# 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

TNE Job No. 1845.00
County Job No. ########

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

## TABLE OF CONTENTS



**APPENDICIES**

## 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, Date

County Engineer / ECM Administrator

Conditions:

# FINAL DRAINAGE REPORT
# FOR
# VOLLMER SUBSTATION
# EL PASO COUTY, 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 6$^{th}$ 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. Bases 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. Bases 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 with stop southernly flow until the runoff reaches the west side of the site and resumes its southernly 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.

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 EXS! 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 EXS! 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 | $ 15,000 |
| | | **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 = | $11,978 |
| | | | | **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 form the site.

PREPARED BY:
**TERRA NOVA ENGINEERING, INC.**

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

**REFERENCE**

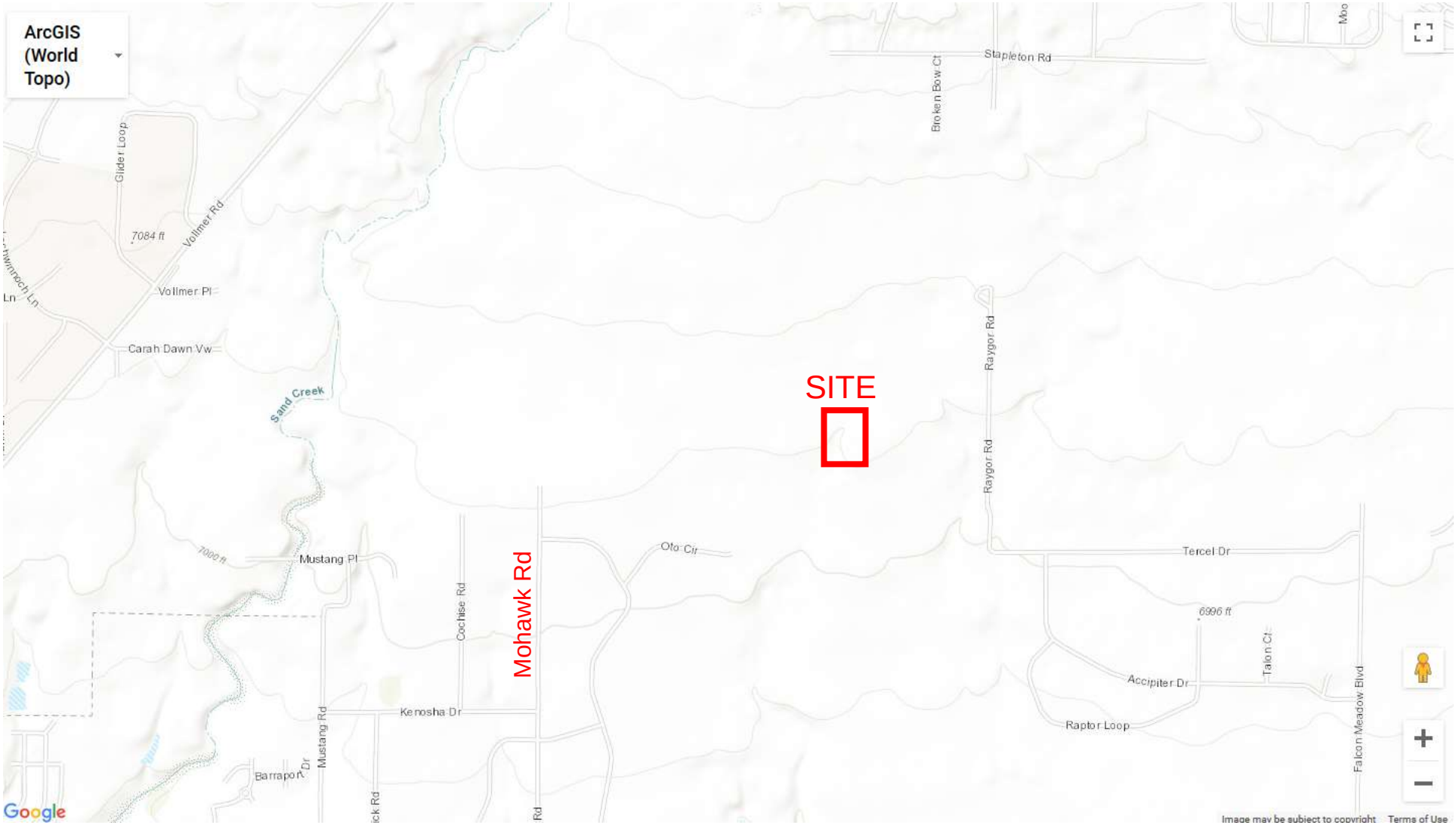
El Paso County Drainage Criteria Manual-Volumes 1 & 2, latest edition

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


| No. | Date | Dwn. | Appd. | Revision | M.F. |
|---|---|---|---|---|---|
| | | | | | |

Dwg. No.

Mfgr.

Reference Drawings

VOLLMER SUBSTATION

PROPOSED SITE PLAN

TRI-STATE GENERATION & TRANSMISSION ASSOCIATION, INCORPORATED

UPDATED BY: SCOMER 4/12/2018 8:27 AM Contract: -

TRI-STATE
Generation and Transmission Association, Inc.
A Touchstone Energy Cooperative
1100 W. 116th Ave.
P.O. Box 33695
Denver, Colorado 80233
303-452-6111

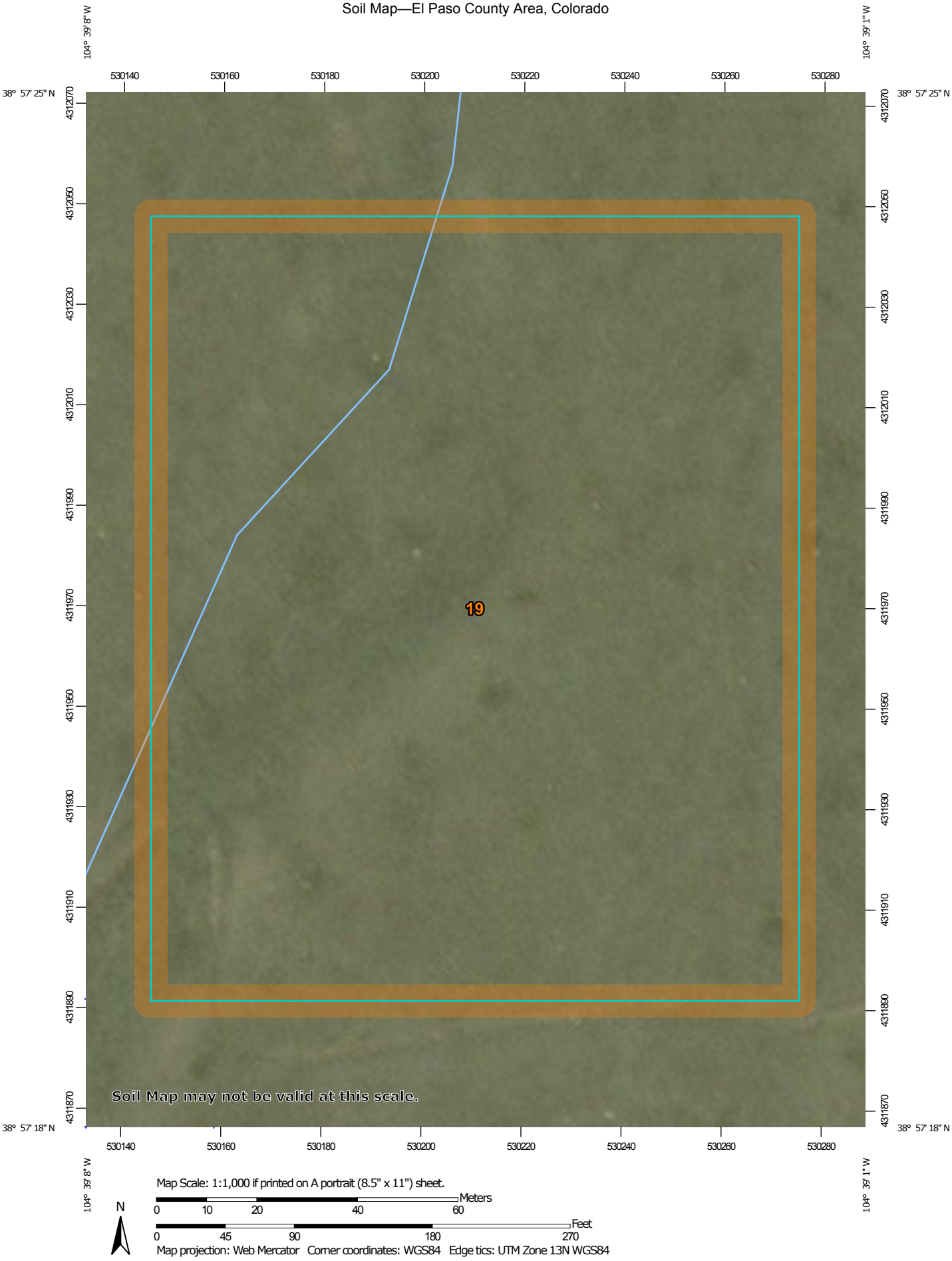
Dwn: SJM Date: 01.04.2018

Appd: Date:

SITE PLAN

# S.C.S. SOILS MAP

# Soil Map—El Paso County Area, Colorado




Map Scale: 1:1,000 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 10 20 40 60

Feet: 0 45 90 180 270

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

## 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

## NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

**Coastal Base Flood Elevations** shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the **North American Vertical Datum of 1988 (NAVD88)**. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at (301) 713-3242 or visit its website at http://www.ngs.noaa.gov/.

**Base Map** information shown on this FIRM was provided in digital format by El Paso County, Colorado Springs Utilities, and Anderson Consulting Engineers, Inc. These data are current as of 2008.

This map reflects more detailed and up-to-date **stream channel configurations and floodplain delineations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map. The profile baselines depicted on this map represent the hydraulic modeling baselines that match the flood profiles and Floodway Data Tables if applicable, in the FIS report. As a result, the profile baselines may deviate significantly from the new base map channel representation and may appear outside of the floodplain.

**Corporate limits** shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

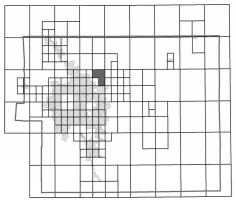
Contact **FEMA Map Service Center** (MSC) via the FEMA Map Information eXchange (FMIX) 1-877-336-2627 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The MSC may also be reached by Fax at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

**El Paso County Vertical Datum Offset Table**

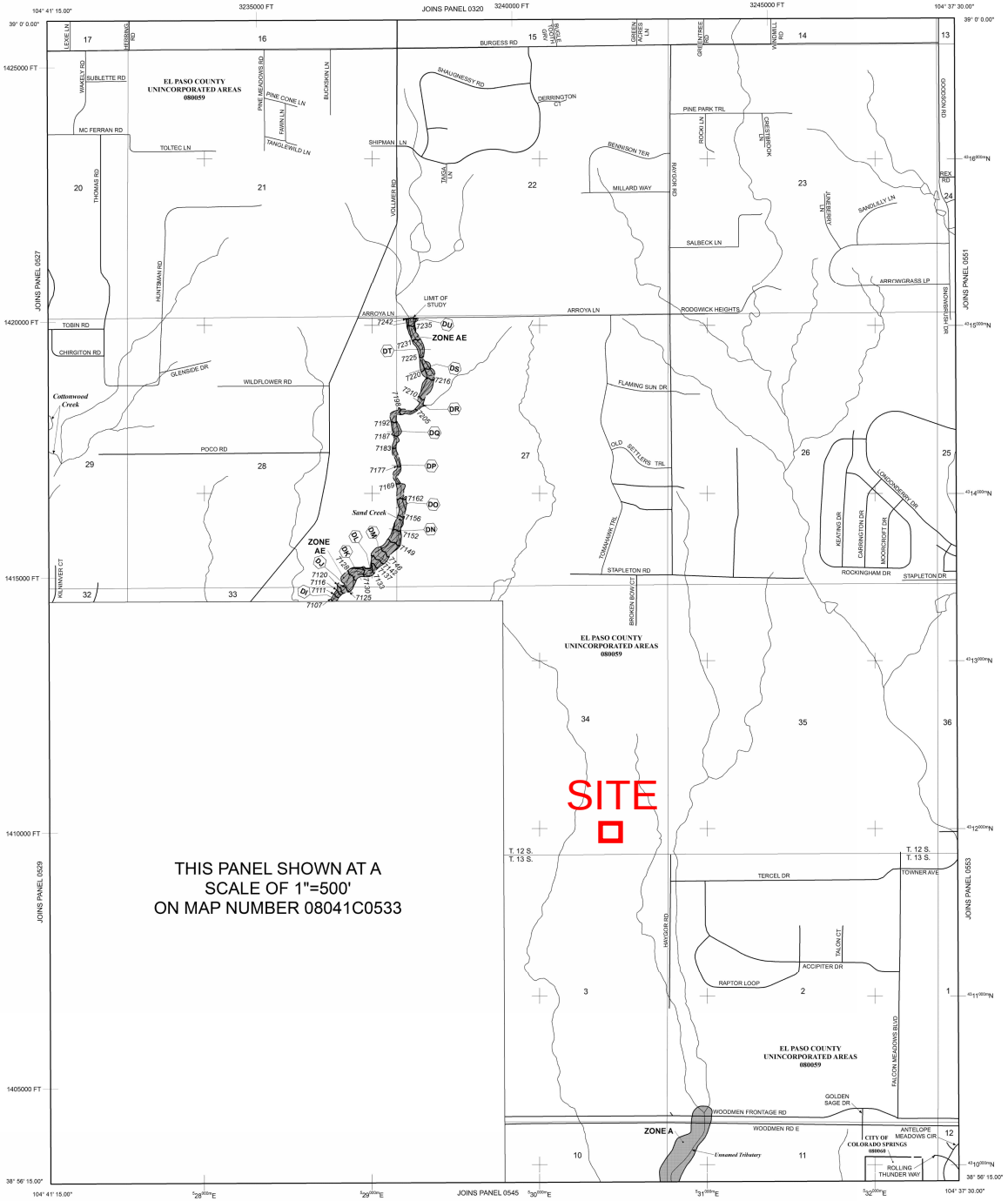
| Flooding Source | Vertical Datum Offset (ft) |
|---|---|
| REFER TO SECTION 3.3 OF THE EL PASO COUNTY FLOOD INSURANCE STUDY FOR STREAM BY STREAM VERTICAL DATUM CONVERSION INFORMATION | |

**Panel Location Map**



This Digital Flood Insurance Rate Map (DFIRM) was produced through a Cooperating Technical Partner (CTP) agreement between the State of Colorado Water Conservation Board (CWCB) and the Federal Emergency Management Agency (FEMA).

Additional Flood Hazard information and resources are available from local communities and the Colorado Water Conservation Board.




NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 12 SOUTH, RANGE 65 WEST, AND TOWNSHIP 13 SOUTH, RANGE 65 WEST.

## LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAS) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

**ZONE A** No Base Flood Elevations determined.
**ZONE AE** Base Flood Elevations determined.
**ZONE AH** Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
**ZONE AO** Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
**ZONE AR** Special Flood Hazard Area Formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
**ZONE A99** Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
**ZONE V** Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
**ZONE VE** Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

**ZONE X** Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

**ZONE X** Areas determined to be outside the 0.2% annual chance floodplain.
**ZONE D** Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary
Floodway boundary
Zone D Boundary
CBRS and OPA boundary
Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
513 — Base Flood Elevation line and value; elevation in feet*
(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

A — A Cross section line
23 - - - - - 23 Transect line
97° 07' 30.00" 32° 22' 30.00" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
4279000mN 1000-meter Universal Transverse Mercator grid ticks, zone 13
6000000 FT 5000-foot grid ticks: Colorado State Plane coordinate system, central zone (FIPSZONE 0502), Lambert Conformal Conic Projection
DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel)
● M1.5 River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
**MARCH 17, 1997**

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
**DECEMBER 7, 2018** - to update corporate limits, to change Base Flood Elevations and Special Flood Hazard Areas, to update map format, to add roads and road names, and to incorporate previously issued Letters of Map Revision.

