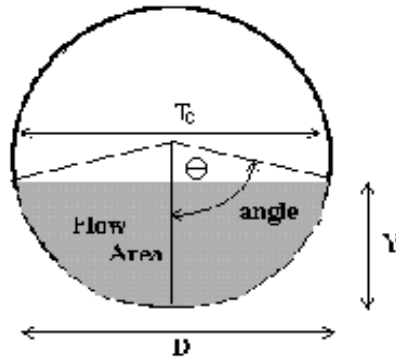
Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7021.50	ft
Upstream Crown Elevation	EUC =	7023.00	ft
Upstream Soil Cover Depth	Upsoil =	3.00	ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Crown Elevation	EDC =	7021.60	ft
Downstream Soil Cover Depth	Dnsoil =	4.40	ft

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC1 - Sand Filter Discharge - 100 Yr**



Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0200	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	18.00	inches
Design discharge	$Q =$	4.40	cfs

Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	1.77	sq ft
Full-flow wetted perimeter	$P_f =$	4.71	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	14.90	cfs

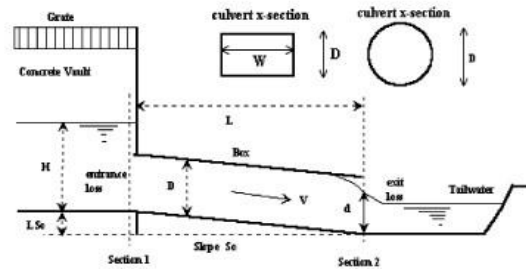
Calculation of Normal Flow Condition

Half Central Angle ($0 < \theta < 3.14$)	$\theta =$	1.31	radians
Flow area	$A_n =$	0.60	sq ft
Top width	$T_n =$	1.45	ft
Wetted perimeter	$P_n =$	1.97	ft
Flow depth	$Y_n =$	0.56	ft
Flow velocity	$V_n =$	7.34	fps
Discharge	$Q_n =$	4.40	cfs
Percent Full Flow	$\text{Flow} =$	29.5%	of full flow
Normal Depth Froude Number	$Fr_n =$	2.01	supercritical

Calculation of Critical Flow Condition

Half Central Angle ($0 < \theta_c < 3.14$)	$\theta_c =$	1.64	radians
Critical flow area	$A_c =$	0.97	sq ft
Critical top width	$T_c =$	1.50	ft
Critical flow depth	$Y_c =$	0.80	ft
Critical flow velocity	$V_c =$	4.56	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC1 - Sand Filter Discharge - 100 Yr**
 Status:



Circular Culvert: Barrel Diameter in Inches
Inlet Edge Type (choose from pull-down list)

D = 18 inches

Grooved End with Headwall

Box Culvert: Barrel Height (Rise) in Feet
Barrel Width (Span) in Feet
Inlet Edge Type (choose from pull-down list)

Height (Rise) = ft.

Width (Span) = ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels
Inlet Elevation at Culvert Invert
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)
Culvert Length in Feet
Manning's Roughness
Bend Loss Coefficient
Exit Loss Coefficient

No = 1

Inlet Elev = 7021.5 ft. elev.

Outlet Elev = 7020.1 ft. elev.

L = ft.

n =	0.013
-----	-------

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient
Friction Loss Coefficient
Sum of All Loss Coefficients
Orifice Inlet Condition Coefficient
Minimum Energy Condition Coefficient

 $K_e = 0.20$

$K_f =$	1.27
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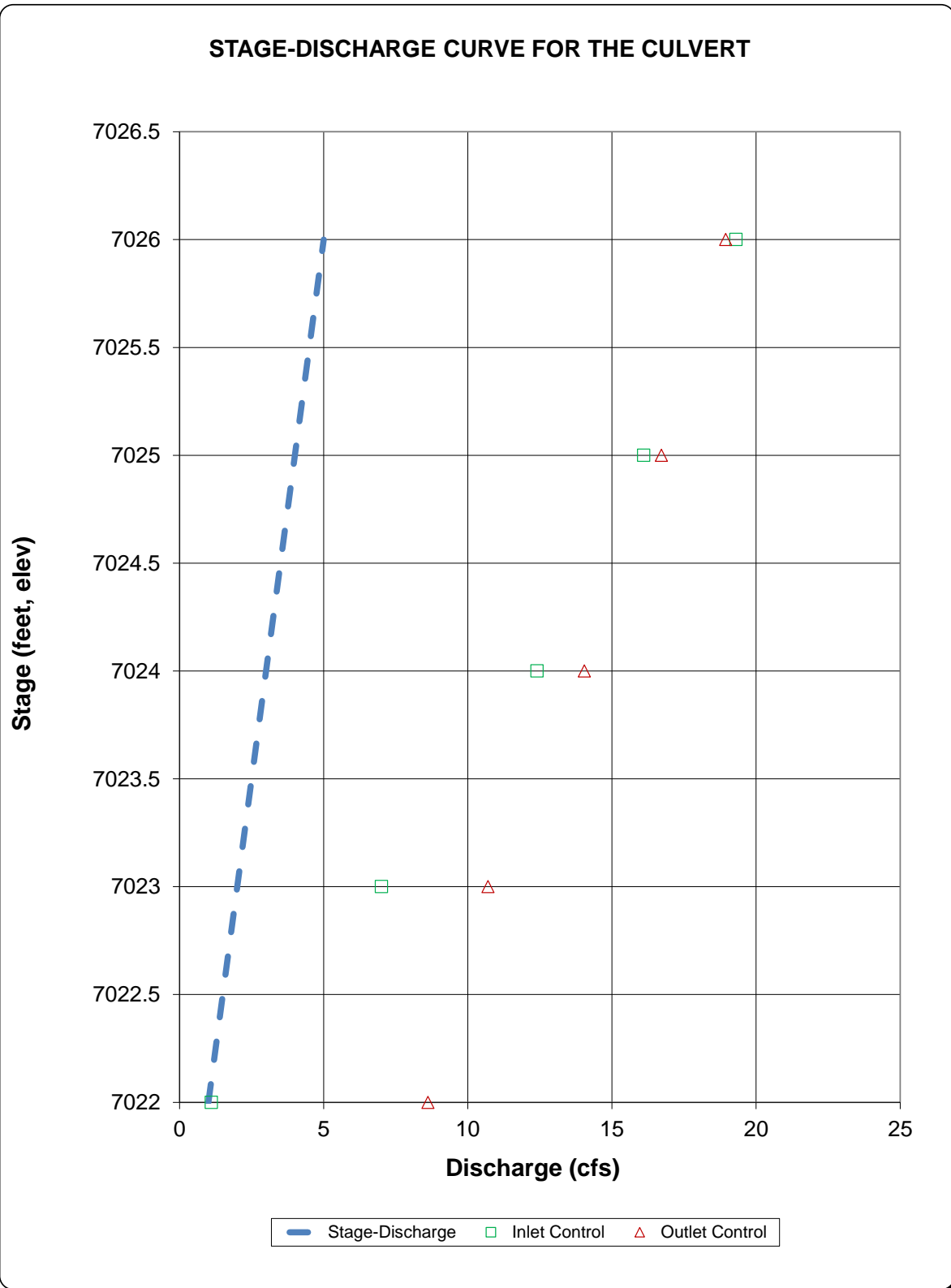
$$K_s = 2.47$$
$$C_d = 0.99$$
$$KE_{\text{low}} = -0.0860$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

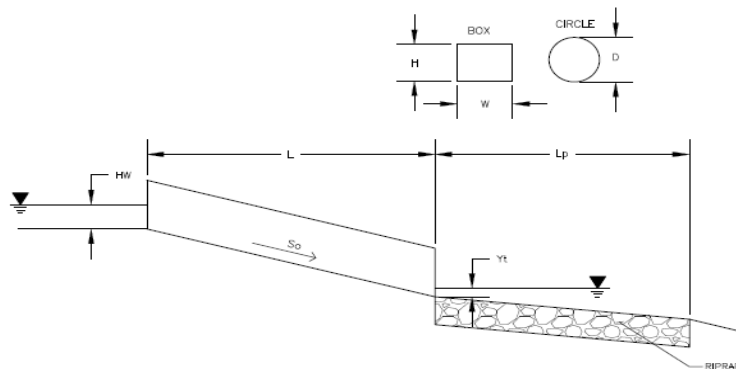
Basin ID: PRC1 - Sand Filter Discharge - 100 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC1 - Sand Filter Discharge - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using D_a to calculate protection type.

Design Information (Input):

Design Discharge

Q = 4.4 cfs

Circular Culvert:

Barrel Diameter in Inches

D = 18 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7021.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7020.1 ft

Culvert Length

L = 70 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t =

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 0.60 ft

Flow Area at Max Channel Velocity

A_t = 0.88 ft²

Culvert Cross Sectional Area Available

A = 1.77 ft²

Entrance Loss Coefficient

k_e = 0.50

Friction Loss Coefficient

k_f = 1.27

Sum of All Losses Coefficients

k_s = 2.77

Culvert Normal Depth

Y_n = 0.56 ft

Culvert Critical Depth

Y_c = 0.80 ft

Tailwater Depth for Design

d = 1.15 ft

Adjusted Diameter **OR** Adjusted Rise

D_a = 1.03 ft

Expansion Factor

$1/(2*\tan(\Theta))$ = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/D^{2.5}$ = 1.60 ft^{0.5}/s

Froude Number

Fr = 2.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/D = 0.58

Supercritical!

Inlet Control Headwater

HW_i = 1.19 ft

Outlet Control Headwater

HW_o = 0.02 ft

Design Headwater Elevation

HW = 7,022.69 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.79

Minimum Theoretical Riprap Size

d_{50} = 2 in

Nominal Riprap Size

d_{50} = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 5 ft

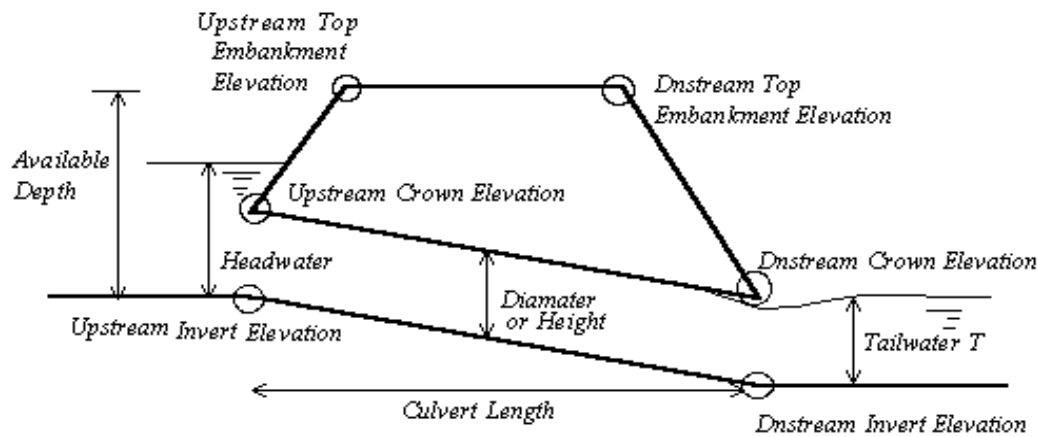
Width of Protection

T = 3 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC1 - Sand Filter Discharge - 100 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	70.00	ft
Barrel Invert Slope	So =	0.0200	ft/ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Top Embankment Elevation	EDT =	7026.00	ft
Upstream Top Embankment Elevation	EUT =	7026.00	ft
Design Headwater Depth (not elev.)	Hw =	1.19	ft
Tailwater Depth (not elev.)	Yt =	1.15	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	4.50	ft
Design Hw/D ratio	Hw/D =	0.79	

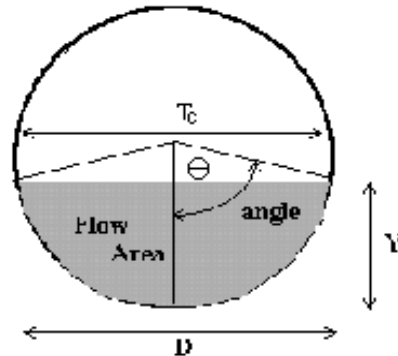
Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7021.50	ft
Upstream Crown Elevation	EUC =	7023.00	ft
Upstream Soil Cover Depth	Upsoil =	3.00	ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Crown Elevation	EDC =	7021.60	ft
Downstream Soil Cover Depth	Dnsoil =	4.40	ft

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**



Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0080	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	30.00	inches
Design discharge	$Q =$	8.60	cfs

Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	4.91	sq ft
Full-flow wetted perimeter	$P_f =$	7.85	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	36.79	cfs

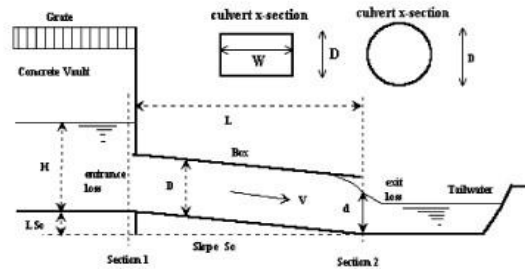
Calculation of Normal Flow Condition

Half Central Angle ($0 < \theta < 3.14$)	$\theta =$	1.22	radians
Flow area	$A_n =$	1.41	sq ft
Top width	$T_n =$	2.35	ft
Wetted perimeter	$P_n =$	3.05	ft
Flow depth	$Y_n =$	0.82	ft
Flow velocity	$V_n =$	6.11	fps
Discharge	$Q_n =$	8.60	cfs
Percent Full Flow	$\text{Flow} =$	23.4%	of full flow
Normal Depth Froude Number	$Fr_n =$	1.39	supercritical

Calculation of Critical Flow Condition

Half Central Angle ($0 < \theta_c < 3.14$)	$\theta_c =$	1.35	radians
Critical flow area	$A_c =$	1.78	sq ft
Critical top width	$T_c =$	2.44	ft
Critical flow depth	$Y_c =$	0.98	ft
Critical flow velocity	$V_c =$	4.84	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**
 Status:



Circular Culvert: Barrel Diameter in Inches
Inlet Edge Type (choose from pull-down list)

D = 30 inches

Grooved End with Headwall

Box Culvert: Barrel Height (Rise) in Feet
Barrel Width (Span) in Feet
Inlet Edge Type (choose from pull-down list)

Height (Rise) = ft.

Width (Span) = ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels
Inlet Elevation at Culvert Invert
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)
Culvert Length in Feet
Manning's Roughness
Bend Loss Coefficient
Exit Loss Coefficient

No = 1

Inlet Elev = 7017.75 ft. elev.

Outlet Elev = 7017.31 ft. elev.