For community map revision history prior to countywide mapping, refer to the Community Map History Table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

**MAP SCALE 1" = 1000'**

500 0 1000 2000 FEET
300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

**PANEL 0535G**

# FIRM
## FLOOD INSURANCE RATE MAP
## EL PASO COUNTY, COLORADO
### AND INCORPORATED AREAS

**PANEL 535 OF 1300**

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| COLORADO SPRINGS, CITY OF | 080060 | 0535 | G |
| EL PASO COUNTY | 080059 | 0535 | G |

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

**MAP NUMBER 08041C0535G**

**MAP REVISED DECEMBER 7, 2018**

Federal Emergency Management Agency

# HYDROLOGIC CALCULATIONS

# *VOLLMER SUBSTATION*
# *(Area Runoff Coefficient Summary)*

## EXISTING CONDITIONS

| | | *DEVELOPED* | | | *UNDEVELOPED* | | | *WEIGHTED* | |
|---|---|---|---|---|---|---|---|---|---|
| **BASIN** | **TOTAL AREA** | **AREA** | $C_5$ | $C_{100}$ | **AREA** | $C_5$ | $C_{100}$ | $C_5$ | $C_{100}$ |
| | *(Acres)* | *(Acres)* | | | *(Acres)* | | | | |
| ***OS-2*** | 79.00 | 0.00 | 0.30 | 0.50 | 79.00 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***EX-A*** | 2.77 | 0.00 | 0.30 | 0.50 | 2.77 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***EX-B*** | 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

| | | *DEVELOPED* | | | *UNDEVELOPED* | | | *WEIGHTED* | |
|---|---|---|---|---|---|---|---|---|---|
| **BASIN** | **TOTAL AREA** | **AREA** | **$C_5$** | **$C_{100}$** | **AREA** | **$C_5$** | **$C_{100}$** | **$C_5$** | **$C_{100}$** |
| | *(Acres)* | *(Acres)* | | | *(Acres)* | | | | |
| ***OS-2*** | 79.00 | 0.00 | 0.30 | 0.50 | 79.00 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***PR-1*** | 0.42 | 0.00 | 0.30 | 0.50 | 0.42 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***PR-2*** | 1.70 | 1.70 | 0.30 | 0.50 | 0.00 | 0.09 | 0.36 | 0.30 | 0.50 |
| ***PR-3*** | 0.15 | 0.02 | 0.30 | 0.50 | 0.13 | 0.09 | 0.36 | 0.12 | 0.38 |
| ***PR-4*** | 1.43 | 0.16 | 0.30 | 0.50 | 1.27 | 0.09 | 0.36 | 0.11 | 0.38 |
| ***PR-5*** | 1.07 | 0.00 | 0.30 | 0.50 | 1.07 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***PR-6*** | 0.06 | 0.00 | 0.30 | 0.50 | 0.06 | 0.09 | 0.36 | 0.09 | 0.36 |
| ***PR-7*** | 0.26 | 0.15 | 0.30 | 0.50 | 0.11 | 0.09 | 0.36 | 0.21 | 0.44 |
| ***PR-8*** | 0.58 | 0.15 | 0.30 | 0.50 | 0.43 | 0.09 | 0.36 | 0.14 | 0.40 |
| ***PR-9*** | 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* | | | | $T_t$ | *INTENSITY* | | *TOTAL FLOWS* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASIN** | **AREA TOTAL** | $C_5$ | $C_{100}$ | $C_5$ | **Length** | **Height** | $T_C$ | **Length** | **Slope** | **Velocity** | $T_t$ | **TOTAL** | $I_5$ | $I_{100}$ | $Q_5$ | $Q_{100}$ |
| | *(Acres)* | ** For Calcs See Runoff Summary* | | | *(ft)* | *(ft)* | *(min)* | *(ft)* | *(%)* | *(fps)* | *(min)* | *(min)* | *(in/hr)* | *(in/hr)* | *(c.f.s.)* | *(c.f.s.)* |
| ***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* | | | | $T_t$ | *INTENSITY* | | *TOTAL FLOWS* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASIN** | **AREA TOTAL** | $C_5$ | $C_{100}$ | $C_5$ | **Length** | **Height** | $T_C$ | **Length** | **Slope** | **Velocity** | $T_t$ | **TOTAL** | $I_5$ | $I_{100}$ | $Q_5$ | $Q_{100}$ |
| | *(Acres)* | ** For Calcs See Runoff Summary* | | | *(ft)* | *(ft)* | *(min)* | *(ft)* | *(%)* | *(fps)* | *(min)* | *(min)* | *(in/hr)* | *(in/hr)* | *(c.f.s.)* | *(c.f.s.)* |
| ***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 ervice 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*

| *Design Point(s)* | *Contributing Basins* | *Area Ac* | *Flow* | | |
|---|---|---|---|---|---|
| | | | $Q_5$ | $Q_{10}$ | $Q_{100}$ |
| *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

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

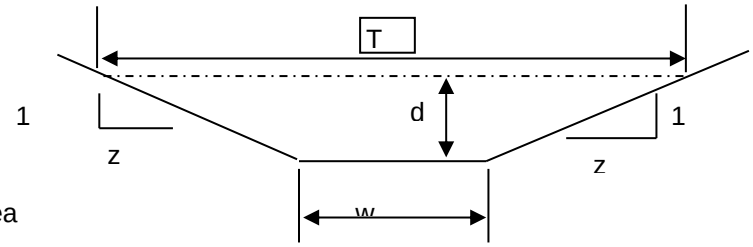
R = A/P

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 x 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

| Depth, ft | Area, sf | Wetted Perimeter, ft | Hydraulic Radius, ft | Low N Velocity, fps | Low N Flow, cfs | High N Velocity, fps | High N Flow, cfs | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.2 | 50.40 | 84.04 | 0.60 | 0.7270711 | 36.6444 | 0.727071 | 36.6444 | T = | 84 |
| | | | | | | | | Dm = | 0.600 |
| | | | | Sc low = | 0.2919 | Sc high = | 0.2919 | | |
| | | | | .7 Sc | 1.3 Sc | .7 Sc | 1.3 Sc | | |
| | | | | 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** | Location: | PRS1 - North edge of PR Yard - Q5 = 0.1 cfs |
| By: | Dane Frank | Date: | 8/27/2018 |
| Chk By: | | Date: | |

version 12-2004

Mannings Formula

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

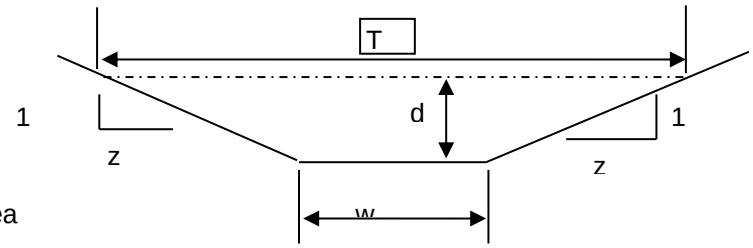
R = A/P

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 x 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 Velocity, fps | Low N Flow, cfs | High N Velocity, fps | High N Flow, cfs | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.33 | 0.44 | 2.72 | 0.16 | 0.23827597 | 0.10379 | 0.238276 | 0.10379 | T = | 2.64 |
| | | | | | | | | Dm = | 0.165 |
| | | | | Sc low = | 0.4671 | Sc high = | 0.4671 | | |
| | | | | .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

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

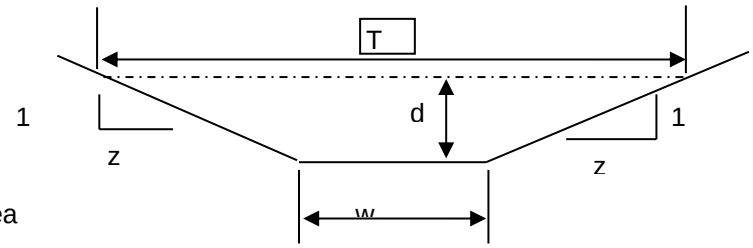
R = A/P

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 x 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 Velocity, fps | Low N Flow, cfs | High N Velocity, fps | High N Flow, cfs | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.68 | 1.85 | 5.61 | 0.33 | 0.38585195 | 0.71367 | 0.385852 | 0.71367 | T = | 5.44 |
| | | | | | | | | Dm = | 0.340 |
| | | | | Sc low = | 0.3671 | Sc high = | 0.3671 | | |
| | | | | .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

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

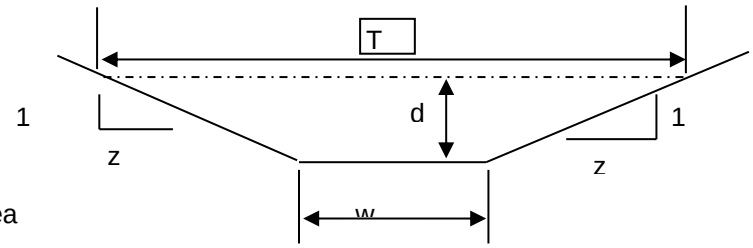
R = A/P

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 x 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 Velocity, fps | Low N Flow, cfs | High N Velocity, fps | High N Flow, cfs | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 0.36 | 2.47 | 0.15 | 0.2828419 | 0.10182 | 0.282842 | 0.10182 | T = | 2.4 |
| | | | | | | | | Dm = | 0.150 |
| | | | | Sc low = | 0.4822 | Sc high = | 0.4822 | | |
| | | | | .7 Sc | 1.3 Sc | .7 Sc | 1.3 Sc | | |
| | | | | 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** | Location: | PRS2 - East edge of PR Yard - Q100 = 0.4 cfs | |
| By: | Dane Frank | Date: | 8/27/2018 | |
| Chk By: | | Date: | | version 12-2004 |

Mannings Formula

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

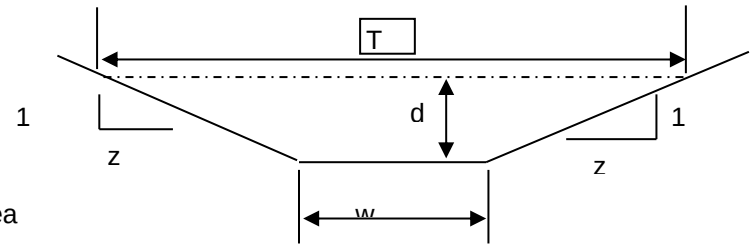
R = A/P

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 x 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

| | | | | Low N | | High N | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth, ft | Area, sf | Wetted Perimeter, ft | Hydraulic Radius, ft | 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 |
| | | | | | | | | Dm = | 0.255 |
| | | | | Sc low = | 0.4040 | Sc high = | 0.4040 | | |
| | | | | .7 Sc | 1.3 Sc | .7 Sc | 1.3 Sc | | |
| | | | | 0.2828 | 0.5252 | 0.2828 | 0.5252 | | |

$s_c$ = critical slope ft / ft

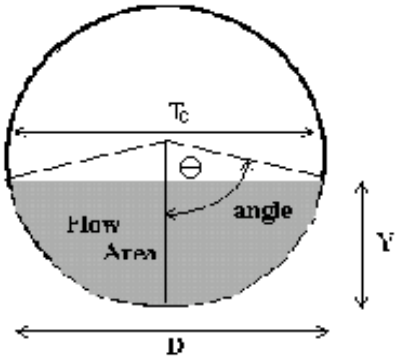
T = top width of the stream

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

Created by: Mike O'Shea

# CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

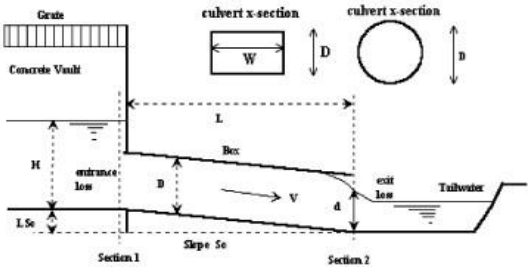
**Project:** **Vollmer Substation**
**Pipe ID:** **PRC1 - Sand Filter Discharge - 5 Yr**




| | | | |
|---|---|---|---|
| **Design Information (Input)** | | | |
| Pipe Invert Slope | So = | 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 | Af = | 1.77 | sq ft |
| Full-flow wetted perimeter | Pf = | 4.71 | ft |
| Half Central Angle | Theta = | 3.14 | radians |
| Full-flow capacity | Qf = | 14.90 | cfs |
| **Calculation of Normal Flow Condition** | | | |
| Half Central Angle (0<Theta<3.14) | Theta = | 0.98 | radians |
| Flow area | An = | 0.29 | sq ft |
| Top width | Tn = | 1.25 | ft |
| Wetted perimeter | Pn = | 1.47 | ft |
| Flow depth | Yn = | 0.33 | ft |
| Flow velocity | Vn = | 5.50 | fps |
| Discharge | Qn = | 1.60 | cfs |
| Percent Full Flow | 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 | Ac = | 0.48 | sq ft |
| Critical top width | Tc = | 1.40 | ft |
| Critical flow depth | Yc = | 0.48 | ft |
| Critical flow velocity | Vc = | 3.33 | fps |
| Critical Depth Froude Number | $Fr_c$ = | 1.00 | |

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

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



## Design Information (Input):

**Circular Culvert:** Barrel Diameter in Inches D = 18 inches
Inlet Edge Type (choose from pull-down list) Grooved End with Headwall

**OR:**

**Box Culvert:** Barrel Height (Rise) in Feet Height (Rise) = ft.
Barrel Width (Span) in Feet Width (Span) = ft.
Inlet Edge Type (choose from pull-down list) Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels No = 1
Inlet Elevation at Culvert Invert Inlet Elev = 7021.5 ft. elev.
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) Outlet Elev = 7020.1 ft. elev.
Culvert Length in Feet L = 70 ft.
Manning's Roughness n = 0.013
Bend Loss Coefficient $K_b$ = 0
Exit Loss Coefficient $K_x$ = 1

## Design Information (calculated):

Entrance Loss Coefficient $K_e$ = 0.20
Friction Loss Coefficient $K_f$ = 1.27
Sum of All Loss Coefficients $K_s$ = 2.47
Orifice Inlet Condition Coefficient $C_d$ = 0.99
Minimum Energy Condition Coefficient $KE_{low}$ = -0.0860

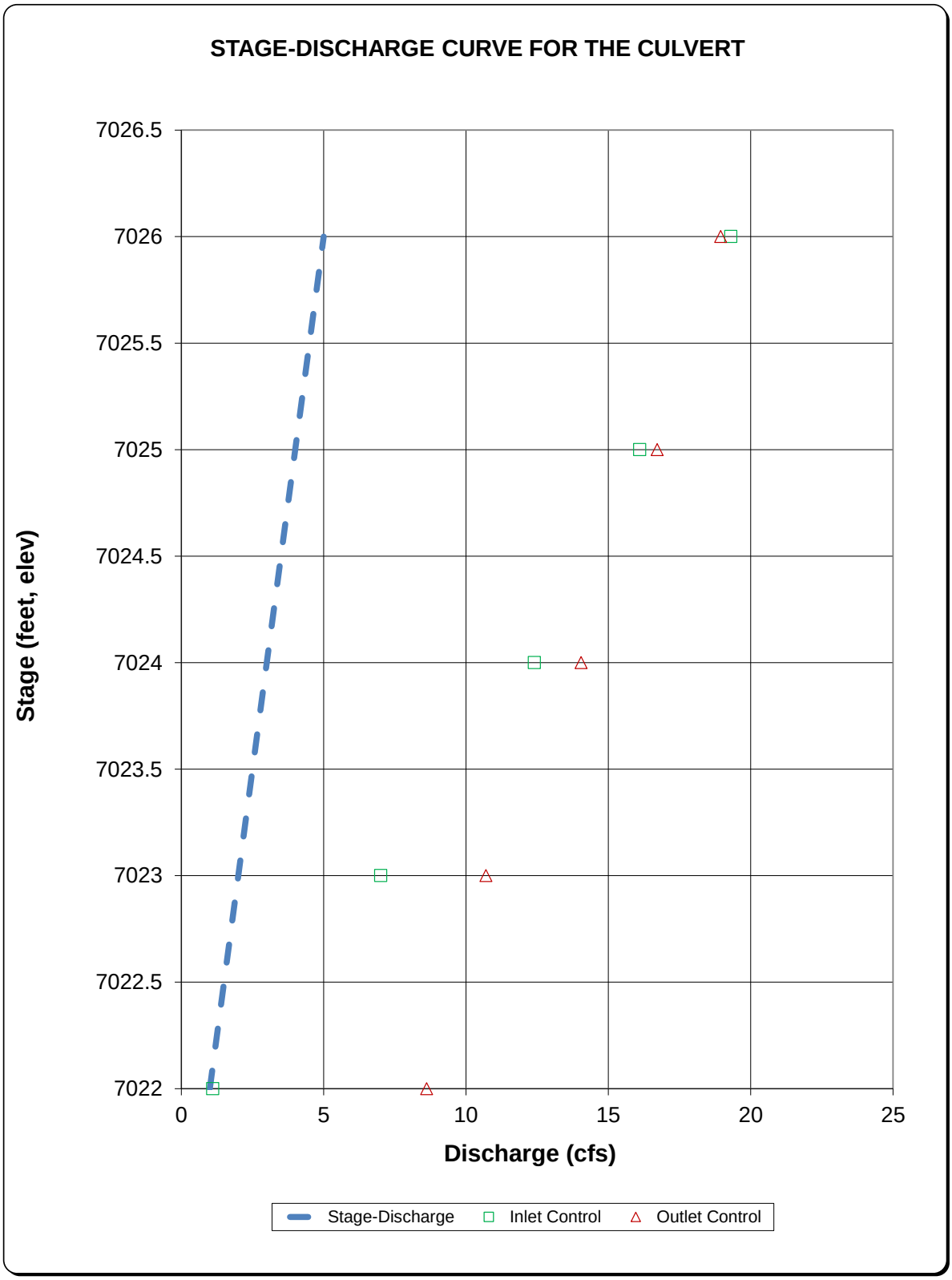
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7022.00 | | 1.10 | 8.62 | **1.10** | Min. Energy. Eqn. | INLET |
| 7023.00 | | 7.00 | 10.70 | **7.00** | Regression Eqn. | INLET |
| 7024.00 | | 12.40 | 14.04 | **12.40** | Regression Eqn. | INLET |
| 7025.00 | | 16.10 | 16.71 | **16.10** | Regression Eqn. | INLET |
| 7026.00 | | 19.30 | 18.94 | **18.94** | Regression Eqn. | OUTLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.15 Seconds

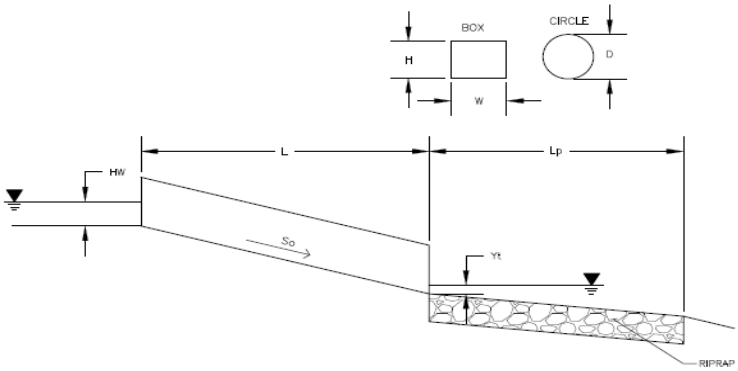
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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 Da to calculate protection type.**

## Design Information (Input):

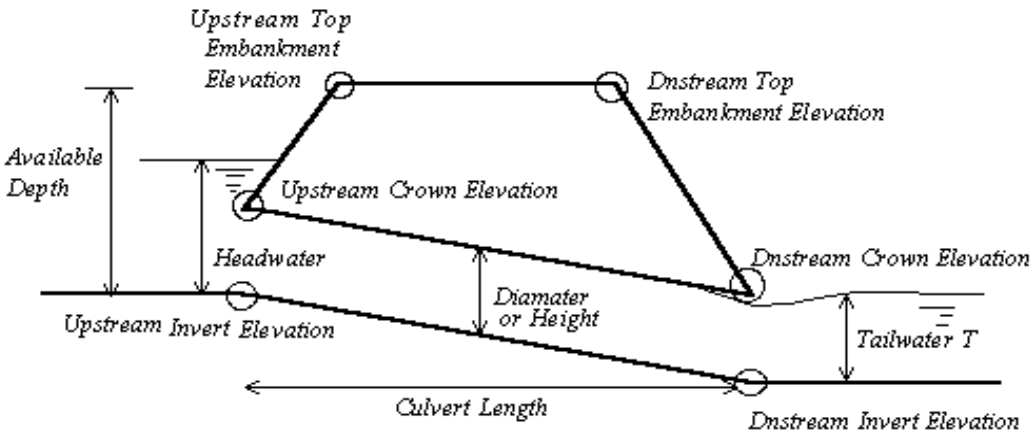
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 1.6 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | 18 | inches |
| Inlet Edge Type (Choose from pull-down list) | Square End Projection | | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | | ft |
| Barrel Width (Span) in Feet | Width (Span) = | | ft |
| 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 $Y_t$ = | | 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 | $A_t$ = | 0.32 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 1.77 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.50 | |
| Friction Loss Coefficient | $k_f$ = | 1.27 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.77 | ft |
| 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(Θ)) = | 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/D = | 0.66 | |
| 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

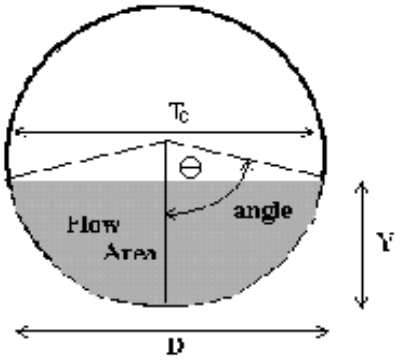
**Project =** **Vollmer Substation**
**Box ID =** **PRC1 - Sand Filter Discharge - 5 Yr**




| **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)

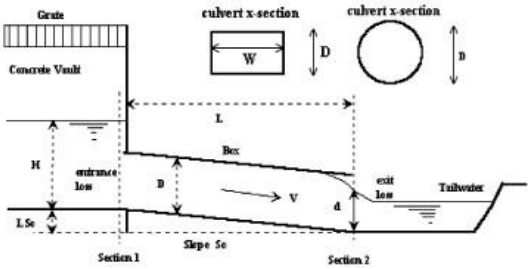
**Project:** **Vollmer Substation**
**Pipe ID:** **PRC1 - Sand Filter Discharge - 100 Yr**




| | | | |
|---|---|---|---|
| **Design Information (Input)** | | | |
| Pipe Invert Slope | So = | 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 | Af = | 1.77 | sq ft |
| Full-flow wetted perimeter | Pf = | 4.71 | ft |
| Half Central Angle | Theta = | 3.14 | radians |
| Full-flow capacity | Qf = | 14.90 | cfs |
| **Calculation of Normal Flow Condition** | | | |
| Half Central Angle (0<Theta<3.14) | Theta = | 1.31 | radians |
| Flow area | An = | 0.60 | sq ft |
| Top width | Tn = | 1.45 | ft |
| Wetted perimeter | Pn = | 1.97 | ft |
| Flow depth | Yn = | 0.56 | ft |
| Flow velocity | Vn = | 7.34 | fps |
| Discharge | Qn = | 4.40 | cfs |
| Percent Full Flow | 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 | Ac = | 0.97 | sq ft |
| Critical top width | Tc = | 1.50 | ft |
| Critical flow depth | Yc = | 0.80 | ft |
| Critical flow velocity | Vc = | 4.56 | fps |
| Critical Depth Froude Number | $Fr_c$ = | 1.00 | |

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

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



## Design Information (Input):

| | | | | |
|---|---|---|---|---|
| **Circular Culvert:** | Barrel Diameter in Inches | D = | 18 | inches |
| | Inlet Edge Type (choose from pull-down list) | | Grooved End with Headwall | |
| **OR:** | | | | |
| **Box Culvert:** | Barrel Height (Rise) in Feet | Height (Rise) = | | ft. |
| | Barrel Width (Span) in Feet | Width (Span) = | | ft. |
| | Inlet Edge Type (choose from pull-down list) | | Square Edge w/ 30-78 deg. Flared Wingwall | |
| | Number of Barrels | No = | 1 | |
| | Inlet Elevation at Culvert Invert | Inlet Elev = | 7021.5 | ft. elev. |
| | Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) | Outlet Elev = | 7020.1 | ft. elev. |
| | Culvert Length in Feet | L = | 70 | ft. |
| | Manning's Roughness | n = | 0.013 | |
| | Bend Loss Coefficient | $K_b$ = | 0 | |
| | Exit Loss Coefficient | $K_x$ = | 1 | |

## Design Information (calculated):

| | | |
|---|---|---|
| Entrance Loss Coefficient | $K_e$ = | 0.20 |
| Friction Loss Coefficient | $K_f$ = | 1.27 |
| Sum of All Loss Coefficients | $K_s$ = | 2.47 |
| Orifice Inlet Condition Coefficient | $C_d$ = | 0.99 |
| Minimum Energy Condition Coefficient | $KE_{low}$ = | -0.0860 |

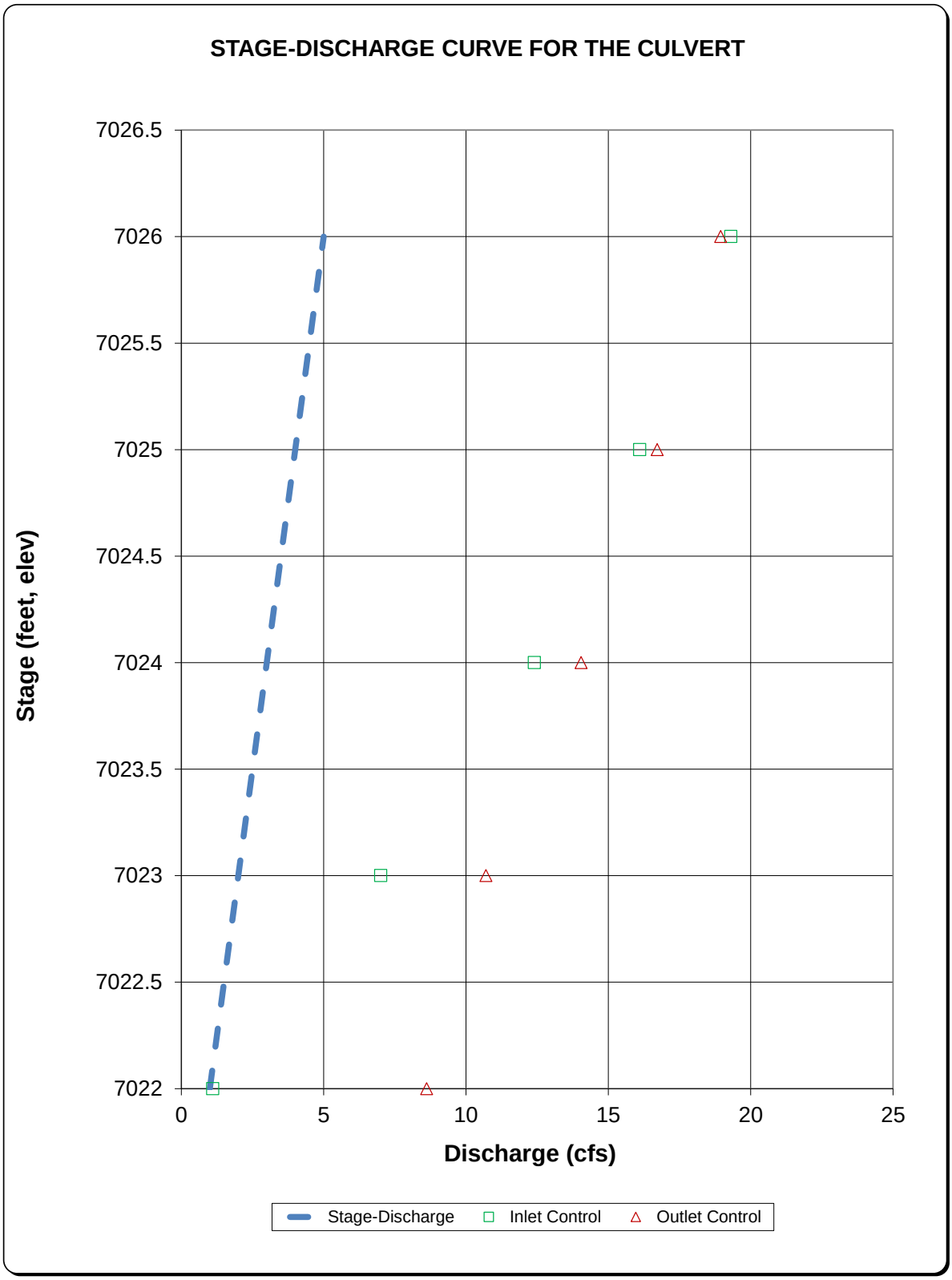
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7022.00 | | 1.10 | 8.62 | **1.10** | Min. Energy. Eqn. | INLET |
| 7023.00 | | 7.00 | 10.70 | **7.00** | Regression Eqn. | INLET |
| 7024.00 | | 12.40 | 14.04 | **12.40** | Regression Eqn. | INLET |
| 7025.00 | | 16.10 | 16.71 | **16.10** | Regression Eqn. | INLET |
| 7026.00 | | 19.30 | 18.94 | **18.94** | Regression Eqn. | OUTLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.23 Seconds

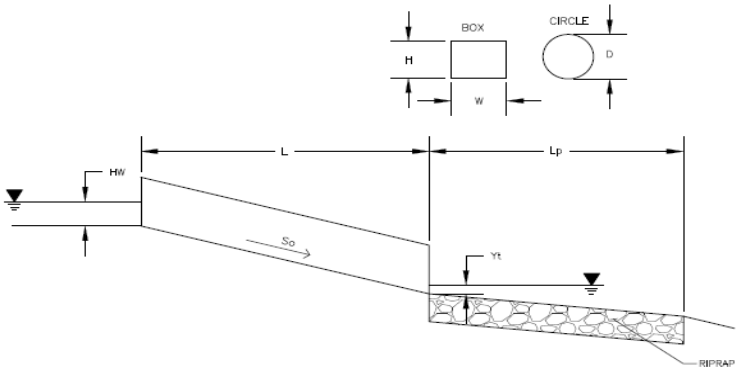
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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 Da to calculate protection type.**

## Design Information (Input):

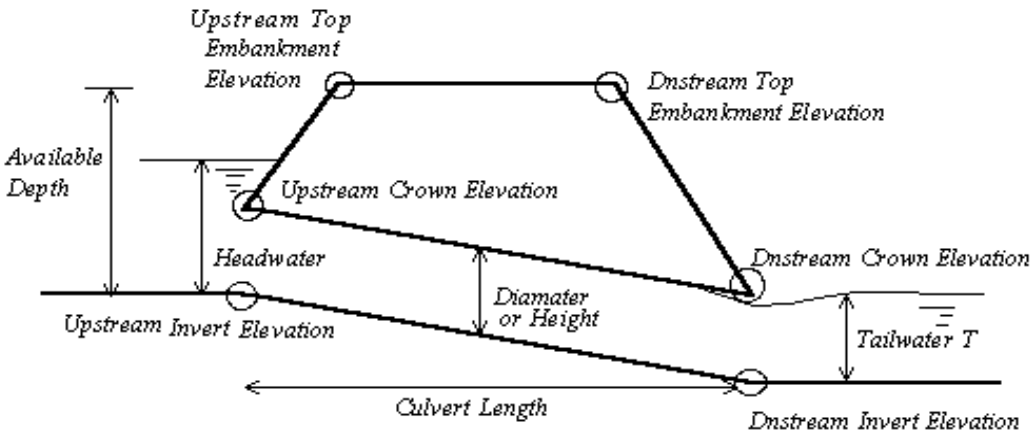
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 4.4 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | 18 | inches |
| Inlet Edge Type (Choose from pull-down list) | Square End Projection | | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | | ft |
| Barrel Width (Span) in Feet | Width (Span) = | | ft |
| 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 $Y_t$ = | | 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 | $A_t$ = | 0.88 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 1.77 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.50 | |
| Friction Loss Coefficient | $k_f$ = | 1.27 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.77 | ft |
| 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(Θ)) = | 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/D = | 0.58 | |
| Inlet Control Headwater | $HW_I$ = | 1.19 | ft |
| Outlet Control Headwater | $HW_O$ = | 0.02 | |
| **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

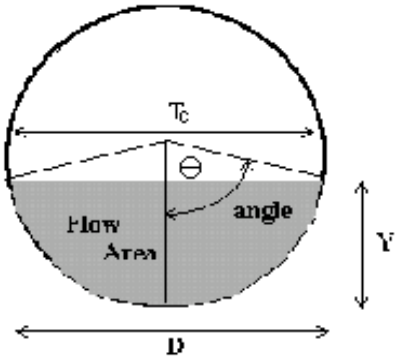
**Project =** **Vollmer Substation**
**Box ID =** **PRC1 - Sand Filter Discharge - 100 Yr**




| **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)