L = ft.

n =	0.013
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$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient
Friction Loss Coefficient
Sum of All Loss Coefficients
Orifice Inlet Condition Coefficient
Minimum Energy Condition Coefficient

$$K_e = 0.20$$
$$K_f = 0.50$$

$K_s =$	1.70
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$C_d =$	0.99
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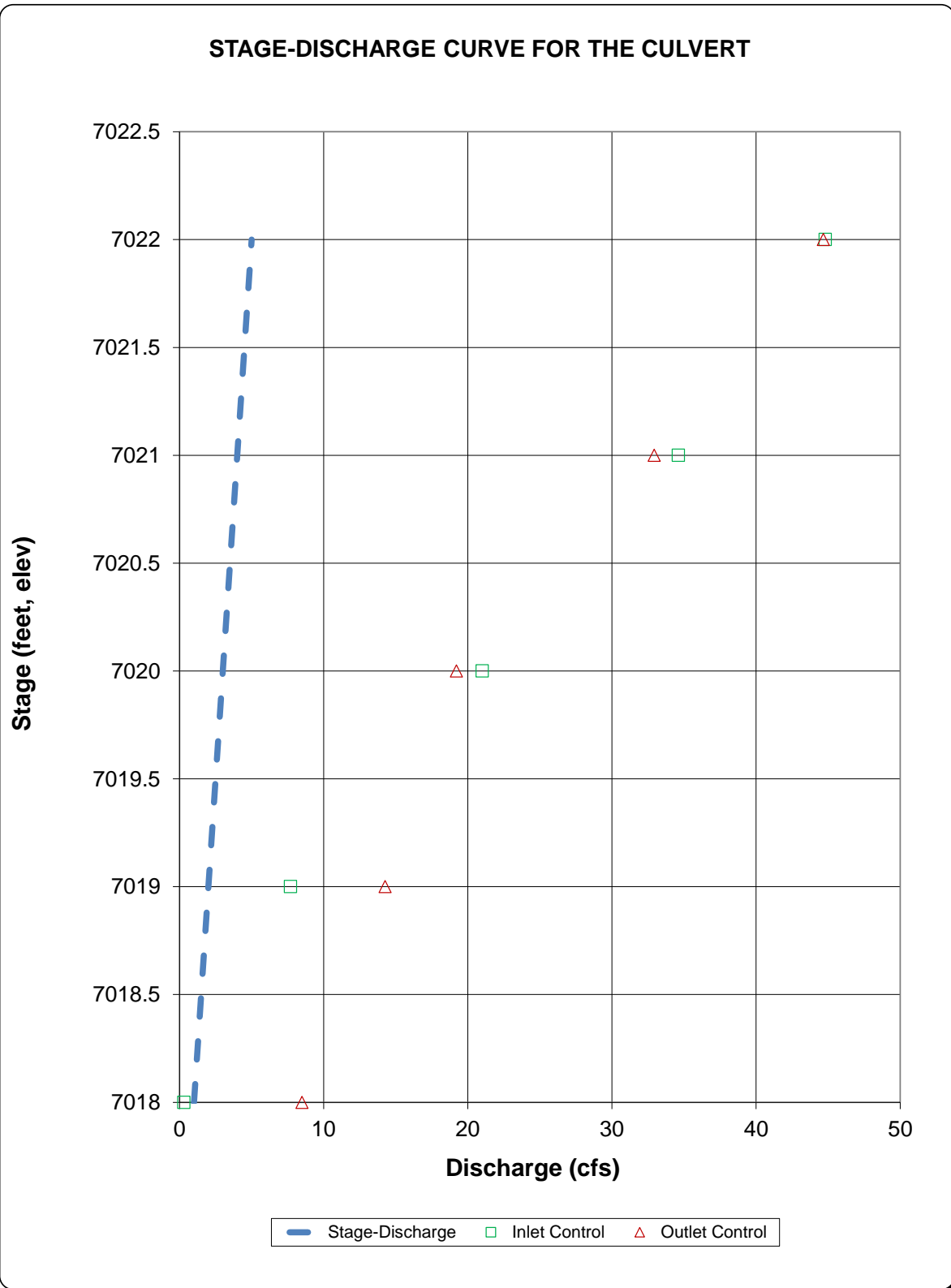
$$KE_{\text{low}} = -0.0373$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

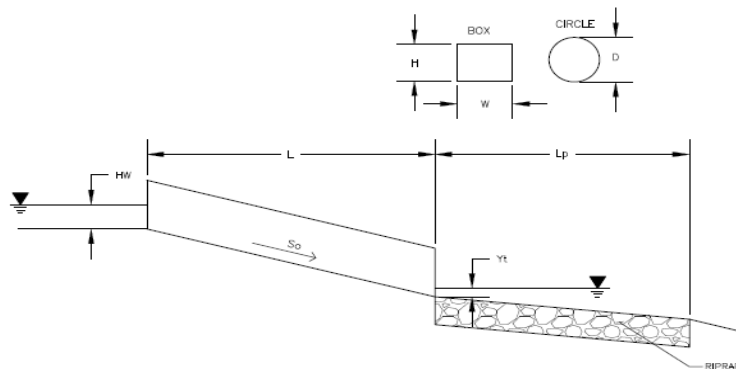
Basin ID: PRC2 - SW Property Corner Access Crossing - 5 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using D_a to calculate protection type.

Design Information (Input):

Design Discharge

Q = 8.6 cfs

Circular Culvert:

Barrel Diameter in Inches

D = 30 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7017.75 ft

Outlet Elevation **OR** Slope

Elev OUT = 7017.31 ft

Culvert Length

L = 55 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t =

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 1.00 ft

Flow Area at Max Channel Velocity

A_t = 1.72 ft²

Culvert Cross Sectional Area Available

A = 4.91 ft²

Entrance Loss Coefficient

k_e = 0.50

Friction Loss Coefficient

k_f = 0.50

Sum of All Losses Coefficients

k_s = 2.00

Culvert Normal Depth

Y_n = 0.82 ft

Culvert Critical Depth

Y_c = 0.98 ft

Tailwater Depth for Design

d = 1.74 ft

Adjusted Diameter **OR** Adjusted Rise

D_a = 1.66 ft

Expansion Factor

$1/(2 \cdot \tan(\Theta))$ = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/D^{2.5}$ = 0.87 ft^{0.5}/s

Froude Number

Fr = 1.39

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/D = 0.60

Supercritical!

Inlet Control Headwater

HW_i = 1.39 ft

Outlet Control Headwater

HW_o = 1.39 ft

Design Headwater Elevation

HW = 7,019.14 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.56

Minimum Theoretical Riprap Size

d_{50} = 2 in

Nominal Riprap Size

d_{50} = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 8 ft

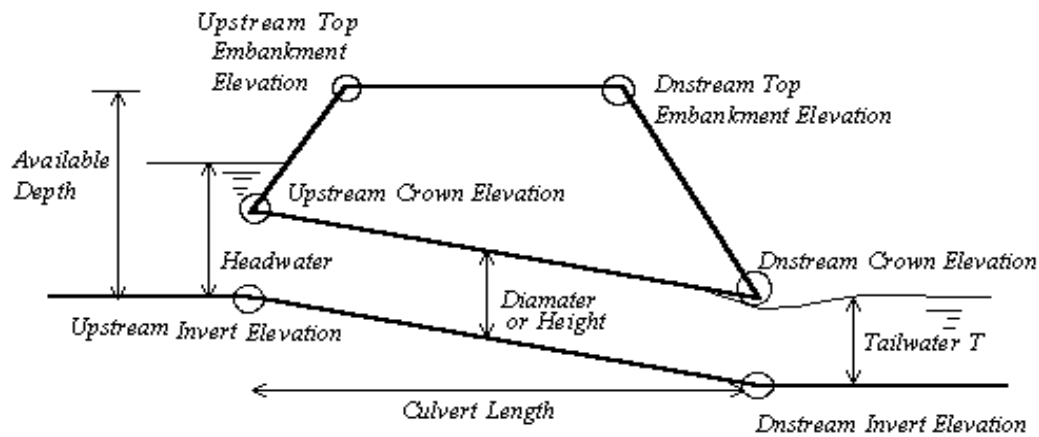
Width of Protection

T = 4 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC2 - SW Property Corner Access Crossing - 5 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	30.00	inches
Barrel Length	L =	55.00	ft
Barrel Invert Slope	So =	0.0080	ft/ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Top Embankment Elevation	EDT =	7021.50	ft
Upstream Top Embankment Elevation	EUT =	7021.50	ft
Design Headwater Depth (not elev.)	Hw =	1.39	ft
Tailwater Depth (not elev.)	Yt =	1.74	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	3.75	ft
Design Hw/D ratio	Hw/D =	0.56	

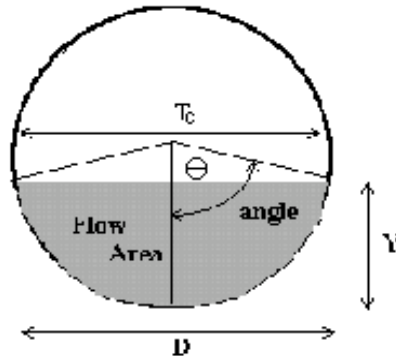
Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7017.75	ft
Upstream Crown Elevation	EUC =	7020.25	ft
Upstream Soil Cover Depth	Upsoil =	1.25	ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Crown Elevation	EDC =	7019.81	ft
Downstream Soil Cover Depth	Dnsoil =	1.69	ft

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**



Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0080	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	30.00	inches
Design discharge	$Q =$	36.60	cfs

Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	4.91	sq ft
Full-flow wetted perimeter	$P_f =$	7.85	ft
Half Central Angle	$\text{Theta} =$	3.14	radians
Full-flow capacity	$Q_f =$	36.79	cfs

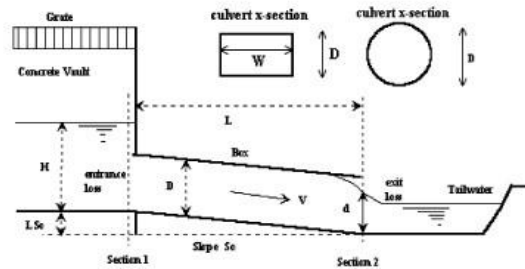
Calculation of Normal Flow Condition

Half Central Angle ($0 < \text{Theta} < 3.14$)	$\text{Theta} =$	2.25	radians
Flow area	$A_n =$	4.28	sq ft
Top width	$T_n =$	1.94	ft
Wetted perimeter	$P_n =$	5.63	ft
Flow depth	$Y_n =$	2.04	ft
Flow velocity	$V_n =$	8.54	fps
Discharge	$Q_n =$	36.60	cfs
Percent Full Flow	$\text{Flow} =$	99.5%	of full flow
Normal Depth Froude Number	$Fr_n =$	1.01	supercritical

Calculation of Critical Flow Condition

Half Central Angle ($0 < \text{Theta-c} < 3.14$)	$\text{Theta-c} =$	2.27	radians
Critical flow area	$A_c =$	4.31	sq ft
Critical top width	$T_c =$	1.92	ft
Critical flow depth	$Y_c =$	2.05	ft
Critical flow velocity	$V_c =$	8.50	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**
 Status:



Circular Culvert: Barrel Diameter in Inches
Inlet Edge Type (choose from pull-down list)

D = 30 inches

Grooved End with Headwall

Box Culvert: Barrel Height (Rise) in Feet
Barrel Width (Span) in Feet
Inlet Edge Type (choose from pull-down list)

Height (Rise) = ft.

Width (Span) = ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels
Inlet Elevation at Culvert Invert
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)
Culvert Length in Feet
Manning's Roughness
Bend Loss Coefficient
Exit Loss Coefficient

No = 1

Inlet Elev = 7017.75 ft. elev.

Outlet Elev = 7017.31 ft. elev.

L = ft.

n =	0.013
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$$K_b = 0$$

$K_x =$	1
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Entrance Loss Coefficient
Friction Loss Coefficient
Sum of All Loss Coefficients
Orifice Inlet Condition Coefficient
Minimum Energy Condition Coefficient

$$K_e = 0.20$$

$K_f =$	0.50
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$K_s =$	1.70
---------	------

$C_d =$	0.99
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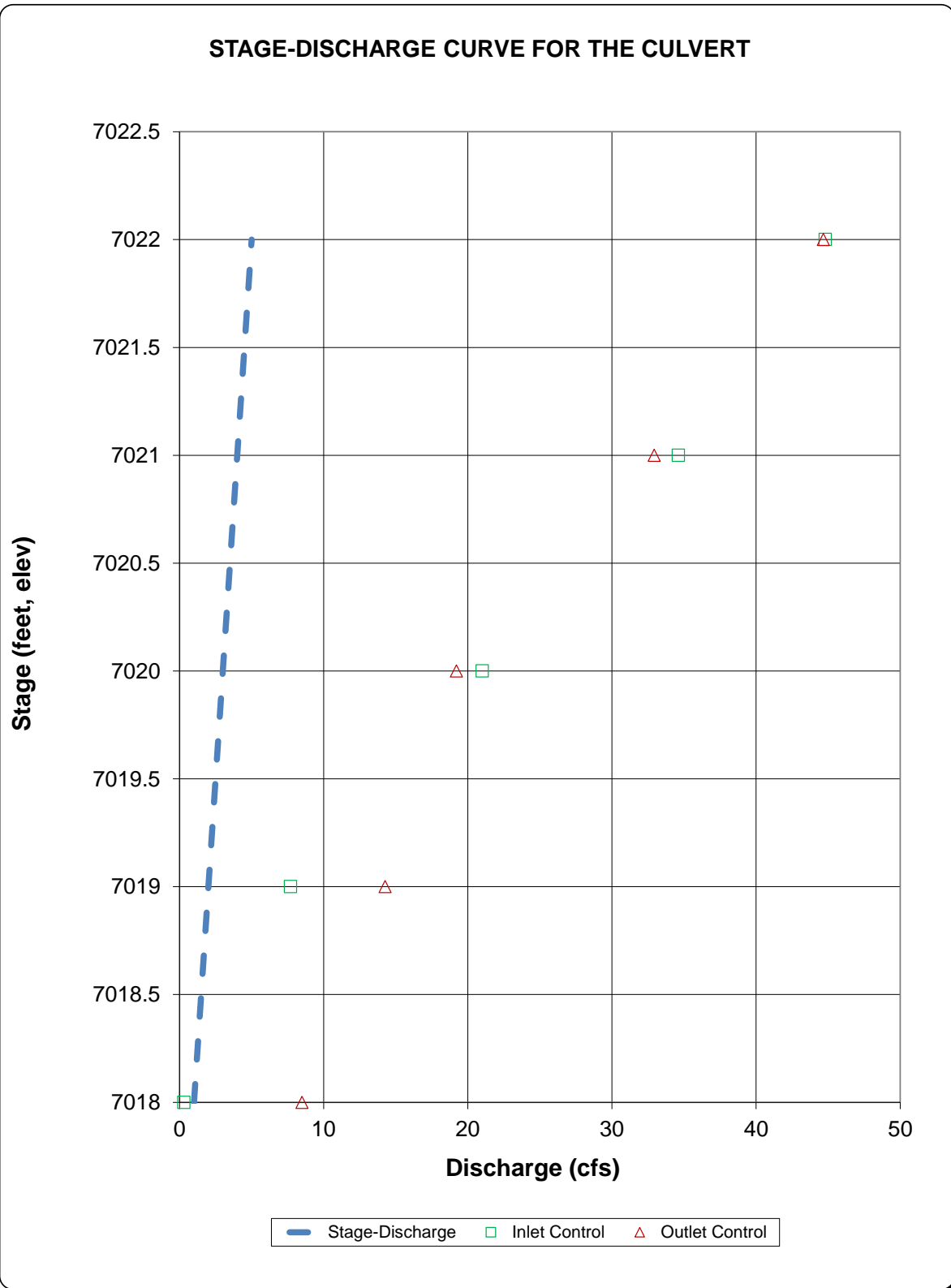
$$KE_{\text{low}} = -0.0373$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

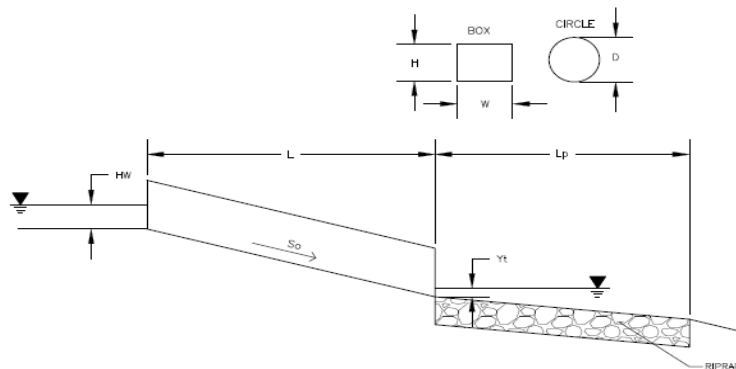
Basin ID: PRC2 - SW Property Corner Access Crossing - 100 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using Da to calculate protection type.