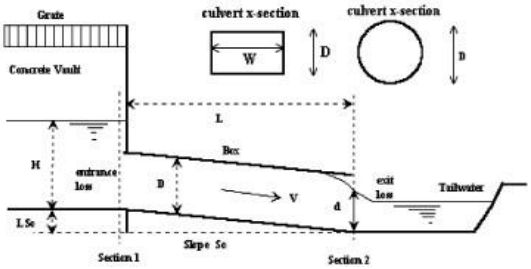
**Project:** Vollmer Substation
**Pipe ID:** PRC2 - SW Property Corner Access Crossing - 5 Yr




| | | | |
|---|---|---|---|
| **Design Information (Input)** | | | |
| Pipe Invert Slope | So = | 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 | Af = | 4.91 | sq ft |
| Full-flow wetted perimeter | Pf = | 7.85 | ft |
| Half Central Angle | Theta = | 3.14 | radians |
| Full-flow capacity | Qf = | 36.79 | cfs |
| **Calculation of Normal Flow Condition** | | | |
| Half Central Angle (0<Theta<3.14) | Theta = | 1.22 | radians |
| Flow area | An = | 1.41 | sq ft |
| Top width | Tn = | 2.35 | ft |
| Wetted perimeter | Pn = | 3.05 | ft |
| Flow depth | Yn = | 0.82 | ft |
| Flow velocity | Vn = | 6.11 | fps |
| Discharge | Qn = | 8.60 | cfs |
| Percent Full Flow | 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 | Ac = | 1.78 | sq ft |
| Critical top width | Tc = | 2.44 | ft |
| Critical flow depth | Yc = | 0.98 | ft |
| Critical flow velocity | Vc = | 4.84 | fps |
| Critical Depth Froude Number | $Fr_c$ = | 1.00 | |

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

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



## Design Information (Input):

| | | | | |
|---|---|---|---|---|
| **Circular Culvert:** | Barrel Diameter in Inches | D = | 30 | inches |
| | Inlet Edge Type (choose from pull-down list) | | Grooved End with Headwall | |
| **OR:** | | | | |
| **Box Culvert:** | Barrel Height (Rise) in Feet | Height (Rise) = | | ft. |
| | Barrel Width (Span) in Feet | Width (Span) = | | ft. |
| | Inlet Edge Type (choose from pull-down list) | | Square Edge w/ 30-78 deg. Flared Wingwall | |
| | Number of Barrels | No = | 1 | |
| | Inlet Elevation at Culvert Invert | Inlet Elev = | 7017.75 | ft. elev. |
| | Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) | Outlet Elev = | 7017.31 | ft. elev. |
| | Culvert Length in Feet | L = | 55 | ft. |
| | Manning's Roughness | n = | 0.013 | |
| | Bend Loss Coefficient | $K_b$ = | 0 | |
| | Exit Loss Coefficient | $K_x$ = | 1 | |

## Design Information (calculated):

| | | |
|---|---|---|
| Entrance Loss Coefficient | $K_e$ = | 0.20 |
| Friction Loss Coefficient | $K_f$ = | 0.50 |
| Sum of All Loss Coefficients | $K_s$ = | 1.70 |
| Orifice Inlet Condition Coefficient | $C_d$ = | 0.99 |
| Minimum Energy Condition Coefficient | $KE_{low}$ = | -0.0373 |

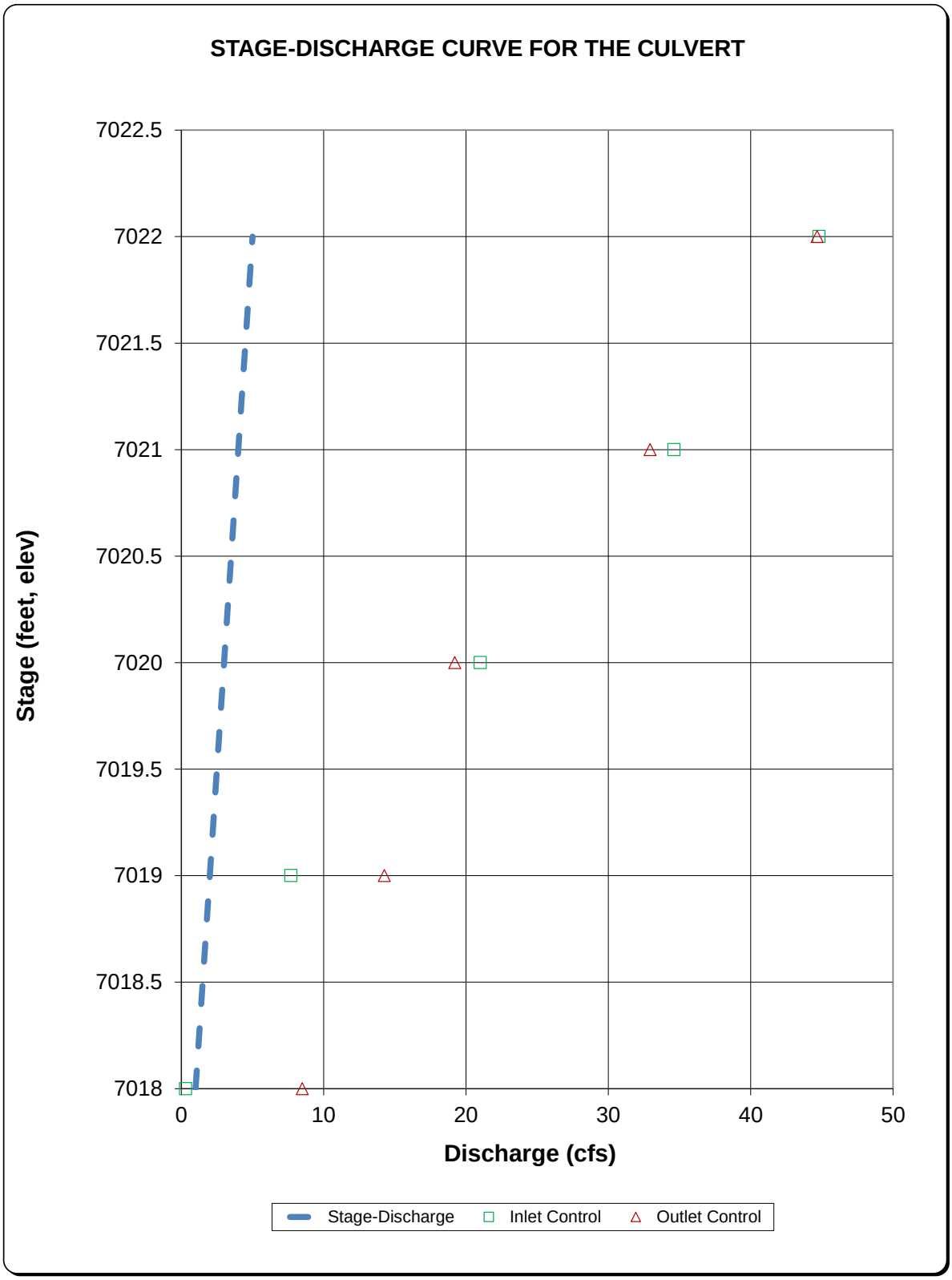
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7018.00 | | 0.30 | 8.49 | **0.30** | Min. Energy. Eqn. | INLET |
| 7019.00 | | 7.70 | 14.25 | **7.70** | Min. Energy. Eqn. | INLET |
| 7020.00 | | 21.00 | 19.21 | **19.21** | Regression Eqn. | OUTLET |
| 7021.00 | | 34.60 | 32.93 | **32.93** | Regression Eqn. | OUTLET |
| 7022.00 | | 44.80 | 44.67 | **44.67** | Regression Eqn. | OUTLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.17 Seconds

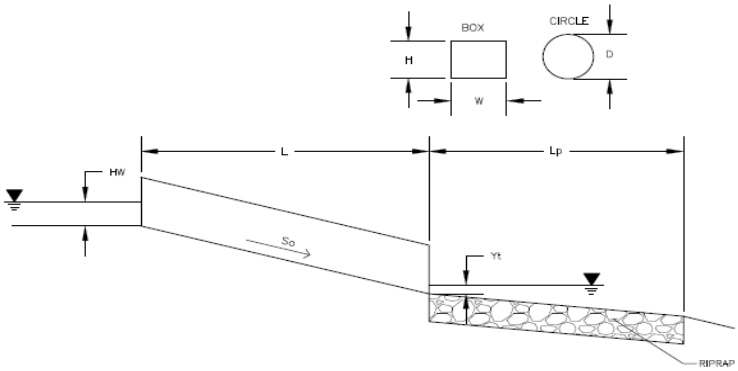
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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 Da to calculate protection type.**

## Design Information (Input):

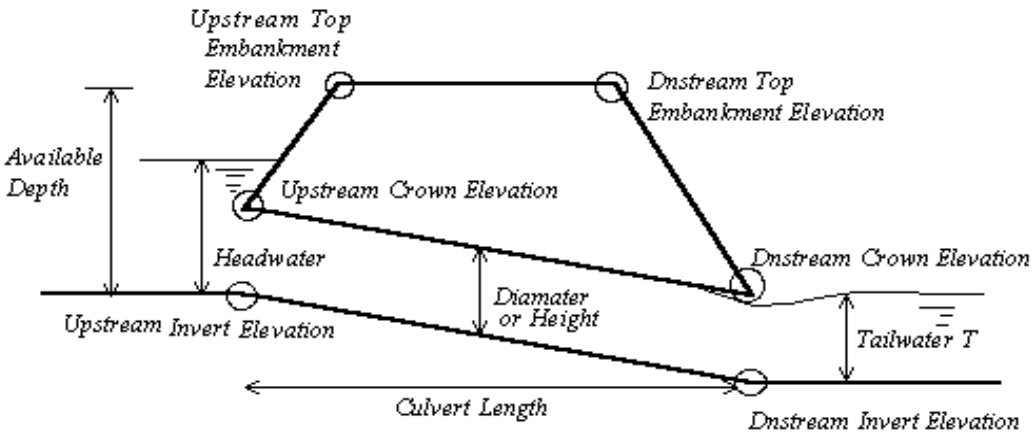
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 8.6 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | 30 | inches |
| Inlet Edge Type (Choose from pull-down list) | Square End Projection | | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | | ft |
| Barrel Width (Span) in Feet | Width (Span) = | | ft |
| 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 $Y_t$ = | | ft |
| 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 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 4.91 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.50 | |
| Friction Loss Coefficient | $k_f$ = | 0.50 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.00 | ft |
| 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*tan(Θ)) = | 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/D = | 0.60 | |
| Inlet Control Headwater | $HW_I$ = | 1.39 | ft |
| Outlet Control Headwater | $HW_O$ = | 1.39 | |
| **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

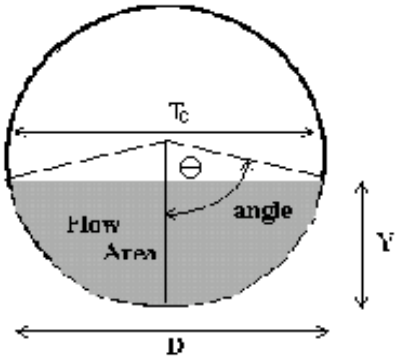
**Project =** **Vollmer Substation**
**Box ID =** **PRC2 - SW Property Corner Access Crossing - 5 Yr**




| **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)

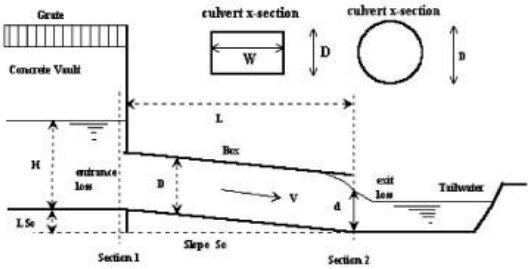
**Project:** **Vollmer Substation**
**Pipe ID:** **PRC2 - SW Property Corner Access Crossing - 100 Yr**




| | | | |
|---|---|---|---|
| **Design Information (Input)** | | | |
| Pipe Invert Slope | So = | 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 | Af = | 4.91 | sq ft |
| Full-flow wetted perimeter | Pf = | 7.85 | ft |
| Half Central Angle | Theta = | 3.14 | radians |
| Full-flow capacity | Qf = | 36.79 | cfs |
| **Calculation of Normal Flow Condition** | | | |
| Half Central Angle (0<Theta<3.14) | Theta = | 2.25 | radians |
| Flow area | An = | 4.28 | sq ft |
| Top width | Tn = | 1.94 | ft |
| Wetted perimeter | Pn = | 5.63 | ft |
| Flow depth | Yn = | 2.04 | ft |
| Flow velocity | Vn = | 8.54 | fps |
| Discharge | Qn = | 36.60 | cfs |
| Percent Full Flow | Flow = | 99.5% | of full flow |
| Normal Depth Froude Number | $Fr_n$ = | 1.01 | supercritical |
| **Calculation of Critical Flow Condition** | | | |
| Half Central Angle (0<Theta-c<3.14) | Theta-c = | 2.27 | radians |
| Critical flow area | Ac = | 4.31 | sq ft |
| Critical top width | Tc = | 1.92 | ft |
| Critical flow depth | Yc = | 2.05 | ft |
| Critical flow velocity | Vc = | 8.50 | fps |
| Critical Depth Froude Number | $Fr_c$ = | 1.00 | |

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

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



## Design Information (Input):

**Circular Culvert:** Barrel Diameter in Inches — D = 30 inches
Inlet Edge Type (choose from pull-down list) — Grooved End with Headwall

**OR:**

**Box Culvert:** Barrel Height (Rise) in Feet — Height (Rise) = ft.
Barrel Width (Span) in Feet — Width (Span) = ft.
Inlet Edge Type (choose from pull-down list) — Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels — No = 1
Inlet Elevation at Culvert Invert — Inlet Elev = 7017.75 ft. elev.
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) — Outlet Elev = 7017.31 ft. elev.
Culvert Length in Feet — L = 55 ft.
Manning's Roughness — n = 0.013
Bend Loss Coefficient — $K_b$ = 0
Exit Loss Coefficient — $K_x$ = 1

## Design Information (calculated):

Entrance Loss Coefficient — $K_e$ = 0.20
Friction Loss Coefficient — $K_f$ = 0.50
Sum of All Loss Coefficients — $K_s$ = 1.70
Orifice Inlet Condition Coefficient — $C_d$ = 0.99
Minimum Energy Condition Coefficient — $KE_{low}$ = -0.0373

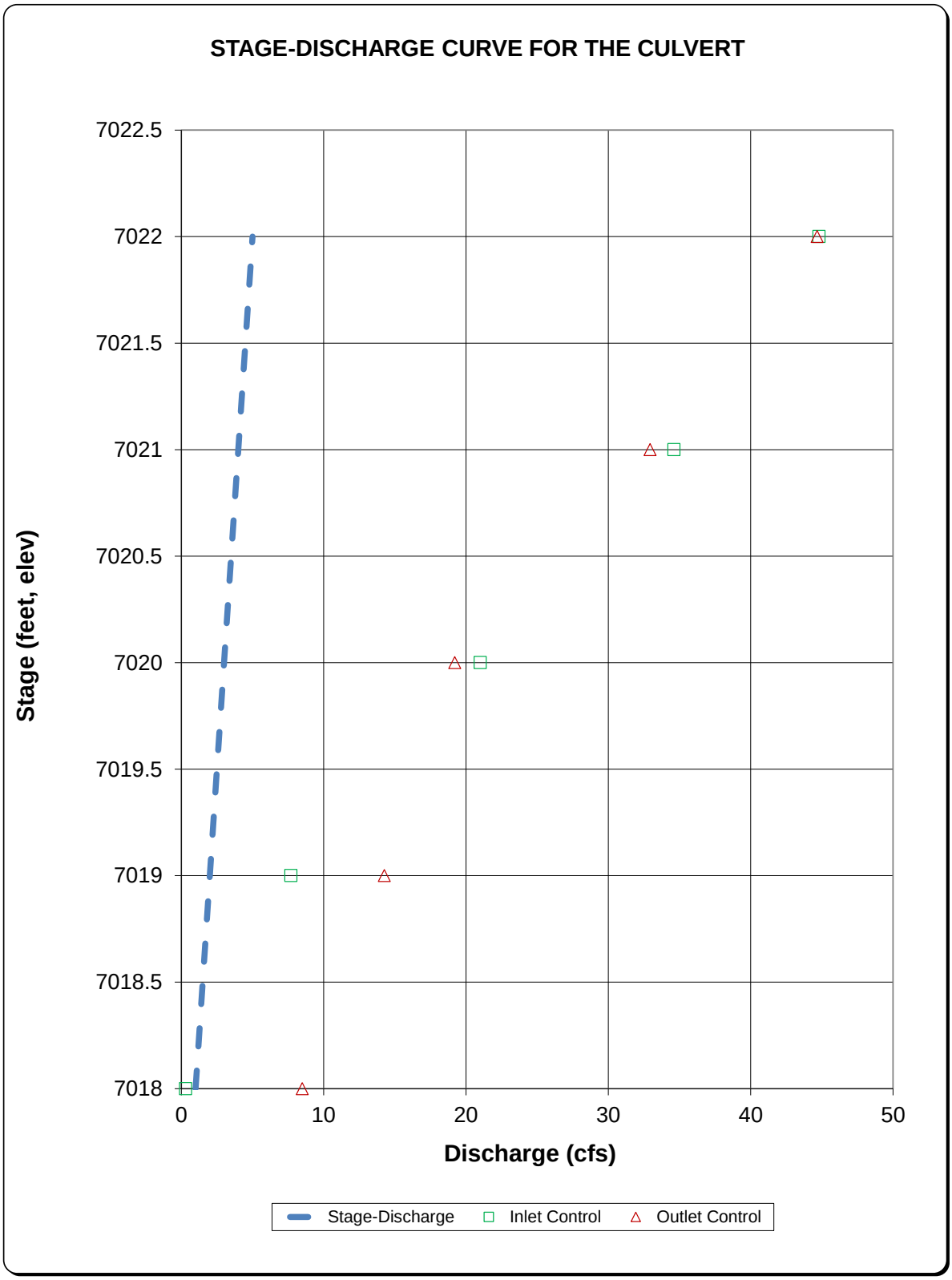
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7018.00 | | 0.30 | 8.49 | **0.30** | Min. Energy. Eqn. | INLET |
| 7019.00 | | 7.70 | 14.25 | **7.70** | Min. Energy. Eqn. | INLET |
| 7020.00 | | 21.00 | 19.21 | **19.21** | Regression Eqn. | OUTLET |
| 7021.00 | | 34.60 | 32.93 | **32.93** | Regression Eqn. | OUTLET |
| 7022.00 | | 44.80 | 44.67 | **44.67** | Regression Eqn. | OUTLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.15 Seconds

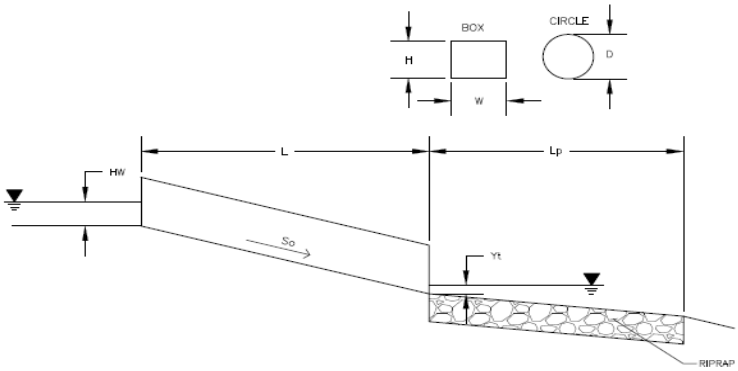
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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):

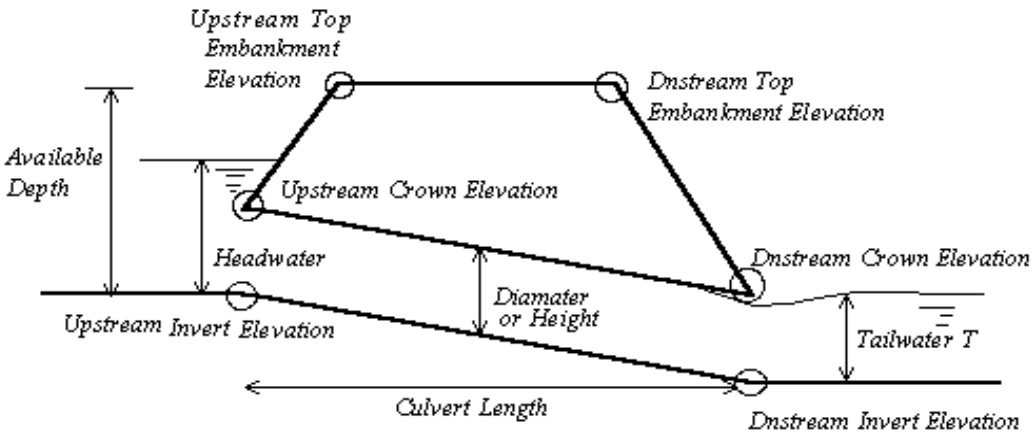
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 36.6 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | 30 | inches |
| Inlet Edge Type (Choose from pull-down list) | | Square End Projection | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | | ft |
| Barrel Width (Span) in Feet | Width (Span) = | | ft |
| 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 $Y_t$ = | | ft |
| 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 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 4.91 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.50 | |
| Friction Loss Coefficient | $k_f$ = | 0.50 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.00 | ft |
| 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/D = | 0.44 | |
| Inlet Control Headwater | $HW_I$ = | 3.92 | ft |
| Outlet Control Headwater | $HW_O$ = | 3.57 | |
| **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 | $d_{50}$ = | 8 | in |
| Nominal Riprap Size | $d_{50}$ = | 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

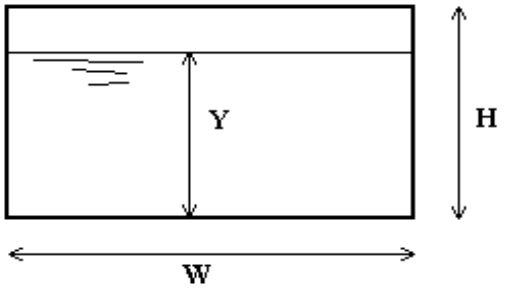
**Project =** **Vollmer Substation**
**Box ID =** **PRC2 - SW Property Corner Access Crossing - 100 Yr**




| **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**

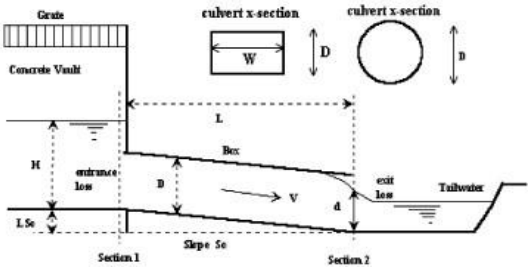



| **Design Information (Input)** | | | |
|---|---|---|---|
| Box conduit invert slope | So = | 0.0100 | ft/ft |
| Box Manning's n-value | n = | 0.0130 | |
| Box Width | W = | 2.00 | ft |
| Box Height | H = | 1.50 | ft |
| **Design discharge** | **Q =** | **3.33** | **cfs** |

| **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 | |

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

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



## Design Information (Input):

| | | | | |
|---|---|---|---|---|
| **Circular Culvert:** | Barrel Diameter in Inches | D = | | inches |
| | Inlet Edge Type (choose from pull-down list) | | Grooved End with Headwall | |
| **OR:** | | | | |
| **Box Culvert:** | Barrel Height (Rise) in Feet | Height (Rise) = | 1.50 | ft. |
| | Barrel Width (Span) in Feet | Width (Span) = | 2.00 | ft. |
| | Inlet Edge Type (choose from pull-down list) | | Square Edge w/ 30-78 deg. Flared Wingwall | |
| | Number of Barrels | No = | 3 | |
| | Inlet Elevation at Culvert Invert | Inlet Elev = | 7011.5 | ft. elev. |
| | Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) | Outlet Elev = | 7011 | ft. elev. |
| | Culvert Length in Feet | L = | 50 | ft. |
| | Manning's Roughness | n = | 0.013 | |
| | Bend Loss Coefficient | $K_b$ = | 0 | |
| | Exit Loss Coefficient | $K_x$ = | 1 | |

## Design Information (calculated):

| | | |
|---|---|---|
| Entrance Loss Coefficient | $K_e$ = | 0.40 |
| Friction Loss Coefficient | $K_f$ = | 0.91 |
| Sum of All Loss Coefficients | $K_s$ = | 2.31 |
| Orifice Inlet Condition Coefficient | $C_d$ = | 0.87 |
| Minimum Energy Condition Coefficient | $KE_{low}$ = | 0.0062 |

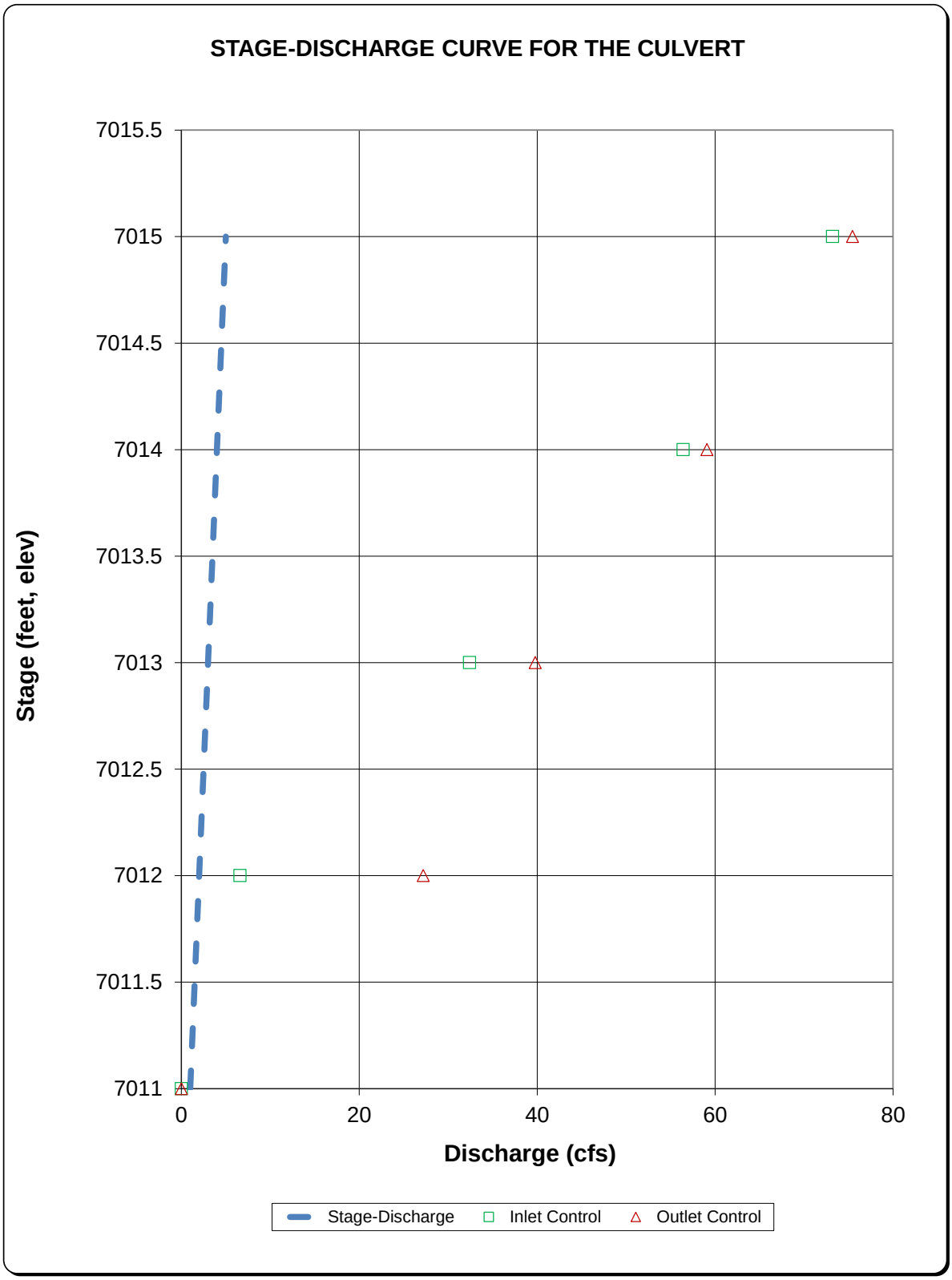
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7011.00 | | 0.00 | 0.00 | **0.00** | No Flow (WS < inlet) | N/A |
| 7012.00 | | 6.60 | 27.19 | **6.60** | Min. Energy. Eqn. | INLET |
| 7013.00 | | 32.40 | 39.77 | **32.40** | Regression Eqn. | INLET |
| 7014.00 | | 56.40 | 59.06 | **56.40** | Regression Eqn. | INLET |
| 7015.00 | | 73.20 | 75.44 | **73.20** | Regression Eqn. | INLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.28 Seconds

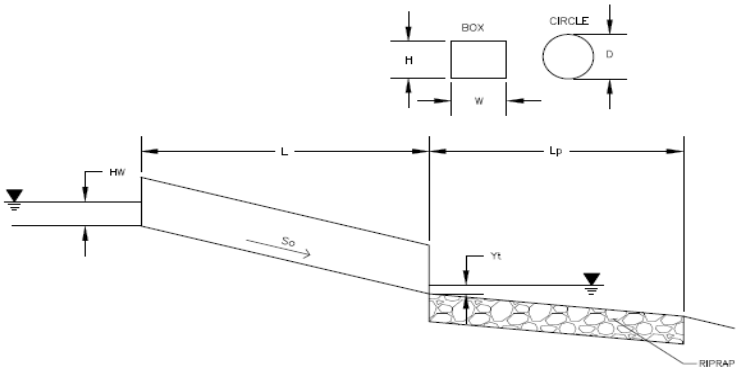
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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 Ha to calculate protection type.**

## Design Information (Input):

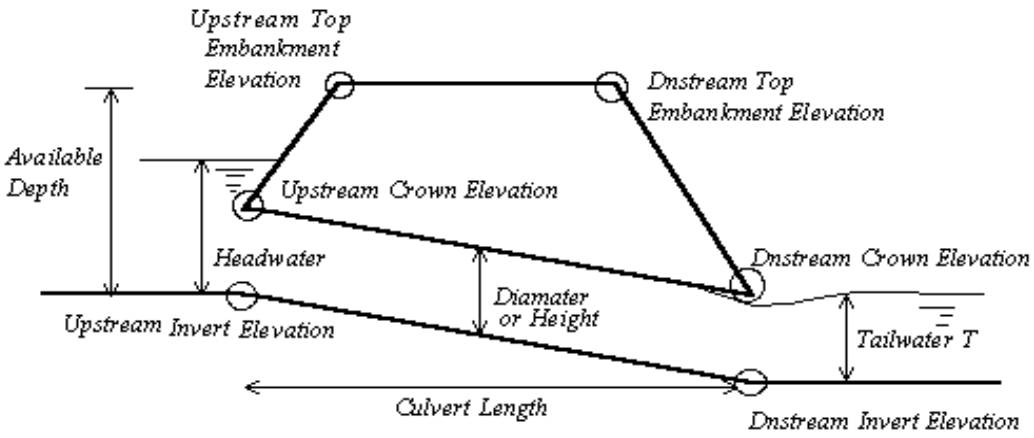
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 3.33 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | | inches |
| Inlet Edge Type (Choose from pull-down list) | Square End Projection | | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | 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 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 3.00 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.40 | |
| Friction Loss Coefficient | $k_f$ = | 0.91 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.31 | ft |
| 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(Θ)) = | 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/H = | 0.72 | |
| Inlet Control Headwater | $HW_I$ = | 0.32 | ft |
| Outlet Control Headwater | $HW_O$ = | 0.36 | |
| **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

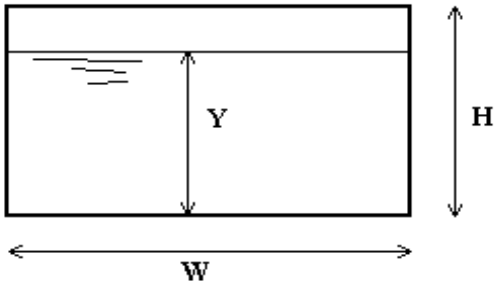
**Project =** **Vollmer Substation**
**Box ID =** **PRC3 - Crossing Access South of Property - 5 Yr**




| **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)