Design Information (Input):

Design Discharge

Q = 36.6 cfs

Circular Culvert:

Barrel Diameter in Inches

D = 30 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7017.75 ft

Outlet Elevation **OR** Slope

Elev OUT = 7017.31 ft

Culvert Length

L = 55 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t =

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 1.00 ft

Flow Area at Max Channel Velocity

A_t = 7.32 ft²

Culvert Cross Sectional Area Available

A = 4.91 ft²

Entrance Loss Coefficient

k_e = 0.50

Friction Loss Coefficient

k_f = 0.50

Sum of All Losses Coefficients

k_s = 2.00

Culvert Normal Depth

Y_n = 2.04 ft

Culvert Critical Depth

Y_c = 2.05 ft

Tailwater Depth for Design

d = 2.28 ft

Adjusted Diameter **OR** Adjusted Rise

D_a = 2.27 ft

Expansion Factor

1/(2*tan(Θ)) = 4.37

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

Q/D^{2.5} = 3.70 ft^{0.5}/s

Froude Number

Fr = 1.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/D = 0.44

Supercritical!

Inlet Control Headwater

HW_i = 3.92 ft

Outlet Control Headwater

HW_o = 3.57 ft

Design Headwater Elevation

HW = 7,021.67 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 1.57

HW/D > 1.5!

Minimum Theoretical Riprap Size

d₅₀ = 8 in

Nominal Riprap Size

d₅₀ = 9 in

UDFCD Riprap Type

Type = L

Length of Protection

L_p = 22 ft

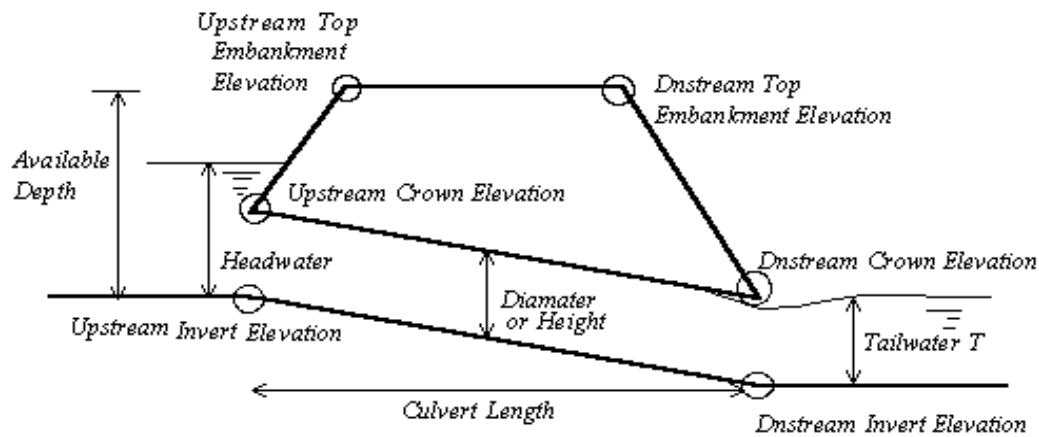
Width of Protection

T = 8 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC2 - SW Property Corner Access Crossing - 100 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	30.00	inches
Barrel Length	L =	55.00	ft
Barrel Invert Slope	So =	0.0080	ft/ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Top Embankment Elevation	EDT =	7021.50	ft
Upstream Top Embankment Elevation	EUT =	7021.50	ft
Design Headwater Depth (not elev.)	Hw =	3.92	ft
Tailwater Depth (not elev.)	Yt =	2.28	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	3.75	ft
Design Hw/D ratio	Hw/D =	1.57	

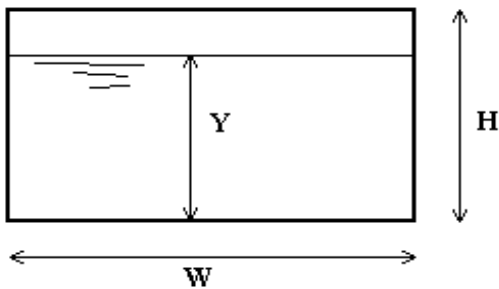
Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7017.75	ft
Upstream Crown Elevation	EUC =	7020.25	ft
Upstream Soil Cover Depth	Upsoil =	1.25	ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Crown Elevation	EDC =	7019.81	ft
Downstream Soil Cover Depth	Dnsoil =	1.69	ft

BOX CONDUIT FLOW (Normal & Critical Depth Computation)

Project: Vollmer Substation

Box ID: PRC3 - Crossing Access South of Property - 5 Yr



Design Information (Input)

Box conduit invert slope	So =	0.0100	ft/ft
Box Manning's n-value	n =	0.0130	
Box Width	W =	2.00	ft
Box Height	H =	1.50	ft
Design discharge	Q =	3.33	cfs

Full-flow capacity (Calculated)

Full-flow area	Af =	3.00	sq ft
Full-flow wetted perimeter	Pf =	7.00	ft
Full-flow capacity	Qf =	19.55	cfs

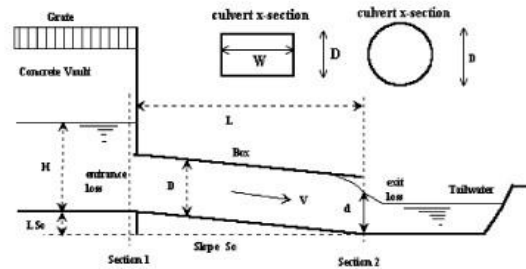
Calculations of Normal Flow Condition

Normal flow depth (<H)	Yn =	0.35	ft
Flow area	An =	0.71	sq ft
Wetted perimeter	Pn =	2.71	ft
Flow velocity	Vn =	4.69	fps
Discharge	Qn =	3.33	cfs
Percent Full	Flow =	17.0%	of full flow
Normal Depth Froude Number	Fr _n =	1.39	supercritical

Calculation of Critical Flow Condition

Critical flow depth	Yc =	0.44	ft
Critical flow area	Ac =	0.88	sq ft
Critical flow velocity	Vc =	3.77	fps
Critical Depth Froude Number	Fr _c =	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC3 - Crossing Access South of Property - 5 Yr**
 Status:



Circular Culvert: Barrel Diameter in Inches
Inlet Edge Type (choose from pull-down list)

D = inches

Grooved End with Headwall

Box Culvert: Barrel Height (Rise) in Feet
Barrel Width (Span) in Feet
Inlet Edge Type (choose from pull-down list)

Height (Rise) = 1.50 ft.

Width (Span) = 2.00 ft.

Square Edge w/ 30-78 deg. Flared Wingwall

No = 3

Inlet Elev = 7011.5 ft. elev.

Outlet Elev = 7011 ft. elev.

L = 50 ft.

n = 0.013

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient
Friction Loss Coefficient
Sum of All Loss Coefficients
Orifice Inlet Condition Coefficient
Minimum Energy Condition Coefficient

 $K_e = 0.40$

$K_f =$	0.91
---------	------

$$K_s = 2.31$$

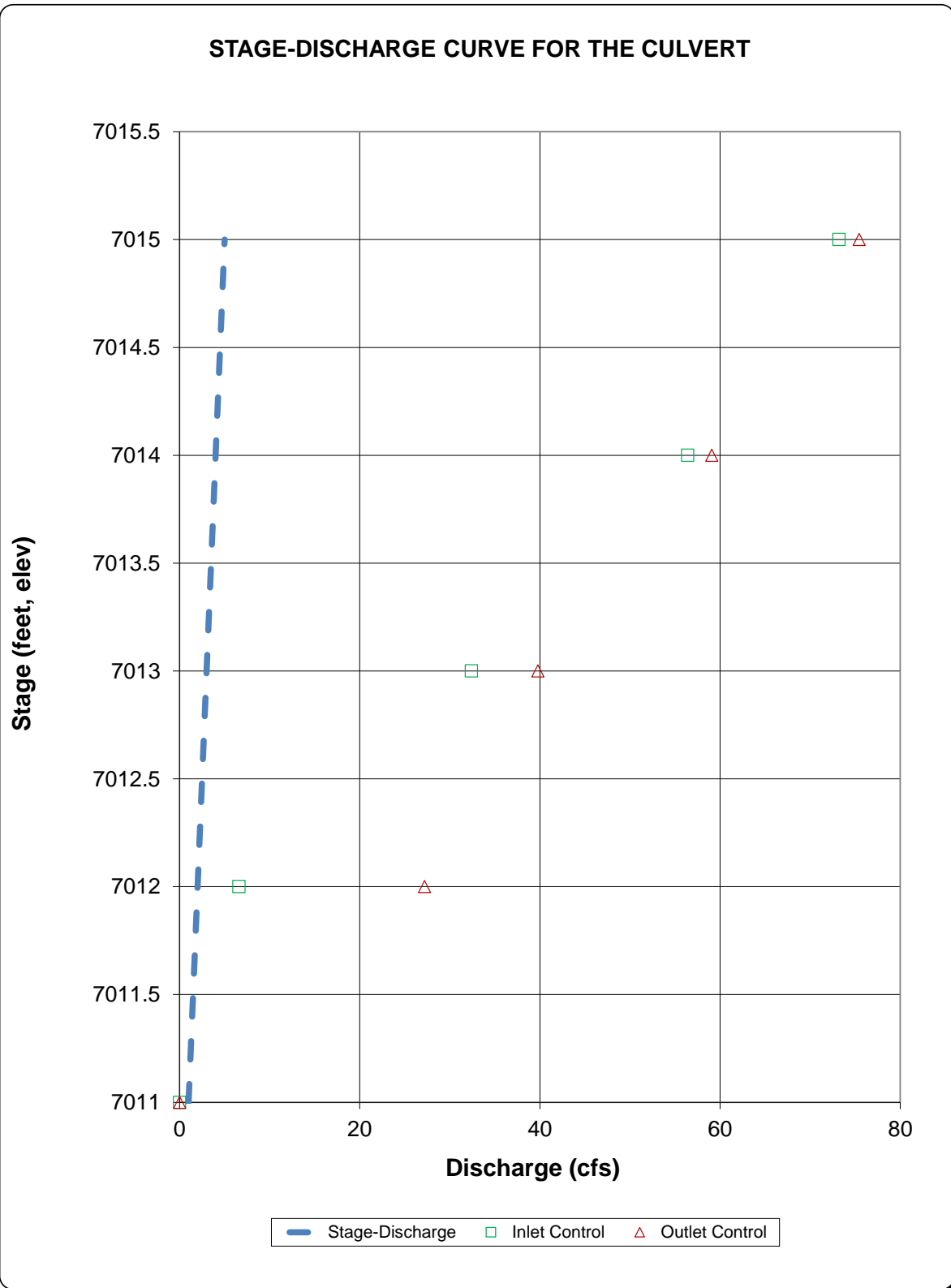
$C_d =$	0.87
---------	------

$$KE_{\text{low}} = 0.0062$$
[illegible]

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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

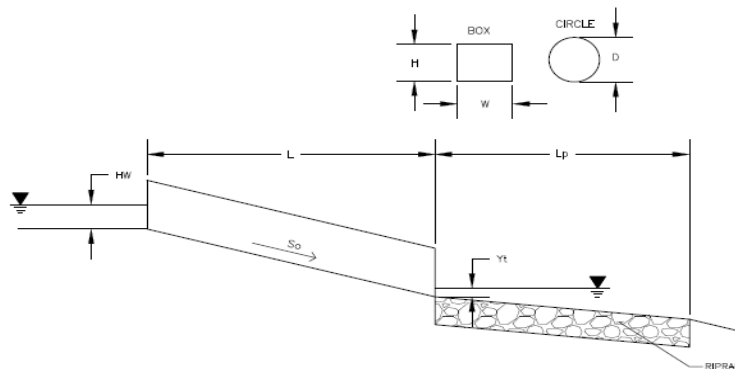
Project: Voolmer Substation
Basin ID: PRC3 - Crossing Access South of Property - 5 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC3 - Crossing Access South of Property - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using H_a to calculate protection type.

Design Information (Input):

Design Discharge

Q = 3.33 cfs

Circular Culvert:

Barrel Diameter in Inches

D = inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) = 1.5 ft

Barrel Width (Span) in Feet

Width (Span) = 2 ft

Inlet Edge Type (Choose from pull-down list)

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels

No = 3

Inlet Elevation

Elev IN = 7011.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7011 ft

Culvert Length

L = 50 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t = ft

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 0.60 ft

Flow Area at Max Channel Velocity

A_t = 0.22 ft²

Culvert Cross Sectional Area Available

A = 3.00 ft²

Entrance Loss Coefficient

k_e = 0.40

Friction Loss Coefficient

k_f = 0.91

Sum of All Losses Coefficients

k_s = 2.31

Culvert Normal Depth

Y_n = 0.17 ft

Culvert Critical Depth

Y_c = 0.21 ft

Tailwater Depth for Design

d = 0.86 ft

Adjusted Diameter **OR** Adjusted Rise

H_a = 0.84 ft

Expansion Factor

$1/(2*\tan(\Theta))$ = 6.65

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/WH^{1.5}$ = 0.30 ft^{0.5}/s

Froude Number

Fr = 1.36

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/H = 0.72

Supercritical!