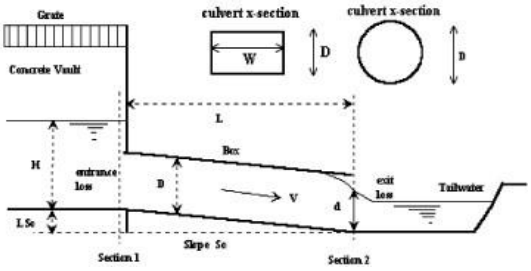
**Project:** Vollmer Substation
**Box ID:** PRC3 - Crossing Access South of Property - 100 Yr




| | | | |
|---|---|---|---|
| **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 | |

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

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



## Design Information (Input):

**Circular Culvert:** Barrel Diameter in Inches — D = inches
Inlet Edge Type (choose from pull-down list) — Grooved End with Headwall

**OR:**

**Box Culvert:** Barrel Height (Rise) in Feet — Height (Rise) = 1.50 ft.
Barrel Width (Span) in Feet — Width (Span) = 2.00 ft.
Inlet Edge Type (choose from pull-down list) — Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels — No = 3
Inlet Elevation at Culvert Invert — Inlet Elev = 7011.5 ft. elev.
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.) — Outlet Elev = 7011 ft. elev.
Culvert Length in Feet — L = 50 ft.
Manning's Roughness — n = 0.013
Bend Loss Coefficient — $K_b$ = 0
Exit Loss Coefficient — $K_x$ = 1

## Design Information (calculated):

Entrance Loss Coefficient — $K_e$ = 0.40
Friction Loss Coefficient — $K_f$ = 0.91
Sum of All Loss Coefficients — $K_s$ = 2.31
Orifice Inlet Condition Coefficient — $C_d$ = 0.87
Minimum Energy Condition Coefficient — $KE_{low}$ = 0.0062

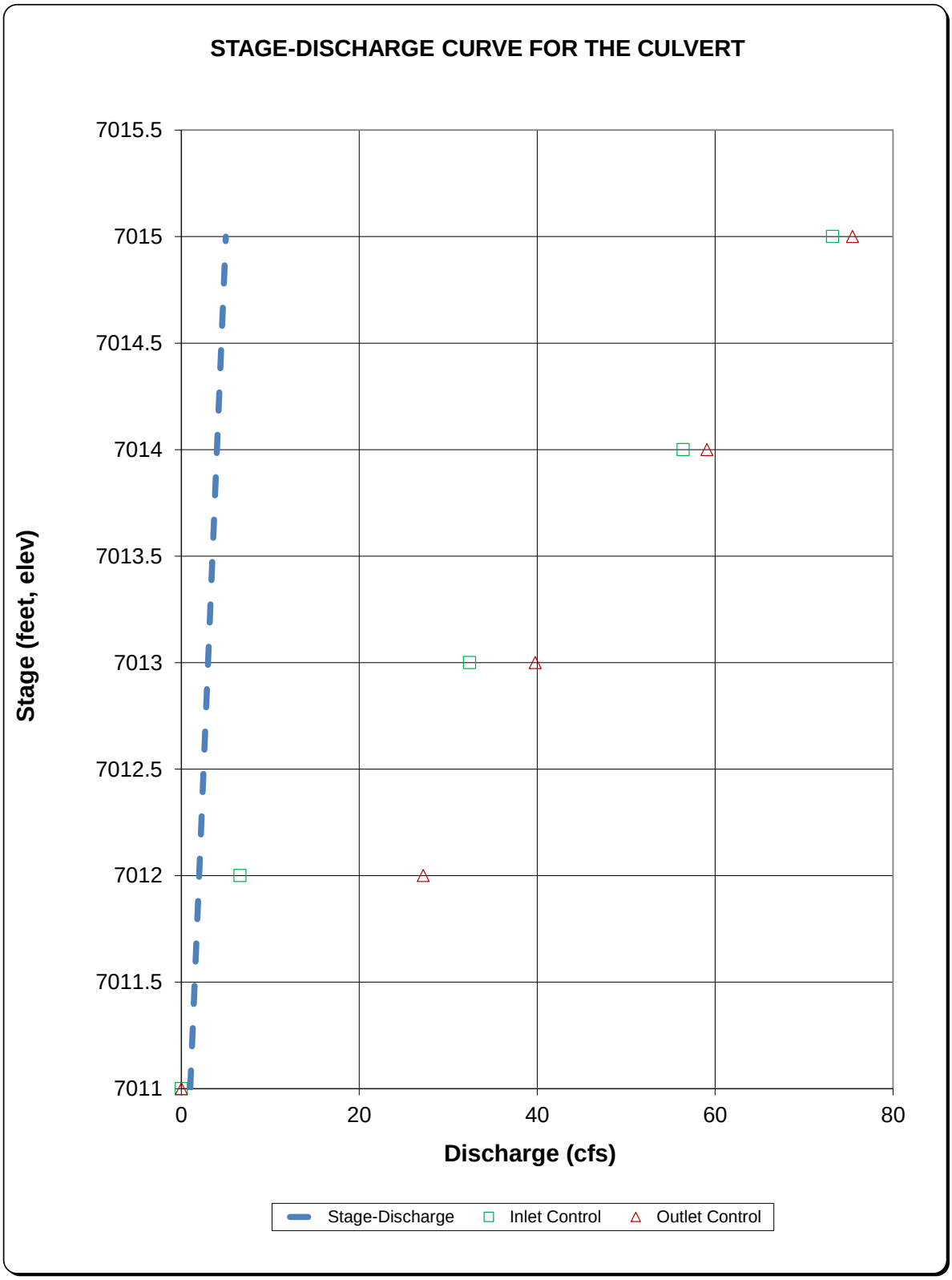
## Calculations of Culvert Capacity (output):

| Water Surface Elevation (ft., linked) | Tailwater Surface Elevation ft | Culvert Inlet-Control Flowrate cfs | Culvert Outlet-Control Flowrate cfs | Controlling Culvert Flowrate cfs (output) | Inlet Equation Used: | Flow Control Used |
|---|---|---|---|---|---|---|
| 7011.00 | | 0.00 | 0.00 | **0.00** | No Flow (WS < inlet) | N/A |
| 7012.00 | | 6.60 | 27.19 | **6.60** | Min. Energy. Eqn. | INLET |
| 7013.00 | | 32.40 | 39.77 | **32.40** | Regression Eqn. | INLET |
| 7014.00 | | 56.40 | 59.06 | **56.40** | Regression Eqn. | INLET |
| 7015.00 | | 73.20 | 75.44 | **73.20** | Regression Eqn. | INLET |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |
| | | | | | Invalid Entry | |

Processing Time: 01.18 Seconds

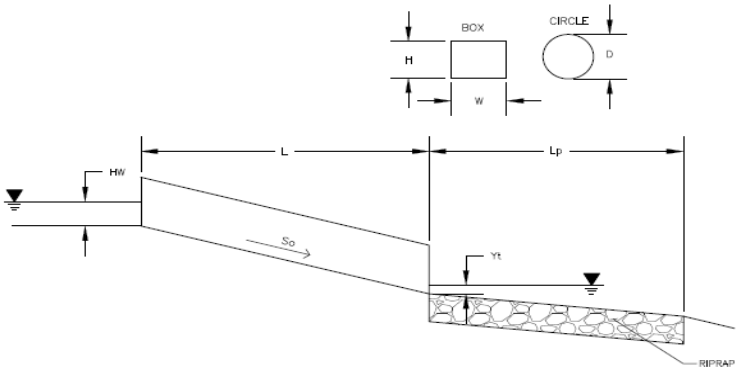
## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

**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 Ha to calculate protection type.**

## Design Information (Input):

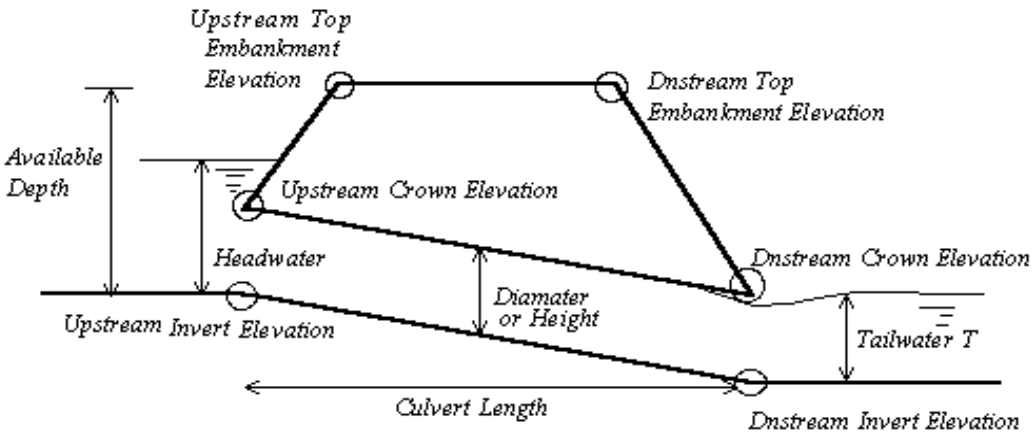
| | | | |
|---|---|---|---|
| Design Discharge | Q = | 48.5 | cfs |
| **Circular Culvert:** | | | |
| Barrel Diameter in Inches | D = | | inches |
| Inlet Edge Type (Choose from pull-down list) | Square End Projection | | |
| **Box Culvert:** | | **OR** | |
| Barrel Height (Rise) in Feet | Height (Rise) = | 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 | $ft^2$ |
| Culvert Cross Sectional Area Available | A = | 3.00 | $ft^2$ |
| Entrance Loss Coefficient | $k_e$ = | 0.40 | |
| Friction Loss Coefficient | $k_f$ = | 0.91 | |
| Sum of All Losses Coefficients | $k_s$ = | 2.31 | ft |
| 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(Θ)) = | 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 | **Supercritical!** |
| Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise | Yt/H = | 0.46 | |
| Inlet Control Headwater | $HW_I$ = | 2.13 | ft |
| Outlet Control Headwater | $HW_O$ = | 1.92 | |
| **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 |

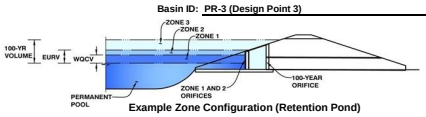
# WATER QUALITY CALCULATIONS

# DETENTION BASIN STAGE-STORAGE TABLE BUILDER

**UD-Detention, Version 3.07 (February 2017)**

**Project:** Vollmer 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 | **Note: L / W Ratio < 1** |
| Watershed Length = | 180 | ft | **L / W Ratio = 0.4** |
| Watershed Slope = | 0.010 | ft/ft | |
| Watershed Imperviousness = | 40.00% | percent | |
| Percentage Hydrologic Soil Group A = | 100.0% | 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 | **Drain Time Too Long** |
| Location for 1-hr Rainfall Depths = | Denver - Capitol Building | | |
| Water Quality Capture Volume (WQCV) = | 0.020 | acre-feet | Optional User Override 1-hr Precipitation |
| Excess Urban Runoff Volume (EURV) = | 0.074 | acre-feet | |
| 2-yr Runoff Volume (P1 = 1.19 in.) = | 0.050 | acre-feet | 1.19 inches |
| 5-yr Runoff Volume (P1 = 1.5 in.) = | 0.066 | acre-feet | 1.50 inches |
| 10-yr Runoff Volume (P1 = 1.75 in.) = | 0.082 | acre-feet | 1.75 inches |
| 25-yr Runoff Volume (P1 = 2 in.) = | 0.105 | acre-feet | 2.00 inches |
| 50-yr Runoff Volume (P1 = 2.25 in.) = | 0.136 | acre-feet | 2.25 inches |
| 100-yr Runoff Volume (P1 = 2.52 in.) = | 0.175 | acre-feet | 2.52 inches |
| 500-yr Runoff Volume (P1 = 3.14 in.) = | 0.265 | acre-feet | inches |
| 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 | |

**Stage-Storage Calculation**

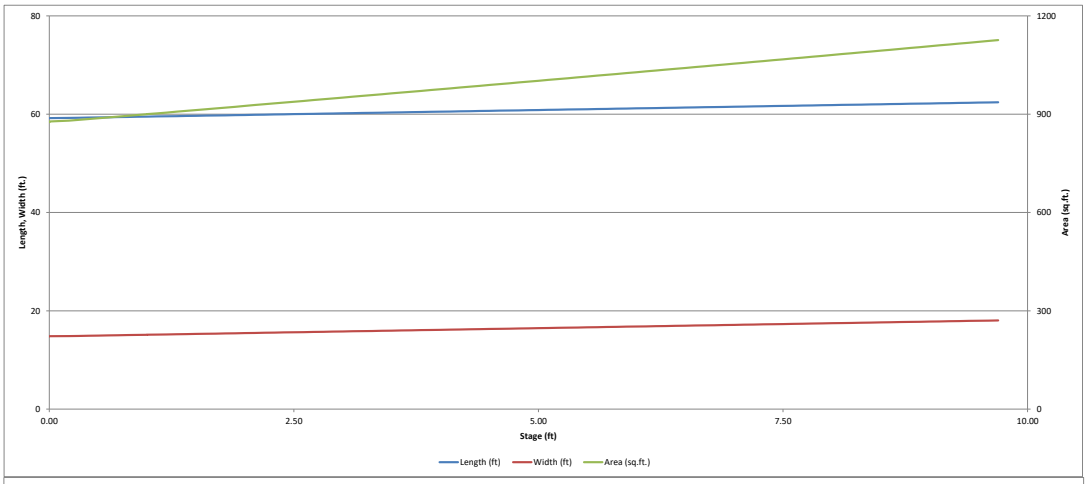
| | | | |
|---|---|---|---|
| Zone 1 Volume (WQCV) = | 0.020 | acre-feet | |
| Select Zone 2 Storage Volume (Optional) = | | acre-feet | **Total detention volume is less than 100-year volume.** |
| Select Zone 3 Storage Volume (Optional) = | | acre-feet | |
| Total Detention Basin Volume = | 0.020 | acre-feet | |
| Initial Surcharge Volume (ISV) = | N/A | ft^3 | |
| 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 | **Smain not typical.** |
| Basin Length-to-Width Ratio ($R_{L/W}$) = | 4 | | |
| Initial Surcharge Area ($A_{ISV}$) = | 0 | ft^2 | |
| Surcharge Volume Length ($L_{ISV}$) = | 0.0 | ft | |
| Surcharge Volume Width ($W_{ISV}$) = | 0.0 | ft | |
| Depth of Basin Floor ($H_{FLOOR}$) = | 0.00 | ft | |
| Length of Basin Floor ($L_{FLOOR}$) = | 59.2 | ft | |
| Width of Basin Floor ($W_{FLOOR}$) = | 14.8 | ft | |
| Area of Basin Floor ($A_{FLOOR}$) = | 875 | ft^2 | |
| Volume of Basin Floor ($V_{FLOOR}$) = | 0 | ft^3 | |
| 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 | ft^2 | |
| Volume of Main Basin ($V_{MAIN}$) = | 888 | ft^3 | |
| Calculated Total Basin Volume ($V_{total}$) = | **0.020** | acre-feet | |

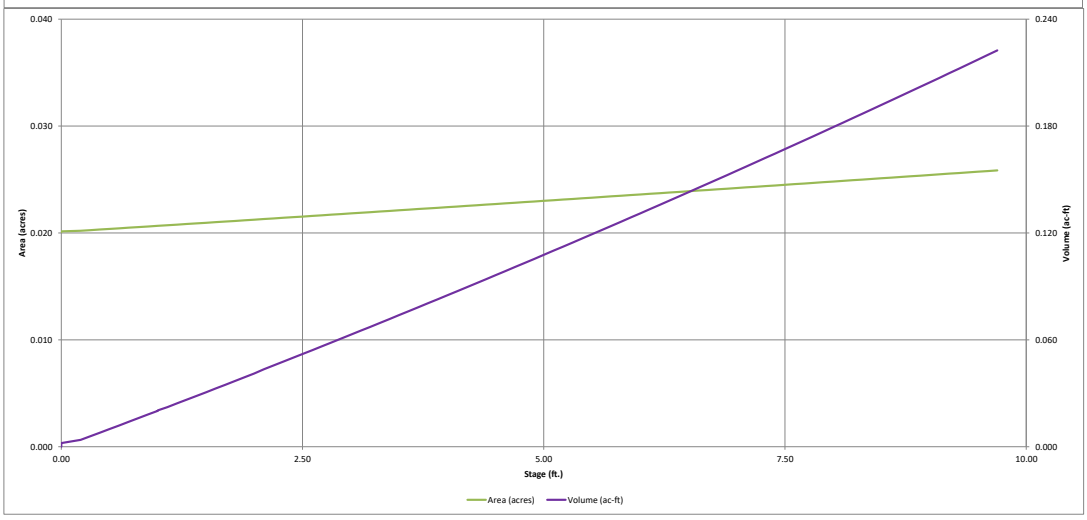
Depth Increment = 0.1 ft

| Stage - Storage Description | Stage (ft) | Optional Override Stage (ft) | Length (ft) | Width (ft) | Area (ft^2) | Optional Override Area (ft^2) | Area (acre) | Volume (ft^3) | Volume (ac-ft) |
|---|---|---|---|---|---|---|---|---|---|
| **Media Surface** | 0.00 | | 59.2 | 14.8 | 875 | | 0.020 | | |
| | 0.10 | | 59.2 | 14.8 | 878 | | 0.020 | 88 | 0.002 |
| | 0.20 | | 59.2 | 14.9 | 880 | | 0.020 | 167 | 0.004 |
| | 0.30 | | 59.3 | 14.9 | 883 | | 0.020 | 255 | 0.006 |
| | 0.40 | | 59.3 | 14.9 | 885 | | 0.020 | 343 | 0.008 |
| | 0.50 | | 59.3 | 15.0 | 888 | | 0.020 | 432 | 0.010 |
| | 0.60 | | 59.4 | 15.0 | 890 | | 0.020 | 521 | 0.012 |
| | 0.70 | | 59.4 | 15.0 | 893 | | 0.020 | 610 | 0.014 |
| | 0.80 | | 59.4 | 15.1 | 895 | | 0.021 | 699 | 0.016 |
| | 0.90 | | 59.5 | 15.1 | 898 | | 0.021 | 789 | 0.018 |
| | 1.00 | | 59.5 | 15.1 | 900 | | 0.021 | 879 | 0.020 |
| **Zone 1 (WQCV)** | 1.00 | | 59.5 | 15.1 | 900 | | 0.021 | 888 | 0.020 |
| | 1.10 | | 59.5 | 15.2 | 903 | | 0.021 | 969 | 0.022 |
| | 1.20 | | 59.6 | 15.2 | 905 | | 0.021 | 1,059 | 0.024 |
| | 1.30 | | 59.6 | 15.2 | 908 | | 0.021 | 1,150 | 0.026 |
| | 1.40 | | 59.6 | 15.3 | 910 | | 0.021 | 1,241 | 0.028 |
| | 1.50 | | 59.7 | 15.3 | 913 | | 0.021 | 1,332 | 0.031 |
| | 1.60 | | 59.7 | 15.3 | 915 | | 0.021 | 1,423 | 0.033 |
| | 1.70 | | 59.7 | 15.4 | 918 | | 0.021 | 1,515 | 0.035 |
| | 1.80 | | 59.8 | 15.4 | 920 | | 0.021 | 1,607 | 0.037 |
| | 1.90 | | 59.8 | 15.4 | 923 | | 0.021 | 1,699 | 0.039 |
| | 2.00 | | 59.8 | 15.5 | 925 | | 0.021 | 1,791 | 0.041 |
| | 2.10 | | 59.9 | 15.5 | 928 | | 0.021 | 1,893 | 0.043 |
| | 2.20 | | 59.9 | 15.5 | 930 | | 0.021 | 1,986 | 0.046 |
| | 2.30 | | 59.9 | 15.6 | 933 | | 0.021 | 2,079 | 0.048 |
| | 2.40 | | 60.0 | 15.6 | 935 | | 0.021 | 2,173 | 0.050 |
| | 2.50 | | 60.0 | 15.6 | 938 | | 0.022 | 2,267 | 0.052 |
| | 2.60 | | 60.0 | 15.7 | 941 | | 0.022 | 2,360 | 0.054 |
| | 2.70 | | 60.1 | 15.7 | 943 | | 0.022 | 2,455 | 0.056 |
| | 2.80 | | 60.1 | 15.7 | 946 | | 0.022 | 2,549 | 0.059 |
| | 2.90 | | 60.1 | 15.8 | 948 | | 0.022 | 2,644 | 0.061 |
| | 3.00 | | 60.2 | 15.8 | 951 | | 0.022 | 2,739 | 0.063 |
| | 3.10 | | 60.2 | 15.8 | 953 | | 0.022 | 2,834 | 0.065 |
| | 3.20 | | 60.2 | 15.9 | 956 | | 0.022 | 2,929 | 0.067 |
| | 3.30 | | 60.3 | 15.9 | 958 | | 0.022 | 3,025 | 0.069 |
| | 3.40 | | 60.3 | 15.9 | 961 | | 0.022 | 3,121 | 0.072 |
| | 3.50 | | 60.3 | 16.0 | 963 | | 0.022 | 3,217 | 0.074 |
| | 3.60 | | 60.4 | 16.0 | 966 | | 0.022 | 3,314 | 0.076 |
| | 3.70 | | 60.4 | 16.0 | 969 | | 0.022 | 3,410 | 0.078 |
| | 3.80 | | 60.4 | 16.1 | 971 | | 0.022 | 3,507 | 0.081 |
| | 3.90 | | 60.5 | 16.1 | 974 | | 0.022 | 3,605 | 0.083 |
| | 4.00 | | 60.5 | 16.1 | 976 | | 0.022 | 3,702 | 0.085 |
| | 4.10 | | 60.5 | 16.2 | 979 | | 0.022 | 3,800 | 0.087 |
| | 4.20 | | 60.6 | 16.2 | 981 | | 0.023 | 3,898 | 0.089 |
| | 4.30 | | 60.6 | 16.2 | 984 | | 0.023 | 3,996 | 0.092 |
| | 4.40 | | 60.6 | 16.3 | 987 | | 0.023 | 4,095 | 0.094 |
| | 4.50 | | 60.7 | 16.3 | 989 | | 0.023 | 4,194 | 0.096 |
| | 4.60 | | 60.7 | 16.3 | 992 | | 0.023 | 4,293 | 0.099 |
| | 4.70 | | 60.7 | 16.4 | 994 | | 0.023 | 4,392 | 0.101 |
| | 4.80 | | 60.8 | 16.4 | 997 | | 0.023 | 4,491 | 0.103 |
| | 4.90 | | 60.8 | 16.4 | 999 | | 0.023 | 4,591 | 0.105 |
| | 5.00 | | 60.8 | 16.5 | 1,002 | | 0.023 | 4,691 | 0.108 |
| | 5.10 | | 60.9 | 16.5 | 1,005 | | 0.023 | 4,792 | 0.110 |
| | 5.20 | | 60.9 | 16.5 | 1,007 | | 0.023 | 4,892 | 0.112 |
| | 5.30 | | 60.9 | 16.6 | 1,010 | | 0.023 | 4,993 | 0.115 |
| | 5.40 | | 61.0 | 16.6 | 1,012 | | 0.023 | 5,094 | 0.117 |
| | 5.50 | | 61.0 | 16.6 | 1,015 | | 0.023 | 5,196 | 0.119 |
| | 5.60 | | 61.0 | 16.7 | 1,018 | | 0.023 | 5,297 | 0.122 |
| | 5.70 | | 61.1 | 16.7 | 1,020 | | 0.023 | 5,399 | 0.124 |
| | 5.80 | | 61.1 | 16.7 | 1,023 | | 0.023 | 5,501 | 0.126 |
| | 5.90 | | 61.2 | 16.8 | 1,025 | | 0.024 | 5,604 | 0.129 |
| | 6.00 | | 61.2 | 16.8 | 1,028 | | 0.024 | 5,706 | 0.131 |
| | 6.10 | | 61.2 | 16.8 | 1,031 | | 0.024 | 5,809 | 0.133 |
| | 6.20 | | 61.3 | 16.9 | 1,033 | | 0.024 | 5,912 | 0.136 |
| | 6.30 | | 61.3 | 16.9 | 1,036 | | 0.024 | 6,016 | 0.138 |
| | 6.40 | | 61.3 | 16.9 | 1,038 | | 0.024 | 6,120 | 0.140 |
| | 6.50 | | 61.4 | 17.0 | 1,041 | | 0.024 | 6,224 | 0.143 |
| | 6.60 | | 61.4 | 17.0 | 1,044 | | 0.024 | 6,328 | 0.145 |
| | 6.70 | | 61.4 | 17.0 | 1,046 | | 0.024 | 6,432 | 0.148 |
| | 6.80 | | 61.5 | 17.1 | 1,049 | | 0.024 | 6,537 | 0.150 |
| | 6.90 | | 61.5 | 17.1 | 1,052 | | 0.024 | 6,642 | 0.152 |
| | 7.00 | | 61.5 | 17.1 | 1,054 | | 0.024 | 6,747 | 0.155 |
| | 7.10 | | 61.6 | 17.2 | 1,057 | | 0.024 | 6,853 | 0.157 |
| | 7.20 | | 61.6 | 17.2 | 1,060 | | 0.024 | 6,959 | 0.160 |
| | 7.30 | | 61.6 | 17.2 | 1,062 | | 0.024 | 7,065 | 0.162 |
| | 7.40 | | 61.7 | 17.3 | 1,065 | | 0.024 | 7,171 | 0.165 |
| | 7.50 | | 61.7 | 17.3 | 1,067 | | 0.025 | 7,278 | 0.167 |
| | 7.60 | | 61.7 | 17.3 | 1,070 | | 0.025 | 7,385 | 0.170 |
| | 7.70 | | 61.8 | 17.4 | 1,073 | | 0.025 | 7,492 | 0.172 |
| | 7.80 | | 61.8 | 17.4 | 1,075 | | 0.025 | 7,599 | 0.174 |
| | 7.90 | | 61.8 | 17.4 | 1,078 | | 0.025 | 7,707 | 0.177 |
| | 8.00 | | 61.9 | 17.5 | 1,081 | | 0.025 | 7,815 | 0.179 |
| | 8.10 | | 61.9 | 17.5 | 1,083 | | 0.025 | 7,923 | 0.182 |
| | 8.20 | | 61.9 | 17.5 | 1,086 | | 0.025 | 8,032 | 0.184 |
| | 8.30 | | 62.0 | 17.6 | 1,089 | | 0.025 | 8,140 | 0.187 |
| | 8.40 | | 62.0 | 17.6 | 1,091 | | 0.025 | 8,249 | 0.189 |
| | 8.50 | | 62.0 | 17.6 | 1,094 | | 0.025 | 8,359 | 0.192 |
| | 8.60 | | 62.1 | 17.7 | 1,097 | | 0.025 | 8,468 | 0.194 |
| | 8.70 | | 62.1 | 17.7 | 1,099 | | 0.025 | 8,578 | 0.197 |
| | 8.80 | | 62.1 | 17.7 | 1,102 | | 0.025 | 8,688 | 0.199 |
| | 8.90 | | 62.2 | 17.8 | 1,105 | | 0.025 | 8,798 | 0.202 |
| | 9.00 | | 62.2 | 17.8 | 1,107 | | 0.025 | 8,909 | 0.205 |
| | 9.10 | | 62.2 | 17.8 | 1,110 | | 0.025 | 9,020 | 0.207 |
| | 9.20 | | 62.3 | 17.9 | 1,113 | | 0.026 | 9,131 | 0.210 |
| | 9.30 | | 62.3 | 17.9 | 1,115 | | 0.026 | 9,242 | 0.212 |
| | 9.40 | | 62.3 | 17.9 | 1,118 | | 0.026 | 9,354 | 0.215 |
| | 9.50 | | 62.4 | 18.0 | 1,121 | | 0.026 | 9,466 | 0.217 |
| | 9.60 | | 62.4 | 18.0 | 1,123 | | 0.026 | 9,578 | 0.220 |
| | 9.70 | | 62.4 | 18.0 | 1,126 | | 0.026 | 9,691 | 0.222 |

# DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)



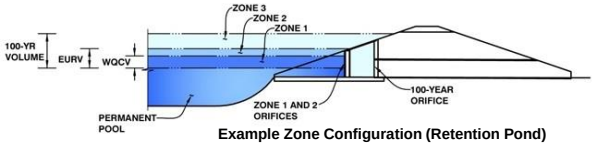



# Detention Basin Outlet Structure Design

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, Ho = | 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, $H_t$ = | 7025.00 | | feet |
| Over Flow Weir Slope Length = | 2.00 | | feet |
| Grate Open Area / 100-yr Orifice Area = | | | should be $\geq$ 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**

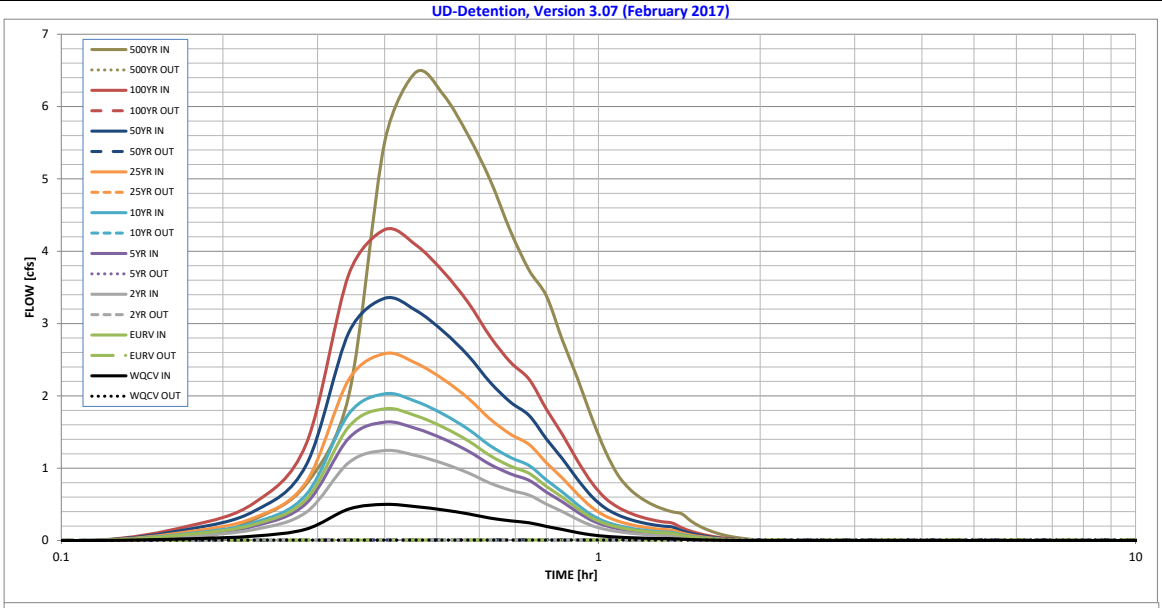
| | | |
|---|---|---|
| Spillway Design Flow Depth= | | feet |
| Stage at Top of Freeboard = | | feet |
| Basin Area at Top of Freeboard = | | acres |