Inlet Control Headwater

HW_i = 0.32 ft

Outlet Control Headwater

HW_o = 0.36 ft

Design Headwater Elevation

HW = 7,011.86 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/H = 0.24

Minimum Theoretical Riprap Size

d_{50} = 0 in

Nominal Riprap Size

d_{50} = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 5 ft

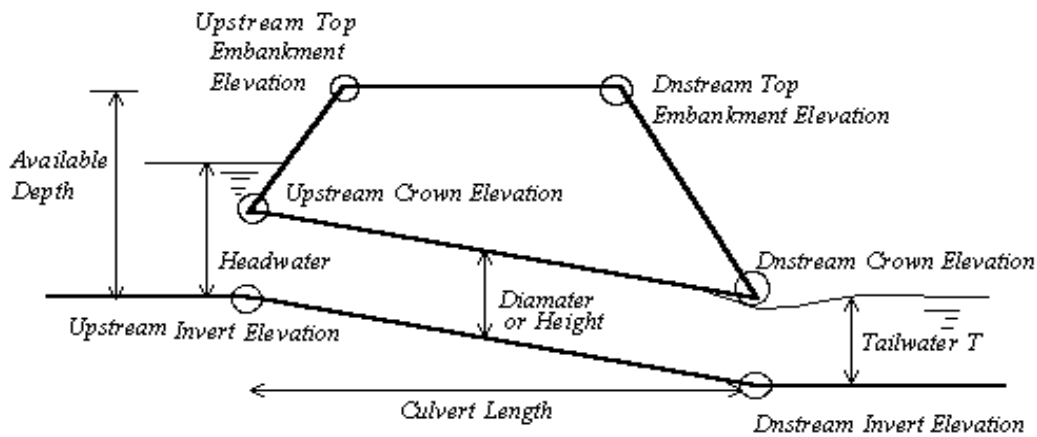
Width of Protection

T = 3 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC3 - Crossing Access South of Property - 5 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	50.00	ft
Barrel Invert Slope	So =	0.0100	ft/ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Top Embankment Elevation	EDT =	7014.00	ft
Upstream Top Embankment Elevation	EUT =	7014.00	ft
Design Headwater Depth (not elev.)	Hw =	0.36	ft
Tailwater Depth (not elev.)	Yt =	0.86	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	2.50	ft
Design Hw/D ratio	Hw/D =	0.24	

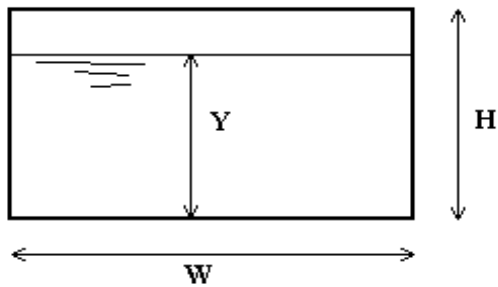
Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7011.50	ft
Upstream Crown Elevation	EUC =	7013.00	ft
Upstream Soil Cover Depth	Upsoil =	1.00	ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Crown Elevation	EDC =	7012.50	ft
Downstream Soil Cover Depth	Dnsoil =	1.50	ft

BOX CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Box ID: **PRC3 - Crossing Access South of Property - 100 Yr**



Design Information (Input)

Box conduit invert slope	So =	0.0100	ft/ft
Box Manning's n-value	n =	0.0130	
Box Width	W =	2.00	ft
Box Height	H =	1.50	ft
Design discharge	Q =	16.20	cfs

Full-flow capacity (Calculated)

Full-flow area	Af =	3.00	sq ft
Full-flow wetted perimeter	Pf =	7.00	ft
Full-flow capacity	Qf =	19.55	cfs

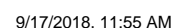
Calculations of Normal Flow Condition

Normal flow depth (<H)	Yn =	1.09	ft
Flow area	An =	2.18	sq ft
Wetted perimeter	Pn =	4.18	ft
Flow velocity	Vn =	7.43	fps
Discharge	Qn =	16.20	cfs
Percent Full	Flow =	82.9%	of full flow
Normal Depth Froude Number	Fr _n =	1.25	supercritical

Calculation of Critical Flow Condition

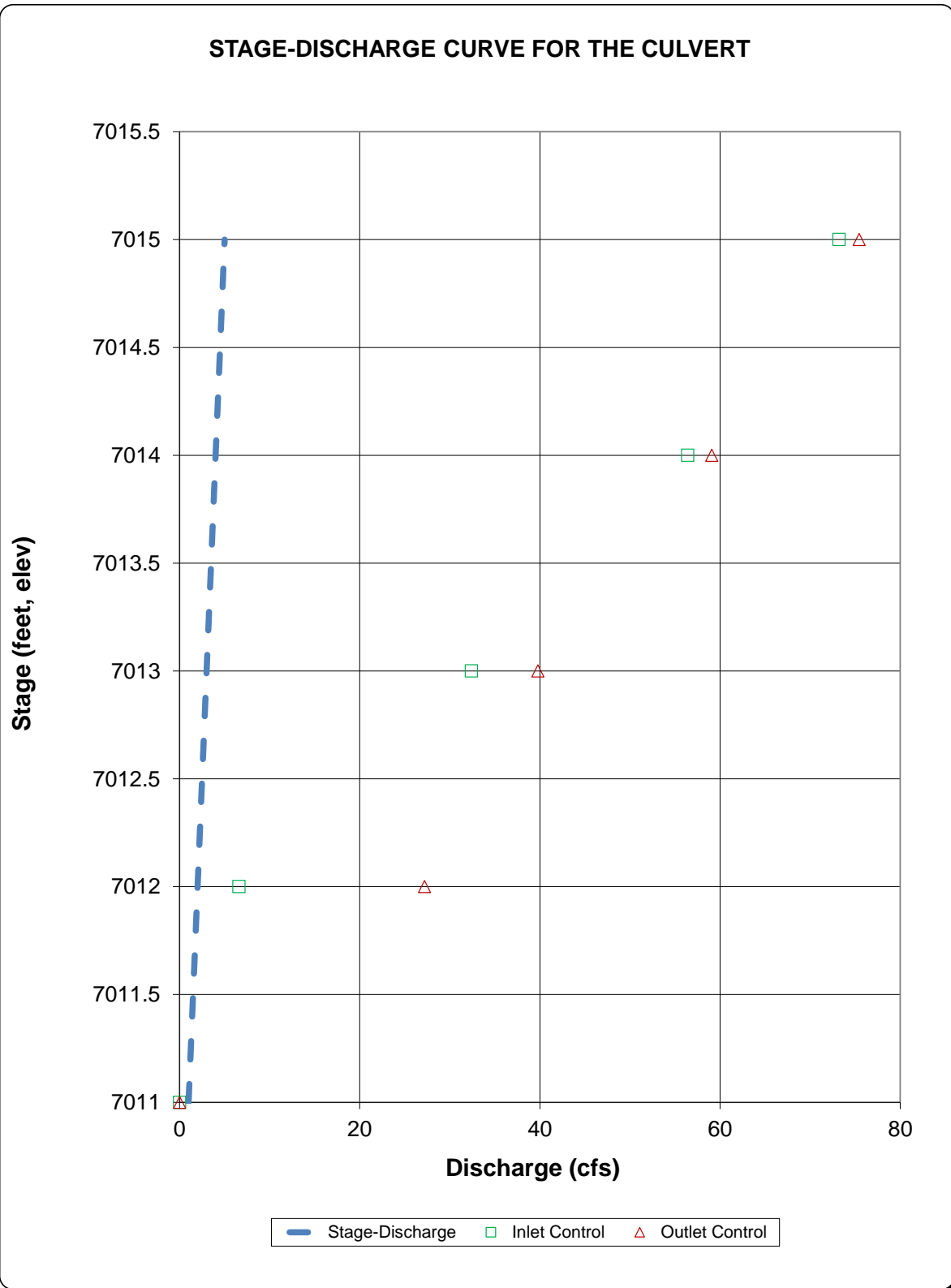
Critical flow depth	Yc =	1.27	ft
Critical flow area	Ac =	2.54	sq ft
Critical flow velocity	Vc =	6.39	fps
Critical Depth Froude Number	Fr _c =	1.00	

Project: **Voolmer Substation**
 Basin ID: **PRC3 - Crossing Access South of Property - 100 Yr**
 Status:



CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

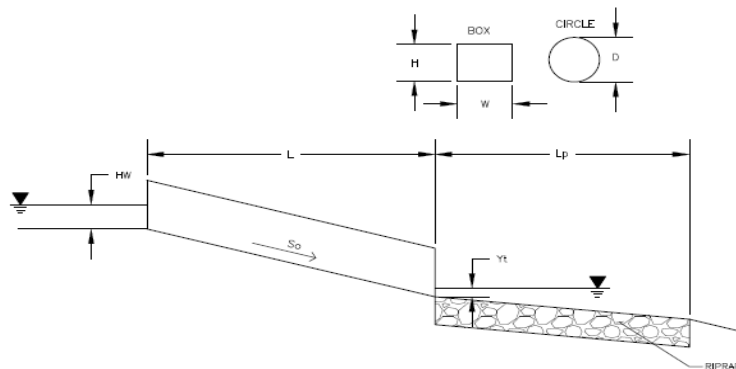
Project: Voolmer Substation
Basin ID: PRC3 - Crossing Access South of Property - 100 Yr



Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC3 - Crossing Access South of Property - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using H_a to calculate protection type.

Design Information (Input):

Design Discharge

Q = 48.5 cfs

Circular Culvert:

Barrel Diameter in Inches

D = inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) = 1.5 ft

Barrel Width (Span) in Feet

Width (Span) = 2 ft

Inlet Edge Type (Choose from pull-down list)

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels

No = 3

Inlet Elevation

Elev IN = 7011.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7011 ft

Culvert Length

L = 50 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k_b = 0

Exit Loss Coefficient

k_x = 1

Tailwater Surface Elevation

Elev Y_t = ft

Max Allowable Channel Velocity

V = 5 ft/s

Required Protection (Output):

Tailwater Surface Height

Y_t = 0.60 ft

Flow Area at Max Channel Velocity

A_t = 3.23 ft²

Culvert Cross Sectional Area Available

A = 3.00 ft²

Entrance Loss Coefficient

k_e = 0.40

Friction Loss Coefficient

k_f = 0.91

Sum of All Losses Coefficients

k_s = 2.31

Culvert Normal Depth

Y_n = 1.09 ft

Culvert Critical Depth

Y_c = 1.27 ft

Tailwater Depth for Design

d = 1.38 ft

Adjusted Diameter **OR** Adjusted Rise

H_a = 1.29 ft

Expansion Factor

$1/(2*\tan(\Theta))$ = 3.01

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/WH^{1.5}$ = 4.40 ft^{0.5}/s

Froude Number

Fr = 1.25

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y_t/H = 0.46

Supercritical!

Inlet Control Headwater

HW_i = 2.13 ft

Outlet Control Headwater

HW_o = 1.92 ft

Design Headwater Elevation

HW = 7,013.63 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/H = 1.42

Minimum Theoretical Riprap Size

d_{50} = 3 in

Nominal Riprap Size

d_{50} = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 11 ft

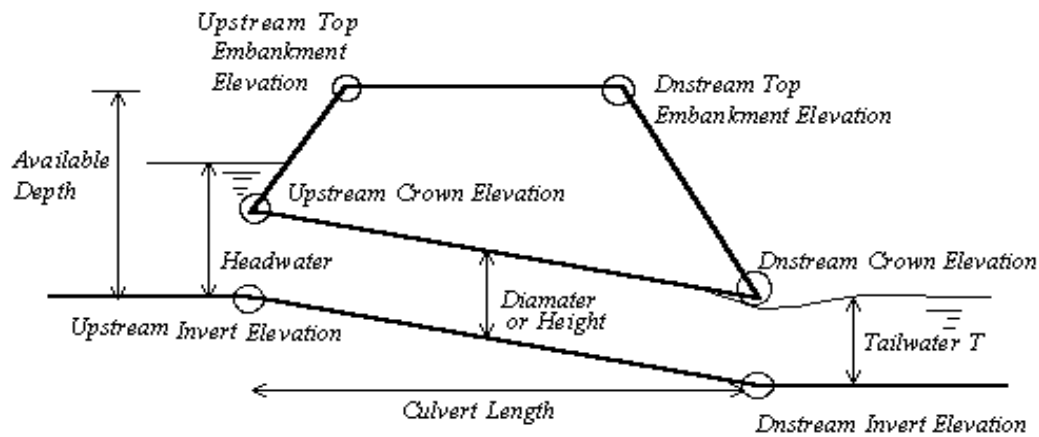
Width of Protection

T = 6 ft

Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC3 - Crossing Access South of Property - 100 Yr



Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	50.00	ft
Barrel Invert Slope	So =	0.0100	ft/ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Top Embankment Elevation	EDT =	7014.00	ft
Upstream Top Embankment Elevation	EUT =	7014.00	ft
Design Headwater Depth (not elev.)	Hw =	2.13	ft
Tailwater Depth (not elev.)	Yt =	1.38	ft

Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	2.50	ft
Design Hw/D ratio	Hw/D =	1.42	

Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7011.50	ft
Upstream Crown Elevation	EUC =	7013.00	ft
Upstream Soil Cover Depth	Upsoil =	1.00	ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Crown Elevation	EDC =	7012.50	ft
Downstream Soil Cover Depth	Dnsoil =	1.50	ft

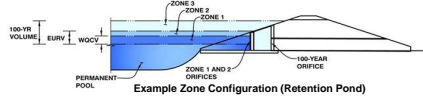
WATER QUALITY CALCULATIONS

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

Project: Volmer Substation

Basin ID: PR-3 (Design Point 3)



Example Zone Configuration (Retention Pond)

Required Volume Calculation

Selected BMP Type =	SF
Watershed Area =	1.70 acres
Watershed Length =	180 ft
Watershed Slope =	0.010 ft/ft
Watershed Imperviousness =	40.00% percent
Percentage Hydrologic Soil Group A =	100.00% percent
Percentage Hydrologic Soil Group B =	0.0% percent
Percentage Hydrologic Soil Groups C/D =	0.0% percent
Desired WQCV Drain Time =	40.0 hours
Location for 1-hr Rainfall Depths =	Denver - Capitol Building
Water Quality Capture Volume (WQCV) =	0.020 acre-feet
Excess Urban Runoff Volume (EURV) =	0.074 acre-feet
2-yr Runoff Volume (P1 = 1.19 in.) =	0.050 acre-feet
5-yr Runoff Volume (P1 = 1.5 in.) =	0.066 acre-feet
10-yr Runoff Volume (P1 = 1.75 in.) =	0.082 acre-feet
25-yr Runoff Volume (P1 = 2 in.) =	0.105 acre-feet
50-yr Runoff Volume (P1 = 2.25 in.) =	0.136 acre-feet
100-yr Runoff Volume (P1 = 2.52 in.) =	0.175 acre-feet
500-yr Runoff Volume (P1 = 3.14 in.) =	0.265 acre-feet
Approximate 2-yr Detention Volume =	0.047 acre-feet
Approximate 5-yr Detention Volume =	0.062 acre-feet
Approximate 10-yr Detention Volume =	0.077 acre-feet
Approximate 25-yr Detention Volume =	0.095 acre-feet
Approximate 50-yr Detention Volume =	0.107 acre-feet
Approximate 100-yr Detention Volume =	0.125 acre-feet

Note: L / W Ratio < 1
L / W Ratio = 0.4

Drain Time Too Long

Optional User Override 1-hr Precipitation	1.19 inches
	1.50 inches
	1.75 inches
	2.00 inches
	2.25 inches
	2.52 inches

Stage-Storage Calculation

Zone 1 Volume (WQCV) =	0.020 acre-feet
Select Zone 2 Storage Volume (Optional) =	acre-feet
Select Zone 3 Storage Volume (Optional) =	acre-feet
Total Detention Basin Volume =	0.020 acre-feet
Initial Surcharge Volume (ISV) =	N/A ft³
Initial Surcharge Depth (ISD) =	N/A ft
Total Available Detention Depth (H _{total}) =	1.00 ft
Depth of Trickle Channel (H _{TC}) =	N/A ft
Slope of Trickle Channel (S _{TC}) =	N/A ft/ft
Slopes of Main Basin Sides (S _{main}) =	4:01 H:V
Basin Length-to-Width Ratio (R _{L/W}) =	4
Initial Surcharge Area (A _{ISV}) =	0 ft²
Surcharge Volume Length (L _{SV}) =	0.0 ft
Surcharge Volume Width (W _{SV}) =	0.0 ft
Depth of Basin Floor (H _{basin}) =	0.00 ft
Length of Basin Floor (L _{basin}) =	59.2 ft
Width of Basin Floor (W _{basin}) =	14.8 ft
Area of Basin Floor (A _{basin}) =	875 ft²
Volume of Basin Floor (V _{basin}) =	0 ft³
Depth of Main Basin (H _{main}) =	1.00 ft
Length of Main Basin (L _{main}) =	59.5 ft
Width of Main Basin (W _{main}) =	15.1 ft
Area of Main Basin (A _{main}) =	900 ft²
Volume of Main Basin (V _{main}) =	888 ft³
Calculated Total Basin Volume (V _{total}) =	0.020 acre-feet

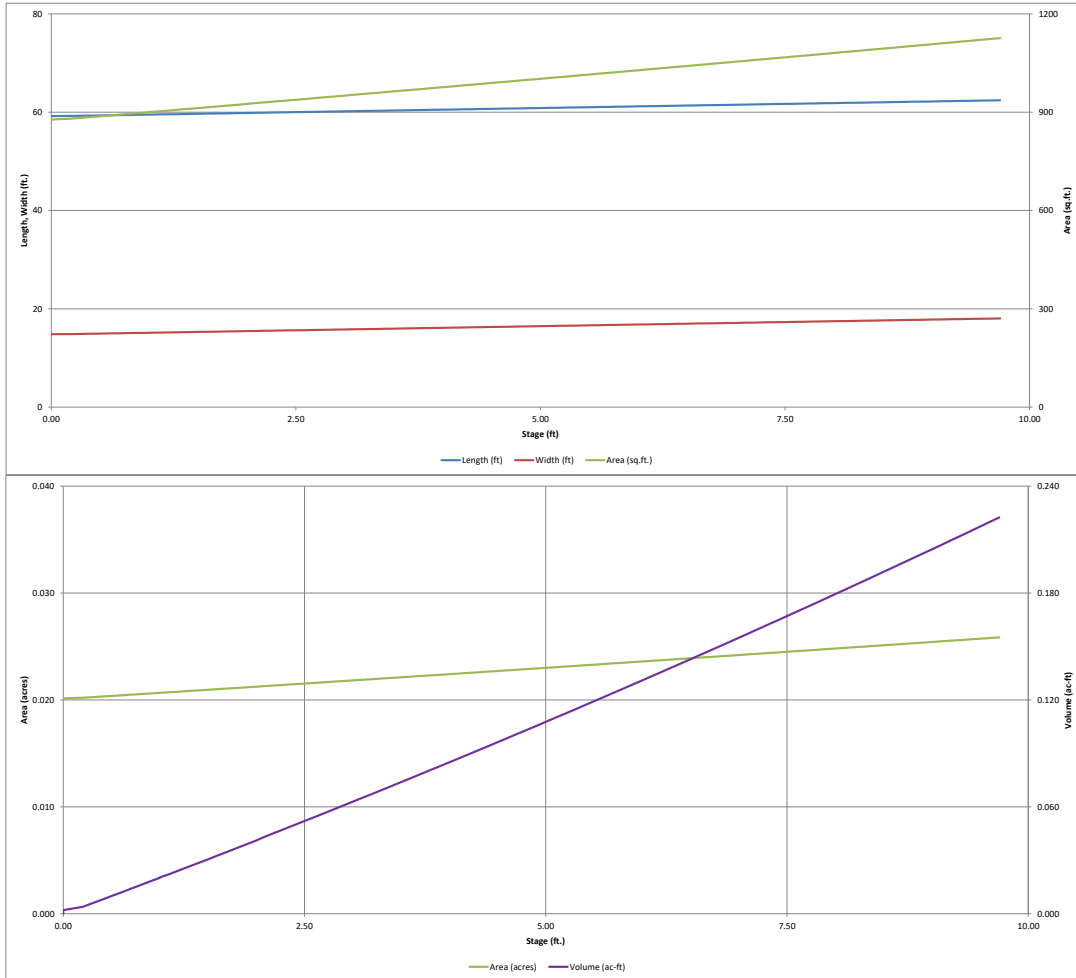
Total detention volume is less than 100-year volume.

Smain not typical.

Depth Increment =	0.1							
Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft²)	Optional Override Area (ft²-2)	Volume (ft³)	Volume (ac-ft)
Media Surface	0.00		59.2	14.8	875		0.020	
	0.10		59.2	14.8	878		88	0.002
	0.20		59.2	14.9	880		167	0.004
	0.30		59.3	14.9	883		255	0.006
	0.40		59.3	14.9	885		343	0.008
	0.50		59.3	15.0	888		432	0.010
	0.60		59.4	15.0	890		521	0.012
	0.70		59.4	15.0	893		610	0.014
	0.80		59.4	15.1	895		699	0.016
	0.90		59.5	15.1	898		789	0.018
Zone 1 (WQCV)	1.00		59.5	15.1	900		879	0.020
	1.10		59.5	15.2	903		888	0.021
	1.20		59.6	15.2	905		969	0.022
	1.30		59.6	15.2	908		1,059	0.024
	1.40		59.6	15.3	910		1,150	0.026
	1.50		59.7	15.3	913		1,241	0.028
	1.60		59.7	15.3	915		1,332	0.031
	1.70		59.7	15.4	918		1,423	0.033
	1.80		59.8	15.4	920		1,515	0.035
	1.90		59.8	15.4	923		1,607	0.037
	2.00		59.8	15.5	925		1,699	0.039
	2.10		59.9	15.5	928		1,791	0.041
	2.20		59.9	15.5	930		1,883	0.043
	2.30		59.9	15.6	933		1,986	0.046
	2.40		60.0	15.6	935		2,079	0.048
	2.50		60.0	15.6	938		2,173	0.050
	2.60		60.0	15.7	941		2,267	0.052
	2.70		60.1	15.7	943		2,360	0.054
	2.80		60.1	15.7	946		2,455	0.056
	2.90		60.1	15.8	948		2,549	0.059
	3.00		60.2	15.8	951		2,644	0.061
	3.10		60.2	15.8	953		2,739	0.063
	3.20		60.2	15.9	956		2,834	0.065
	3.30		60.3	15.9	958		2,929	0.067
	3.40		60.3	15.9	961		3,025	0.069
	3.50		60.3	16.0	963		3,121	0.072
	3.60		60.4	16.0	966		3,217	0.074
	3.70		60.4	16.0	969		3,314	0.076
	3.80		60.4	16.1	971		3,410	0.078
	3.90		60.5	16.1	974		3,507	0.081
	4.00		60.5	16.1	976		3,605	0.083
	4.10		60.5	16.2	979		3,702	0.085
	4.20		60.6	16.2	981		3,800	0.087
	4.30		60.6	16.2	984		3,898	0.089
	4.40		60.6	16.3	987		3,996	0.092
	4.50		60.7	16.3	989		4,095	0.094
	4.60		60.7	16.3	992		4,194	0.096
	4.70		60.7	16.4	994		4,293	0.099
	4.80		60.8	16.4	997		4,392	0.101
	4.90		60.8	16.4	999		4,491	0.103
	5.00		60.8	16.5	1,002		4,591	0.105
	5.10		60.9	16.5	1,005		4,691	0.108
	5.20		60.9	16.5	1,007		4,792	0.110
	5.30		60.9	16.6	1,010		4,892	0.112
	5.40		61.0	16.6	1,012		4,993	0.115
	5.50		61.0	16.6	1,015		5,094	0.117
	5.60		61.0	16.7	1,018		5,196	0.119
	5.70		61.1	16.7	1,020		5,297	0.122
	5.80		61.1	16.7	1,023		5,399	0.124
	5.90		61.2	16.8	1,025		5,501	0.126
6.00		61.2	16.8	1,028		5,604	0.129	
6.10		61.2	16.8	1,031		5,706	0.131	
6.20		61.3	16.9	1,033		5,808	0.133	
6.30		61.3	16.9	1,036		5,912	0.136	
6.40		61.3	16.9	1,038		6,016	0.138	
6.50		61.4	17.0	1,041		6,120	0.140	
6.60		61.4	17.0	1,044		6,224	0.143	
6.70		61.4	17.0	1,046		6,328	0.145	
6.80		61.5	17.1	1,049		6,432	0.148	
6.90		61.5	17.1	1,052		6,537	0.150	
7.00		61.5	17.1	1,054		6,642	0.152	
7.10		61.6	17.2	1,057		6,747	0.155	
7.20		61.6	17.2	1,060		6,853	0.157	
7.30		61.6	17.2	1,062		6,959	0.160	
7.40		61.7	17.3	1,065		7,065	0.162	
7.50		61.7	17.3	1,067		7,171	0.165	
7.60		61.7	17.3	1,070		7,278	0.167	
7.70		61.8	17.4	1,073		7,385	0.170	
7.80		61.8	17.4	1,075		7,492	0.172	
7.90		61.8	17.4	1,078		7,599	0.174	
8.00		61.9	17.5	1,081		7,707	0.177	
8.10		61.9	17.5	1,083		7,815	0.179	
8.20		61.9	17.5	1,086		7,923	0.182	
8.30		62.0	17.6	1,089		8,032	0.184	
8.40		62.0	17.6	1,091		8,140	0.187	
8.50		62.0	17.6	1,094		8,249	0.189	
8.60		62.1	17.7	1,097		8,359	0.192	
8.70		62.1	17.7	1,099		8,468	0.194	
8.80		62.1	17.7	1,102		8,578	0.197	
8.90		62.2	17.8	1,105		8,688	0.199	
9.00		62.2	17.8	1,107		8,798	0.202	
9.10		62.2	17.8	1,110		8,909	0.205	
9.20		62.3	17.9	1,113		9,020	0.207	
9.30		62.3	17.9	1,115		9,131	0.210	
9.40		62.3	17.9	1,118		9,242	0.212	
9.50		62.4	18.0	1,121		9,354	0.215	
9.60		62.4	18.0	1,123		9,466	0.217	
9.70		62.4	18.0	1,126		9,578	0.220	

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

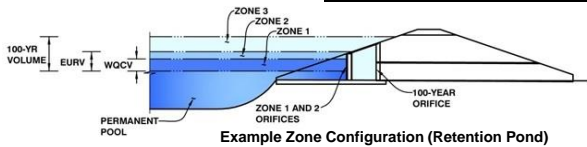


Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Project: Vollmer Substation

Basin ID: PR-3 (Design Point 3)



Example Zone Configuration (Retention Pond)

	Stage (ft)	Zone Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	1.00	0.020	Filtration Media
Zone 2			
Zone 3			
		0.020	Total

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration BMP)

Underdrain Orifice Invert Depth =	2.17	ft (distance below the filtration media surface)
Underdrain Orifice Diameter =	0.37	inches

Calculated Parameters for Underdrain

Underdrain Orifice Area =	0.0	ft ²
Underdrain Orifice Centroid =	0.02	feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation BMP)

Invert of Lowest Orifice =		ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =		ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =		inches
Orifice Plate: Orifice Area per Row =		inches

Calculated Parameters for Plate

WQ Orifice Area per Row =	N/A	ft ²
Elliptical Half-Width =	N/A	feet
Elliptical Slot Centroid =	N/A	feet
Elliptical Slot Area =	N/A	ft ²

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (optional)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								
	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								

User Input: Vertical Orifice (Circular or Rectangular)

	Not Selected	Not Selected	
Invert of Vertical Orifice =			ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Vertical Orifice =			ft (relative to basin bottom at Stage = 0 ft)
Vertical Orifice Diameter =			inches

Calculated Parameters for Vertical Orifice

	Not Selected	Not Selected	
Vertical Orifice Area =			ft ²
Vertical Orifice Centroid =			feet

User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)

	Not Selected	Not Selected	
Overflow Weir Front Edge Height, H _o =	7025.00		ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	2.00		feet
Overflow Weir Slope =	0.00		H:V (enter zero for flat grate)
Horiz. Length of Weir Sides =	2.00		feet
Overflow Grate Open Area % =	70%		%, grate open area/total area
Debris Clogging % =	50%		%

Calculated Parameters for Overflow Weir

	Not Selected	Not Selected	
Height of Grate Upper Edge, H _g =	7025.00		feet
Over Flow Weir Slope Length =	2.00		feet
Grate Open Area / 100-yr Orifice Area =			should be ≥ 4
Overflow Grate Open Area w/o Debris =	2.80		ft ²
Overflow Grate Open Area w/ Debris =	1.40		ft ²

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Not Selected	Not Selected	
Depth to Invert of Outlet Pipe =			ft (distance below basin bottom at Stage = 0 ft)
Circular Orifice Diameter =			inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Not Selected	Not Selected	
Outlet Orifice Area =			ft ²
Outlet Orifice Centroid =			feet
Half-Central Angle of Restrictor Plate on Pipe =	N/A	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage =		ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =		feet
Spillway End Slopes =		H:V
Freeboard above Max Water Surface =		feet

Calculated Parameters for Spillway

Spillway Design Flow Depth =		feet
Stage at Top of Freeboard =		feet
Basin Area at Top of Freeboard =		acres

Routed Hydrograph Results

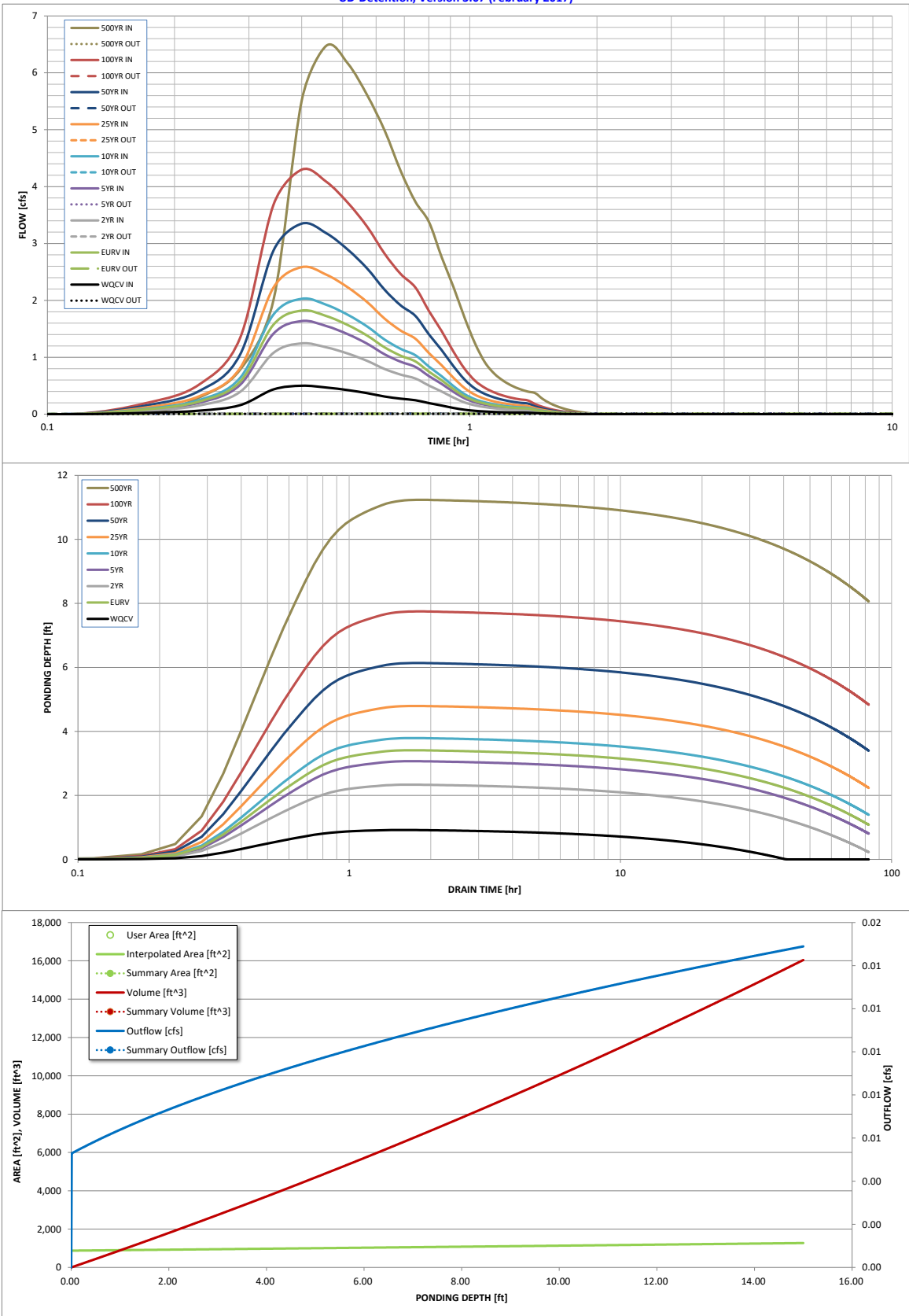
	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
Design Storm Return Period =									
One-Hour Rainfall Depth (in) =	0.53	1.07	1.19	1.50	1.75	2.00	2.25	2.52	3.14
Calculated Runoff Volume (acre-ft) =	0.020	0.074	0.050	0.066	0.082	0.105	0.136	0.175	0.265
OPTIONAL Override Runoff Volume (acre-ft) =									
Inflow Hydrograph Volume (acre-ft) =	0.020	0.073	0.049	0.065	0.081	0.104	0.136	0.175	0.265
Predevelopment Unit Peak Flow, q (cfs/acre) =	0.00	0.00	0.00	0.01	0.01	0.03	0.23	0.56	1.25
Predevelopment Peak Q (cfs) =	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.9	2.1
Peak Inflow Q (cfs) =	0.5	1.8	1.2	1.6	2.0	2.6	3.3	4.3	6.5
Peak Outflow Q (cfs) =	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.8	0.4	0.2	0.0	0.0	0.0
Structure Controlling Flow =	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time to Drain 97% of Inflow Volume (hours) =	40	≥120	≥120	≥120	≥120	≥120	≥120	≥120	≥120
Time to Drain 99% of Inflow Volume (hours) =	40	≥120	≥120	≥120	≥120	≥120	≥120	≥120	≥120
Maximum Ponding Depth (ft) =	0.92	3.41	2.33	3.07	3.79	4.79	6.14	7.75	11.24
Area at Maximum Ponding Depth (acres) =	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Maximum Volume Stored (acre-ft) =	0.019	0.072	0.048	0.064	0.080	0.103	0.134	0.173	0.263

Maximum drain times need to be met. Reference

https://udfcd.org/wp-content/uploads/uploads/resources/guidance%20documents/UDFCD_Stormwater_Legislation_Memo_2016-03-09.pdf

Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)



S-A-V-D Chart Axis Override	X-axis	Left Y-Axis	Right Y-Axis
minimum bound			
maximum bound			

DRAINAGE MAPS

VOLLMER SUBSTATION
EL PASO COUNTY, CO
EXISTING DRAINAGE MAP
SEPTEMBER 2018

DESIGN POINT SUMMARY

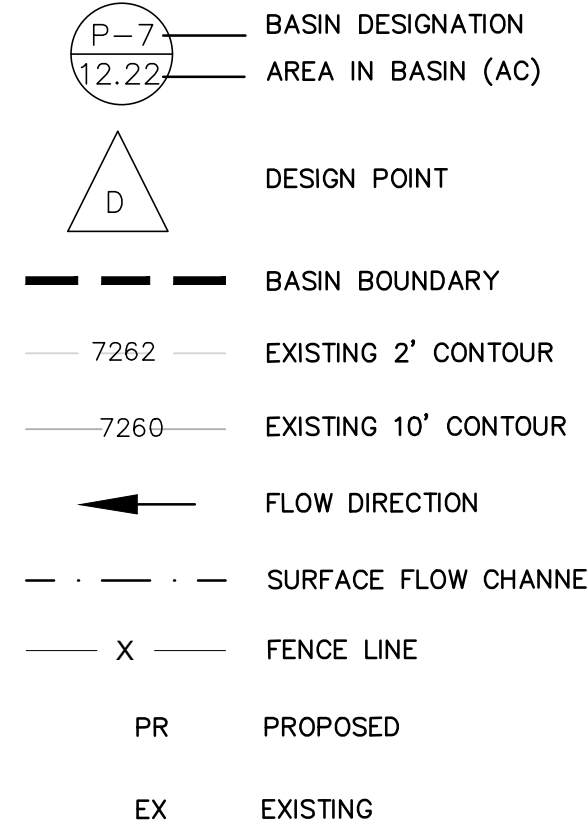
DP	CONTRIBUTING BASINS	AREA AC.	Q5 CFS	Q10 CFS	Q100 CFS
Z	OS-1	138	---	20	---
Y	OS-2	79	7.1	---	43.7
A	EX-A	2.77	0.7	---	4.8
B	EX-B, OS-2	81	7.7	---	36.6*

* NOTE: THE EXISTING SWALE EXS1 HAS A MAX CAPACITY OF 36.6 CFS.

PROPOSED CONDITIONS

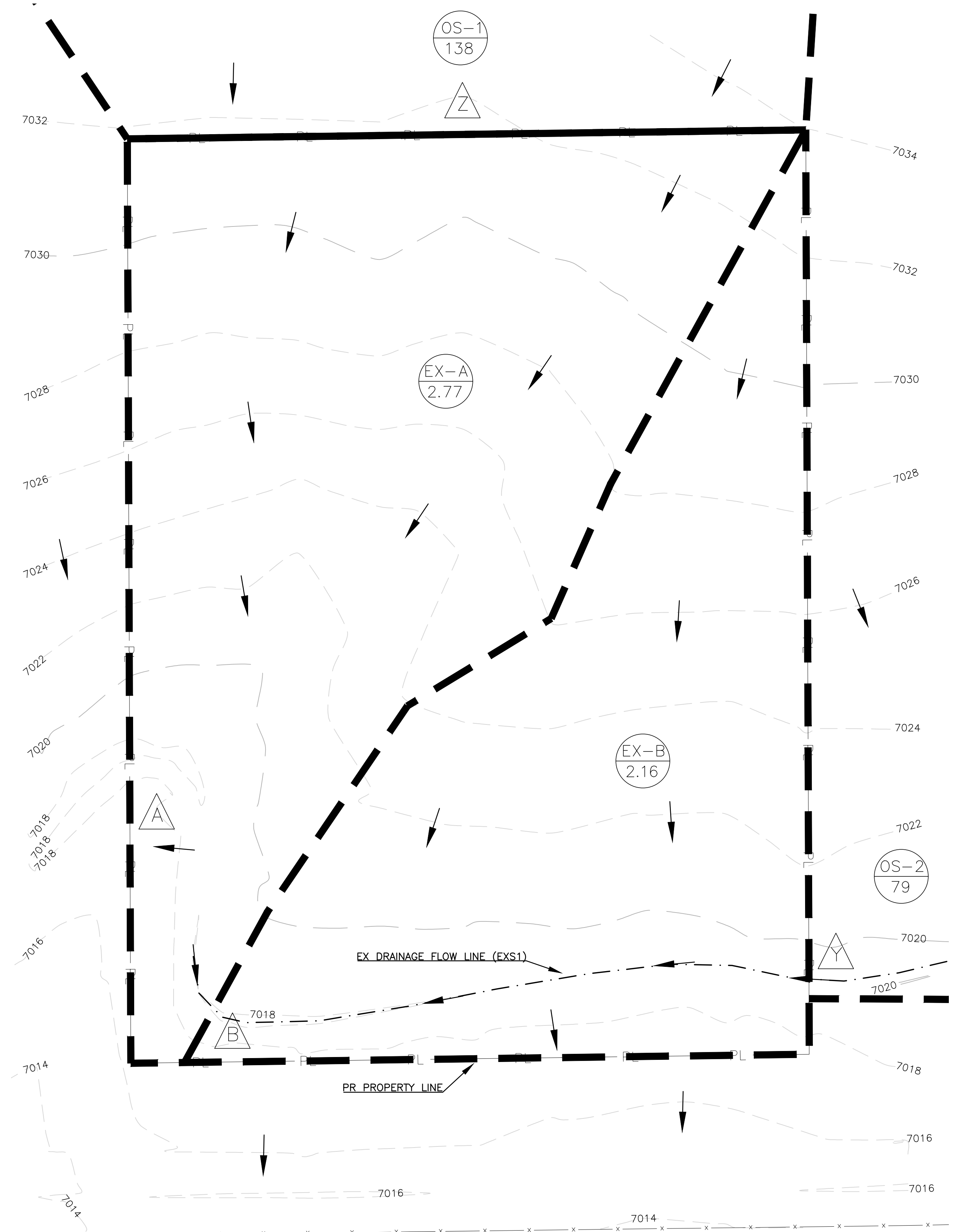
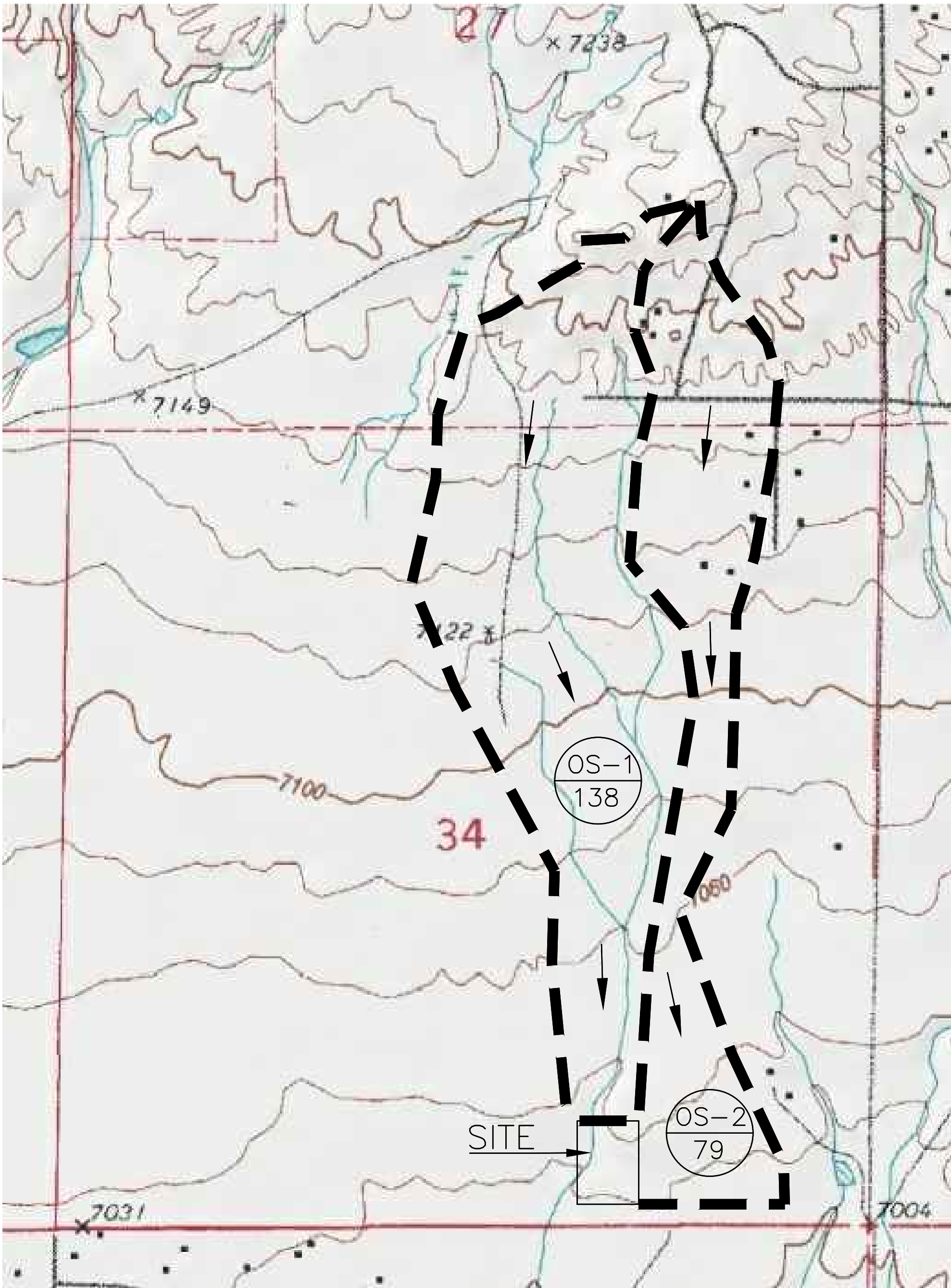
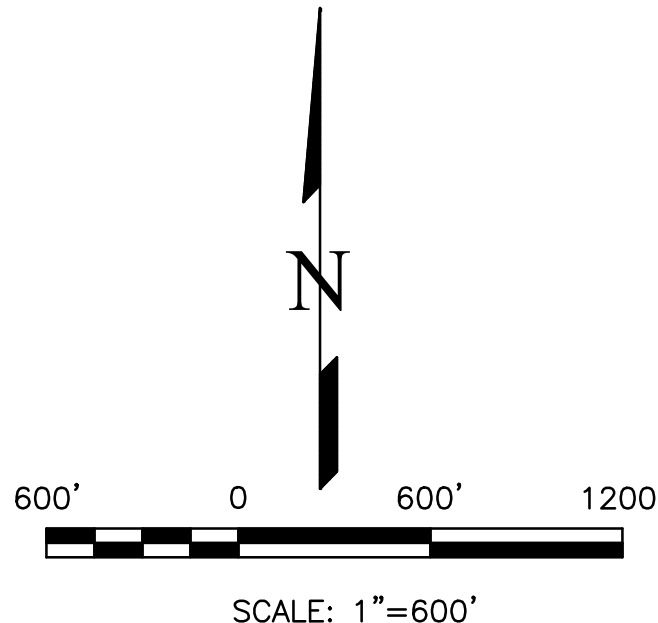
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
EX-A	2.77	0.9	---	6.4
EX-B	2.16	0.7	---	5.0

LEGEND



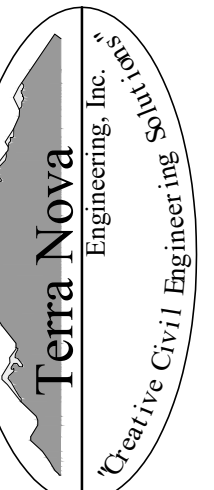
NOTES

1. EXISTING GROUND SURFACE CONDITIONS ARE PRIMARILY PRAIRIE GRASSES IN NATURAL CONDITION.

[illegible]

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ATTN: DAVE WALDMAN
11140 E. WOODMEAD
PEYTON, CO 80555
(719) 495-2211



21 S. 23RD STREET
COLORADO SPRINGS, CO 80904
OFFICE: 719-635-6422
AX: 719-635-6426
www.tnesinc.com

VOLLMER SUBSTATION

SIGNED BY LD

AWN BY DLF

CHECKED BY LD

SCALE 1"=40'

SCALE NA

3 NO. 1845.00

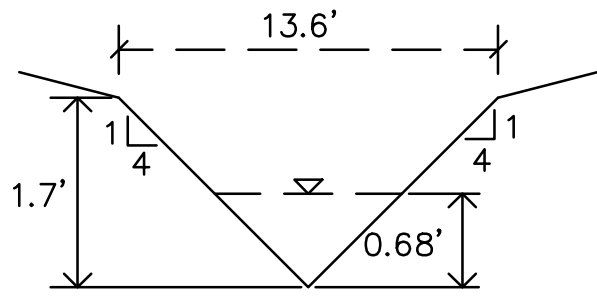
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VOLLMER SUBSTATION
EL PASO COUNTY, CO
DEVELOPED DRAINAGE MAP
SEPTEMBER 2018

DESIGN POINT SUMMARY

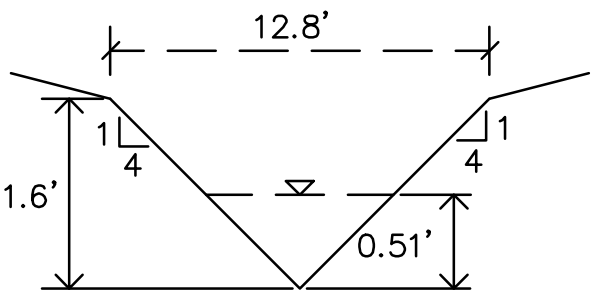
DP	CONTRIBUTING BASINS	AREA AC.	Q5 CFS	Q10 CFS	Q100 CFS
Z	OS-1	138	---	20	---
Y	OS-2	79	7.1	---	36.6*
1	PR-1	0.42	0.1	---	0.7
2	PR-2	1.70	1.6	---	4.4
3	PR-3	0.15	0.1	---	0.4
4	PR-3, PR-4, OS-2	81	8.6	---	36.6*
5	PR-1,PR-2,PR-3,PR-4,PR-5,OS-2	84	9.7	---	47.5*
6	PR-6	0.06	0.03	---	0.2
7	PR-7	0.26	0.3	---	1.1
8	PR-8	0.58	0.4	---	2.1
9	PR-9	3.09	4.1	---	13.6

* NOTE: THE EXISTING SWALE EXS1 HAS A MAX CAPACITY OF 36.6 CFS.



Q = 0.7 CFS
SLOPE = 0.5%
n VALUE = 0.13
DEPTH = 0.68'
VELOCITY = 0.39 FT/S

SWALE CROSS SECTION - PRS1 (TYP)



Q = 0.4 CFS
SLOPE = 0.8%
n VALUE = 0.13
DEPTH = 0.51'
VELOCITY = 0.40 FT/S

SWALE CROSS SECTION - PRS2 (TYP)

PROPOSED CONDITIONS

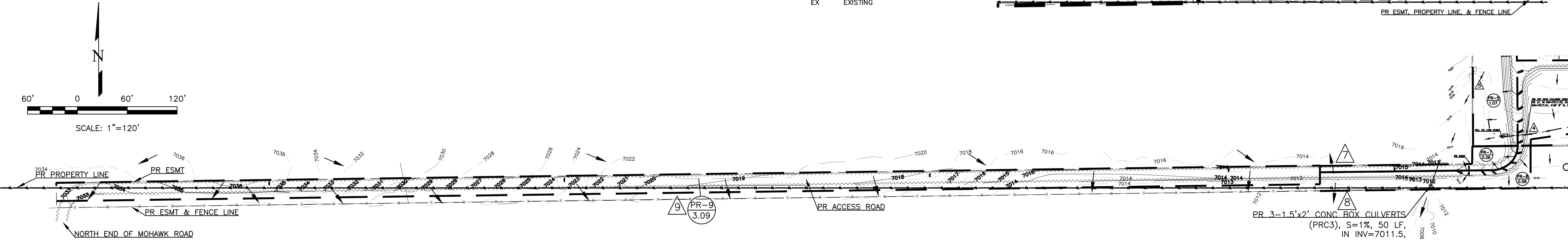
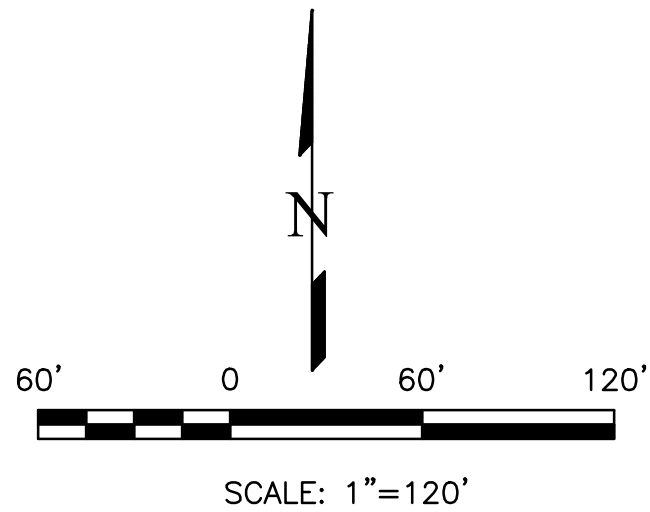
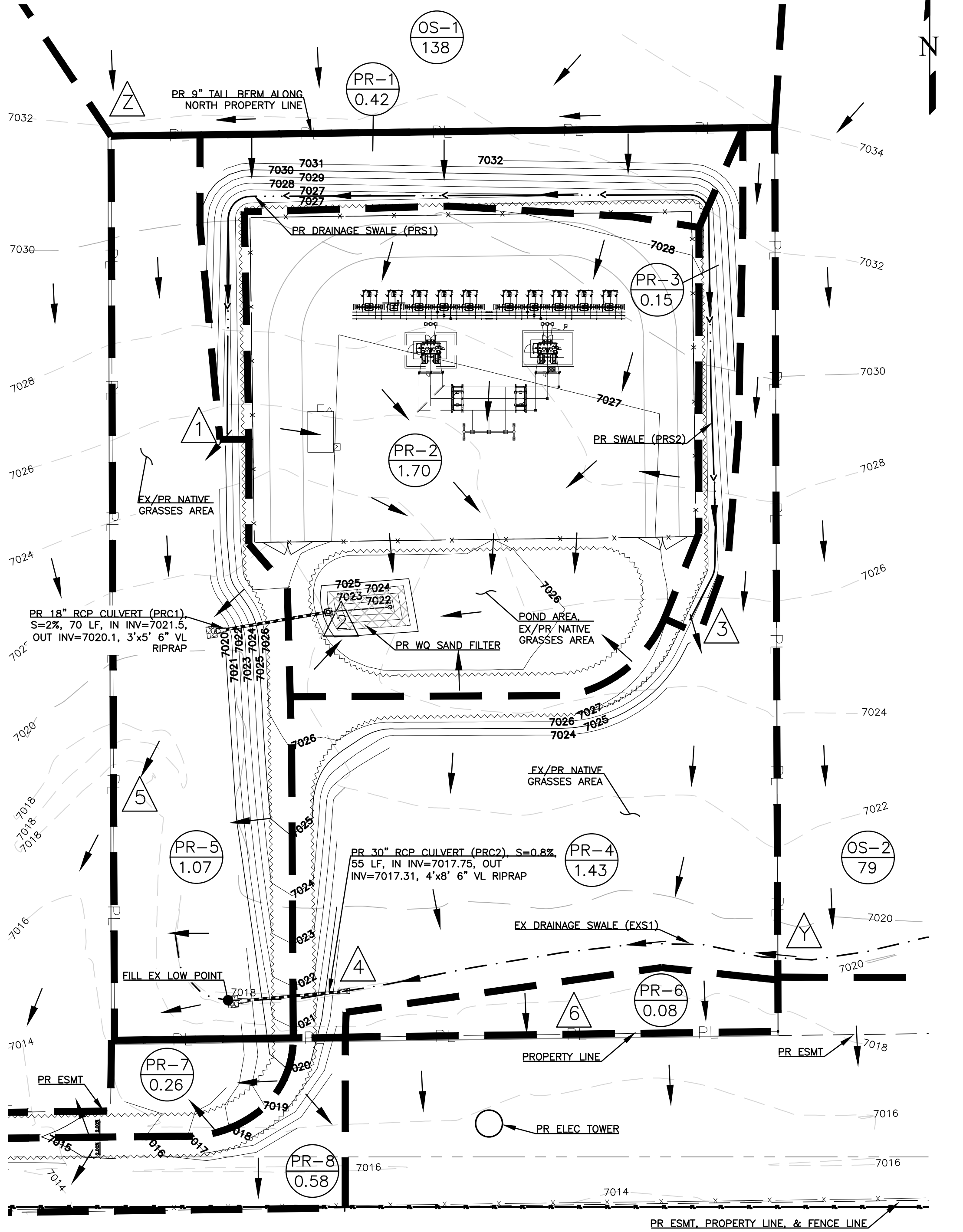
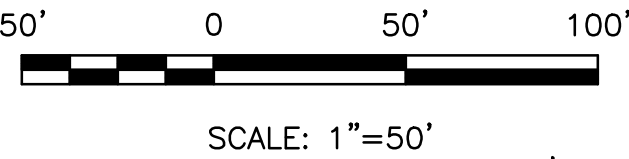
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
PR-1	0.42	0.1	---	0.7
PR-2	1.70	1.6	---	4.4
PR-3	0.15	0.1	---	0.4
PR-4	1.43	0.4	---	2.4
PR-5	1.07	0.4	---	3.0
PR-6	0.06	0.03	---	0.2
PR-7	0.26	0.3	---	1.1
PR-8	0.58	0.4	---	2.1
PR-9	3.09	4.1	---	13.6

LEGEND

- BASIN DESIGNATION
- AREA IN BASIN (AC)
- DESIGN POINT
- BASIN BOUNDARY
- EXISTING 2' CONTOUR
- EXISTING 10' CONTOUR
- FLOW DIRECTION
- SURFACE FLOW CHANNEL
- FENCE LINE
- PROPOSED 1' CONTOUR
- PROPOSED 5' CONTOUR
- PROPOSED EDGE OF GRAVEL
- PROPOSED
- EXISTING

NOTES

1. THE MAJORITY OF PROPOSED BASINS PR-2, PR-5, AND PR-6 HAVE AN EXISTING AND PROPOSED GROUND SURFACE OF ESTABLISHED NATIVE GRASSES.



DATE

DESCRIPTION

REVISIONS

NO.

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PREPARED FOR:

MVEA

ATTN: DAVE WALDNER

11140 E. WOODMEN RD

PEYTON, CO 80831

(719) 495-2283

721 S. 2960 STREET

COLORADO SPRINGS, CO 80904

OFFICE: 719-635-6422

FAX: 719-635-6426

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VOLLMER SUBSTATION

DEVELOPED DRAINAGE MAP

DESIGNED BY LD

DRAWN BY DLF

CHECKED BY LD

H-SCALE AS SHOWN

V-SCALE NA

JOB NO. 1845.00

DATE ISSUED 09/17/18

SHEET NO. 2 OF 3

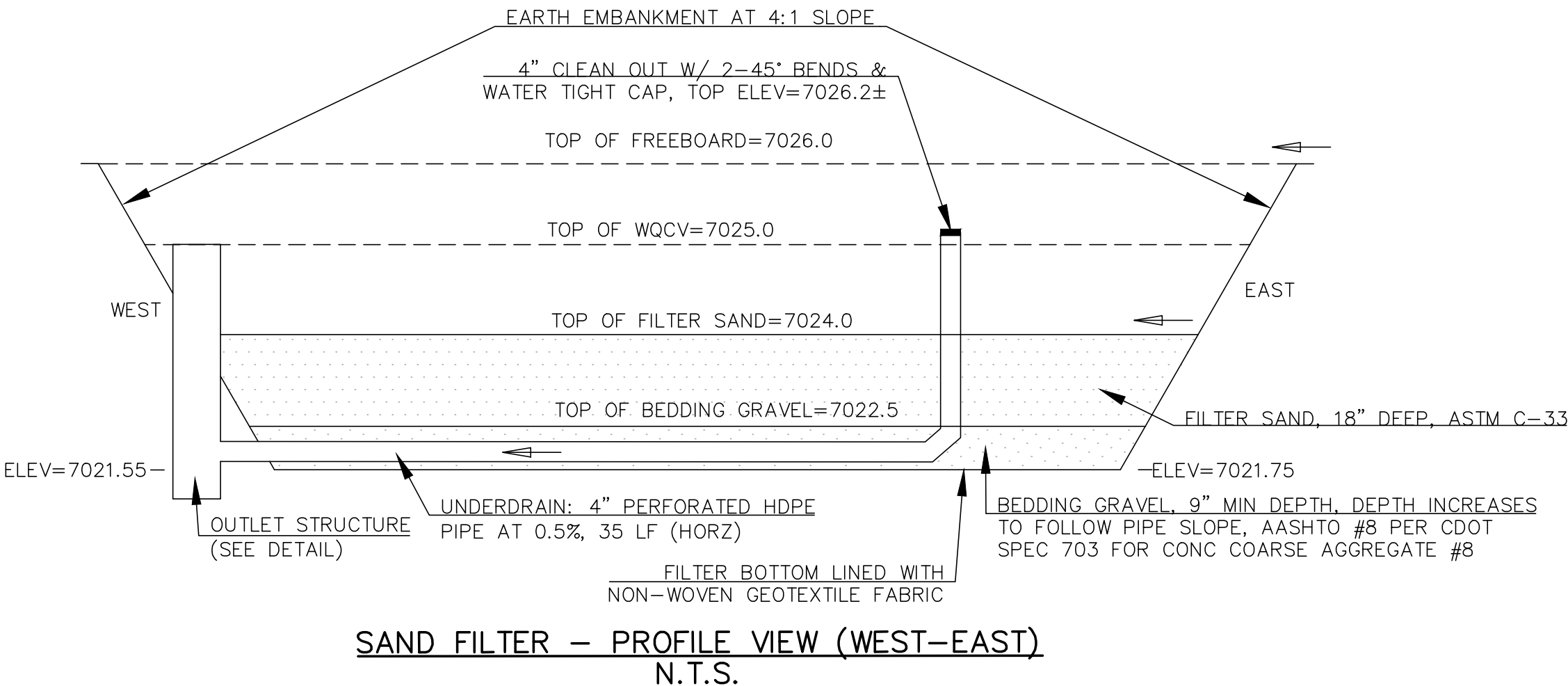
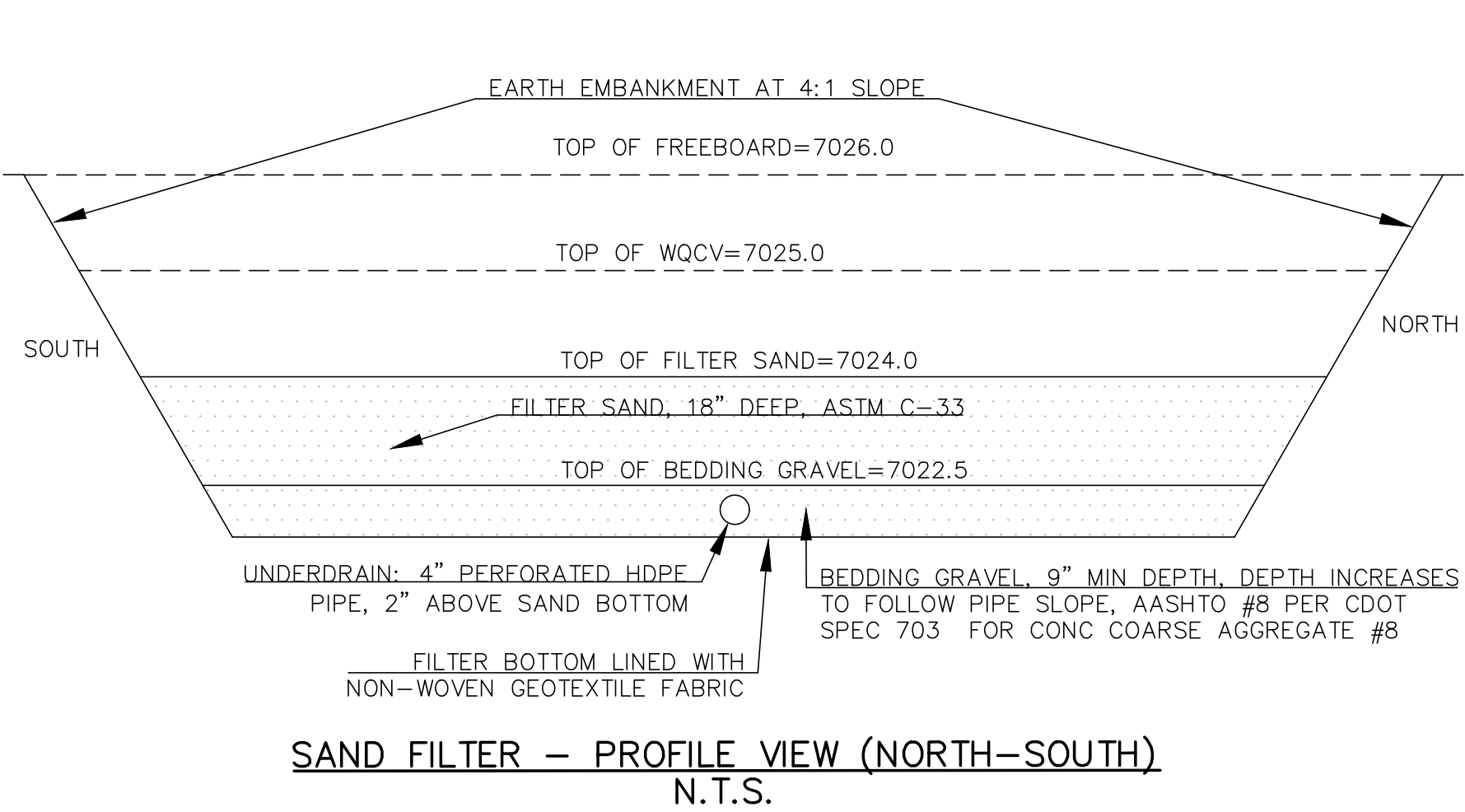
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VOLLMER SUBSTATION
EL PASO COUNTY, CO
WATER QUALITY DETAILS
SEPTEMBER 2018

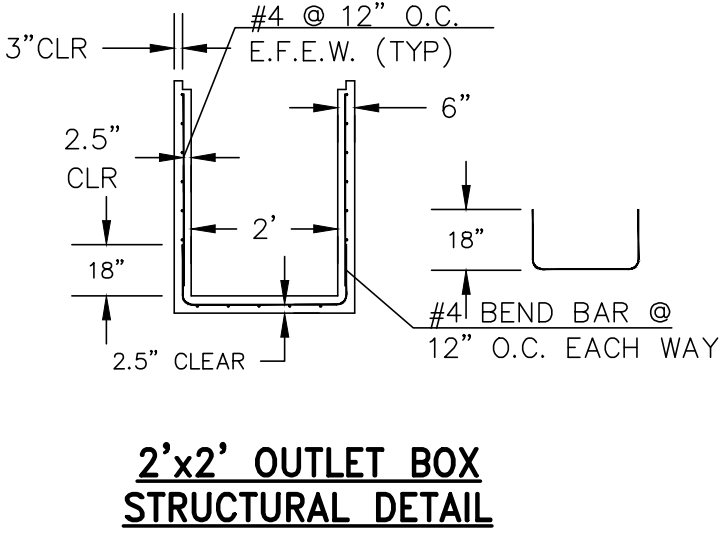
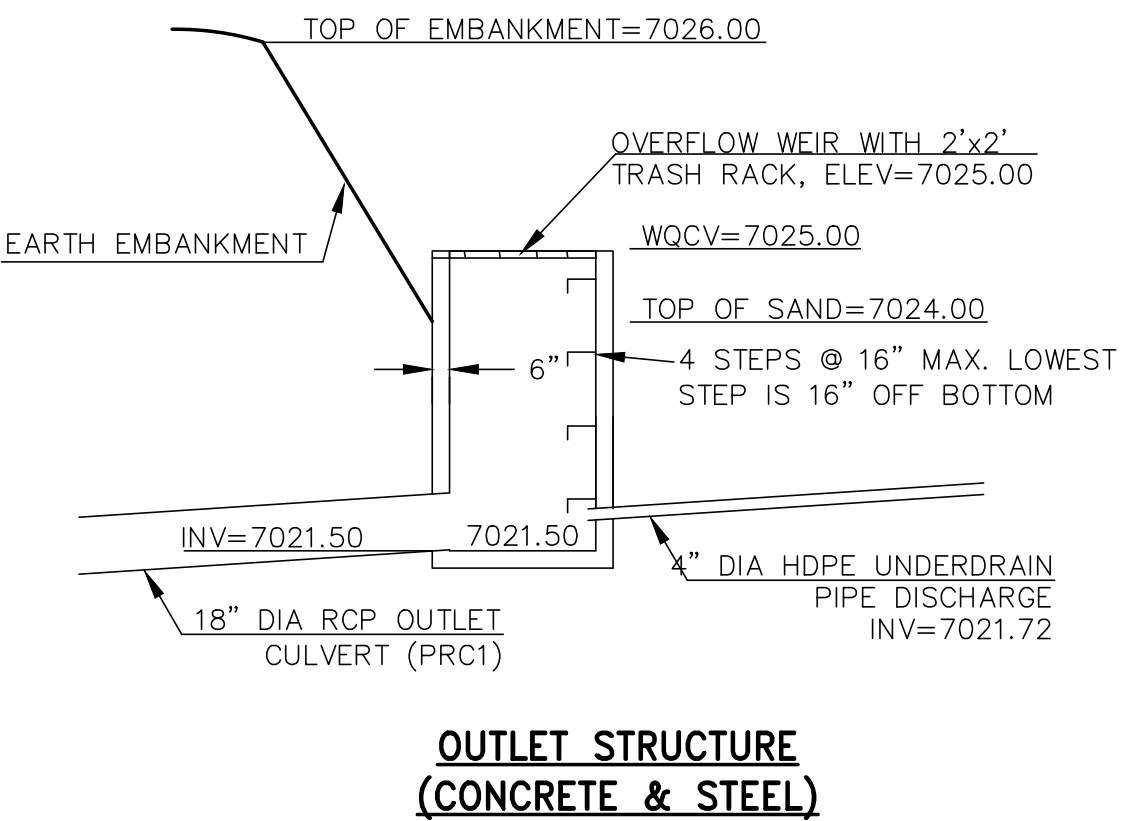
NOTES

1. COMBINED WQCV PROVIDED BY SAND FILTER = 2662 CU FT = 0.06 AC-FT.
2. PROTECT SAND FILTERS FROM SEDIMENT LOADING DURING CONSTRUCTION ACTIVITIES. SITE MUST BE STABILIZED BEFORE ALLOWING FLOW INTO THE SAND FILTERS.

PRELIMINARY
NOT FOR CONSTRUCTION

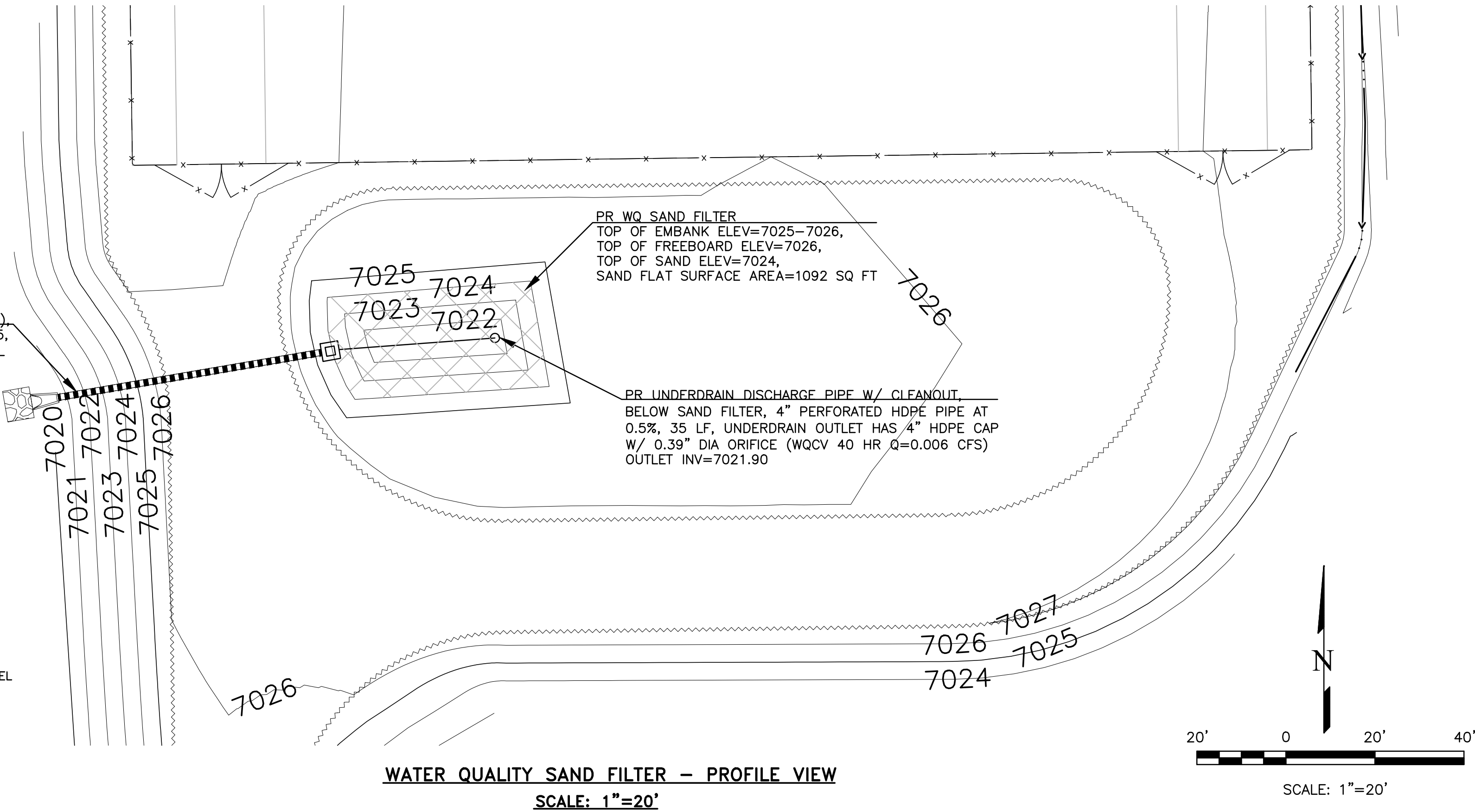


PRELIMINARY
NOT FOR CONSTRUCTION



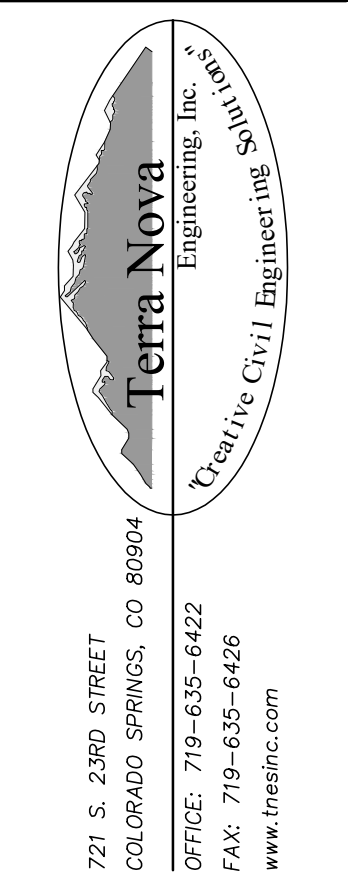
LEGEND

- X FENCE LINE
7261 PROPOSED 1' CONTOUR
7265 PROPOSED 5' CONTOUR
~ PROPOSED EDGE OF GRAVEL
PR PROPOSED
EX EXISTING



REVISIONS	NO.	DESCRIPTION	DATE
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PREPARED FOR:
MVEA
ATTN: DAVE WALDNER
11140 E. WOODMEN RD
PEYTON, CO 80831
(719) 495-2283



VOLLMER SUBSTATION	WATER QUALITY DETAILS
--------------------	-----------------------

DESIGNED BY LD	DRAWN BY DLF
CHECKED BY LD	H-SCALE AS SHOWN
V-SCALE NA	JOB NO. 1845.00
DATE ISSUED 09/17/18	SHEET NO. 3 OF 3