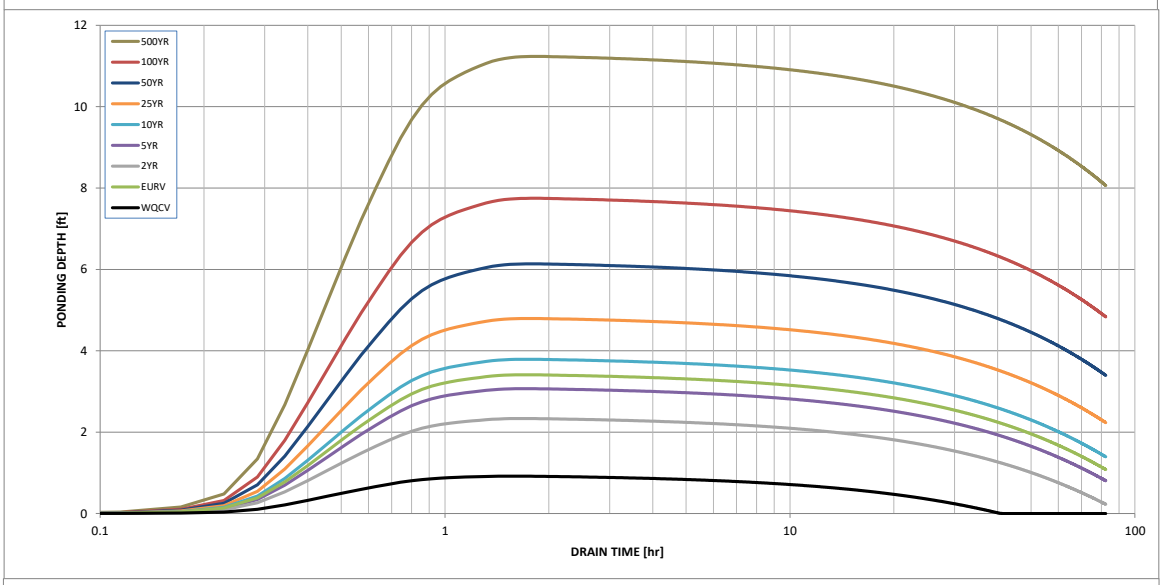
**Routed Hydrograph Results**

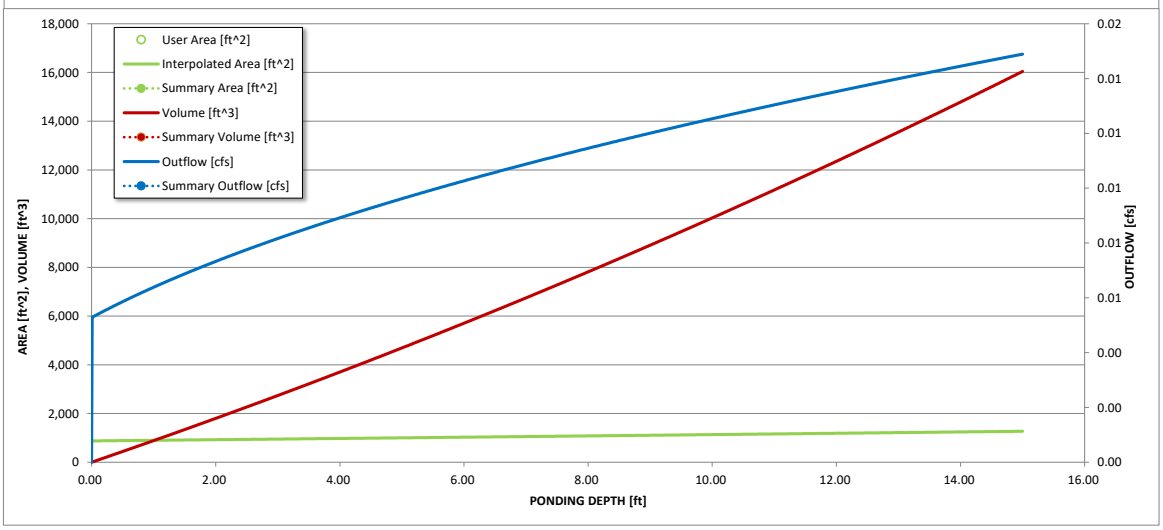
| Design Storm Return Period = | WQCV | EURV | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | 500 Year |
|---|---|---|---|---|---|---|---|---|---|
| One-Hour Rainfall Depth (in) = | 0.53 | 1.07 | 1.19 | 1.50 | 1.75 | 2.00 | 2.25 | 2.52 | 3.14 |
| Calculated Runoff Volume (acre-ft) = | 0.020 | 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 |

# 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 | | | |

# Detention Basin Outlet Structure Design

Outflow Hydrograph Workbook Filename:

**Storm Inflow Hydrographs** **UD-Detention, Version 3.07 (February 2017)**

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

| | SOURCE | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK | WORKBOOK |
|---|---|---|---|---|---|---|---|---|---|---|
| Time Interval | TIME | WQCV [cfs] | EURV [cfs] | 2 Year [cfs] | 5 Year [cfs] | 10 Year [cfs] | 25 Year [cfs] | 50 Year [cfs] | 100 Year [cfs] | 500 Year [cfs] |
| 3.43 min | 0:00:00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0:03:26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hydrograph | 0:06:52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Constant | 0:10:17 | 0.02 | 0.08 | 0.06 | 0.08 | 0.09 | 0.12 | 0.15 | 0.20 | 0.29 |
| 1.457 | 0:13:43 | 0.06 | 0.22 | 0.15 | 0.20 | 0.25 | 0.31 | 0.41 | 0.52 | 0.78 |
| | 0:17:09 | 0.16 | 0.57 | 0.39 | 0.51 | 0.64 | 0.81 | 1.05 | 1.34 | 2.01 |
| | 0:20:35 | 0.44 | 1.57 | 1.08 | 1.42 | 1.75 | 2.23 | 2.88 | 3.68 | 5.52 |
| | 0:24:01 | 0.50 | 1.82 | 1.24 | 1.64 | 2.03 | 2.59 | 3.35 | 4.30 | 6.48 |
| | 0:27:26 | 0.47 | 1.73 | 1.18 | 1.55 | 1.92 | 2.45 | 3.18 | 4.09 | 6.16 |
| | 0:30:52 | 0.42 | 1.57 | 1.07 | 1.41 | 1.75 | 2.23 | 2.89 | 3.72 | 5.61 |
| | 0:34:18 | 0.37 | 1.38 | 0.94 | 1.24 | 1.54 | 1.97 | 2.56 | 3.29 | 4.98 |
| | 0:37:44 | 0.31 | 1.17 | 0.79 | 1.05 | 1.31 | 1.68 | 2.19 | 2.82 | 4.28 |
| | 0:41:10 | 0.27 | 1.03 | 0.70 | 0.92 | 1.15 | 1.47 | 1.91 | 2.46 | 3.74 |
| | 0:44:35 | 0.25 | 0.93 | 0.63 | 0.83 | 1.04 | 1.33 | 1.73 | 2.23 | 3.38 |
| | 0:48:01 | 0.19 | 0.75 | 0.50 | 0.67 | 0.84 | 1.07 | 1.40 | 1.81 | 2.76 |
| | 0:51:27 | 0.15 | 0.60 | 0.40 | 0.53 | 0.67 | 0.86 | 1.13 | 1.46 | 2.24 |
| | 0:54:53 | 0.11 | 0.44 | 0.29 | 0.39 | 0.49 | 0.64 | 0.84 | 1.10 | 1.70 |
| | 0:58:19 | 0.08 | 0.31 | 0.21 | 0.28 | 0.35 | 0.46 | 0.61 | 0.80 | 1.24 |
| | 1:01:44 | 0.06 | 0.23 | 0.16 | 0.21 | 0.26 | 0.34 | 0.45 | 0.59 | 0.91 |
| | 1:05:10 | 0.05 | 0.19 | 0.12 | 0.17 | 0.21 | 0.27 | 0.36 | 0.46 | 0.71 |
| | 1:08:36 | 0.04 | 0.15 | 0.10 | 0.14 | 0.17 | 0.22 | 0.29 | 0.38 | 0.59 |
| | 1:12:02 | 0.03 | 0.13 | 0.09 | 0.12 | 0.15 | 0.19 | 0.25 | 0.33 | 0.50 |
| | 1:15:28 | 0.03 | 0.12 | 0.08 | 0.10 | 0.13 | 0.17 | 0.22 | 0.29 | 0.44 |
| | 1:18:53 | 0.03 | 0.11 | 0.07 | 0.09 | 0.12 | 0.15 | 0.20 | 0.26 | 0.40 |
| | 1:22:19 | 0.03 | 0.10 | 0.07 | 0.09 | 0.11 | 0.14 | 0.19 | 0.24 | 0.37 |
| | 1:25:45 | 0.02 | 0.07 | 0.05 | 0.07 | 0.08 | 0.10 | 0.14 | 0.18 | 0.27 |
| | 1:29:11 | 0.01 | 0.05 | 0.04 | 0.05 | 0.06 | 0.08 | 0.10 | 0.13 | 0.20 |
| | 1:32:37 | 0.01 | 0.04 | 0.03 | 0.03 | 0.04 | 0.06 | 0.07 | 0.09 | 0.14 |
| | 1:36:02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 | 0.11 |
| | 1:39:28 | 0.00 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 |
| | 1:42:54 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.03 | 0.05 |
| | 1:46:20 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.04 |
| | 1:49:46 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| | 1:53:11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| | 1:56:37 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| | 2:00:03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:03:29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:06:55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:10:20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:13:46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:17:12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:20:38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:24:04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:27:29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:30:55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:34:21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:37:47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:41:13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:44:38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:48:04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:51:30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:54:56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2:58:22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:01:47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:05:13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:08:39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:12:05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:15:31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:18:56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:22:22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:25:48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:29:14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:32:40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:36:05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:39:31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:42:57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:46:23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:49:49 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:53:14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3:56:40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 4:00:06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 4:03:32 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 4:06:58 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# 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.

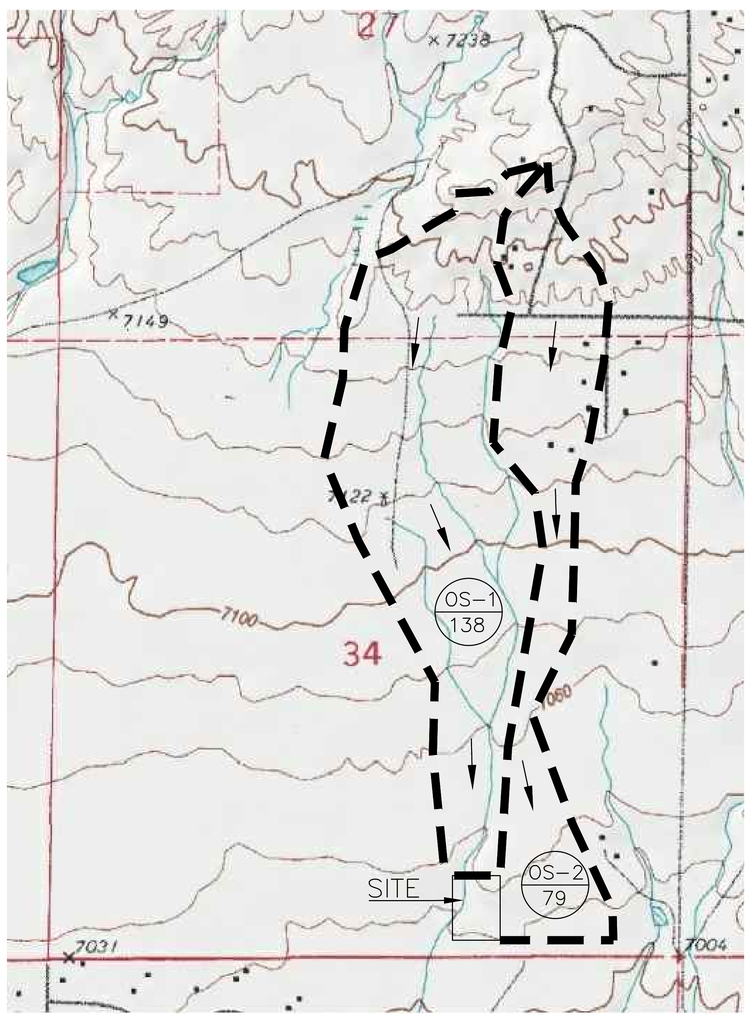
**PROPOSED CONDITIONS**

| 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 |

N

600' 0 600' 1200'

SCALE: 1"=600'




**LEGEND**

- P-7 / 12.22 — BASIN DESIGNATION / AREA IN BASIN (AC)
- D — DESIGN POINT
- BASIN BOUNDARY
- 7262 — EXISTING 2' CONTOUR
- 7260 — EXISTING 10' CONTOUR
- FLOW DIRECTION
- SURFACE FLOW CHANNEL
- X — FENCE LINE
- PR — PROPOSED
- EX — EXISTING

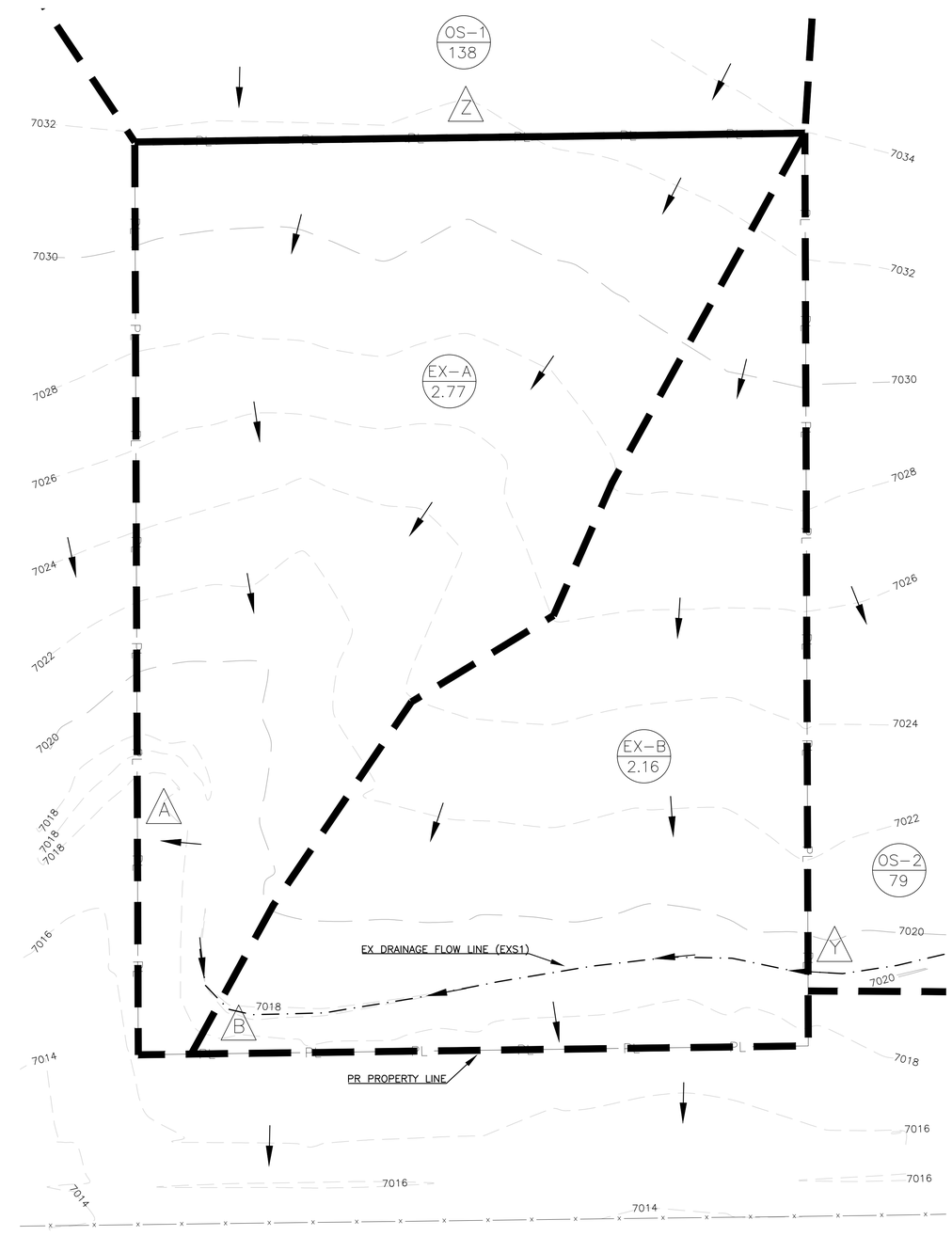
**NOTES**

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

N

40' 0 40' 80'

SCALE: 1"=40'




**REVISIONS**

| NO. | DESCRIPTION | DATE |
|---|---|---|
| | | |

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE APPROPRIATE REVIEWING AGENCIES, TERRA NOVA ENGINEERING, INC. APPROVES THEIR USE ONLY FOR THE PURPOSES DESIGNATED BY WRITTEN AUTHORIZATION.

PREPARED FOR:
MVEA
ATTN: DAVE WALDNER
11140 E. WOODMEN RD
PEYTON, CO 80831
(719) 495-2283


Terra Nova Engineering, Inc.
Creative Civil Engineering Solutions
721 S. 23RD STREET
COLORADO SPRINGS, CO 80904
OFFICE: 719-635-6422
FAX: 719-635-6426
www.tnesinc.com


VOLLMER SUBSTATION

EXISTING DRAINAGE MAP

DESIGNED BY LD
DRAWN BY DLF
CHECKED BY LD
H-SCALE 1"=40'
V-SCALE NA
JOB NO. 1845.00
DATE ISSUED 09/17/18
SHEET NO. 1 OF 3

# 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 |

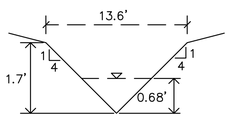
* NOTE: THE EXISTING SWALE EXS1 HAS A MAX CAPACITY OF 36.6 CFS.

### 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 |

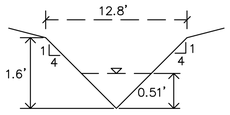
### NOTES

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




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

**SWALE CROSS SECTION – PRS1 (TYP)**

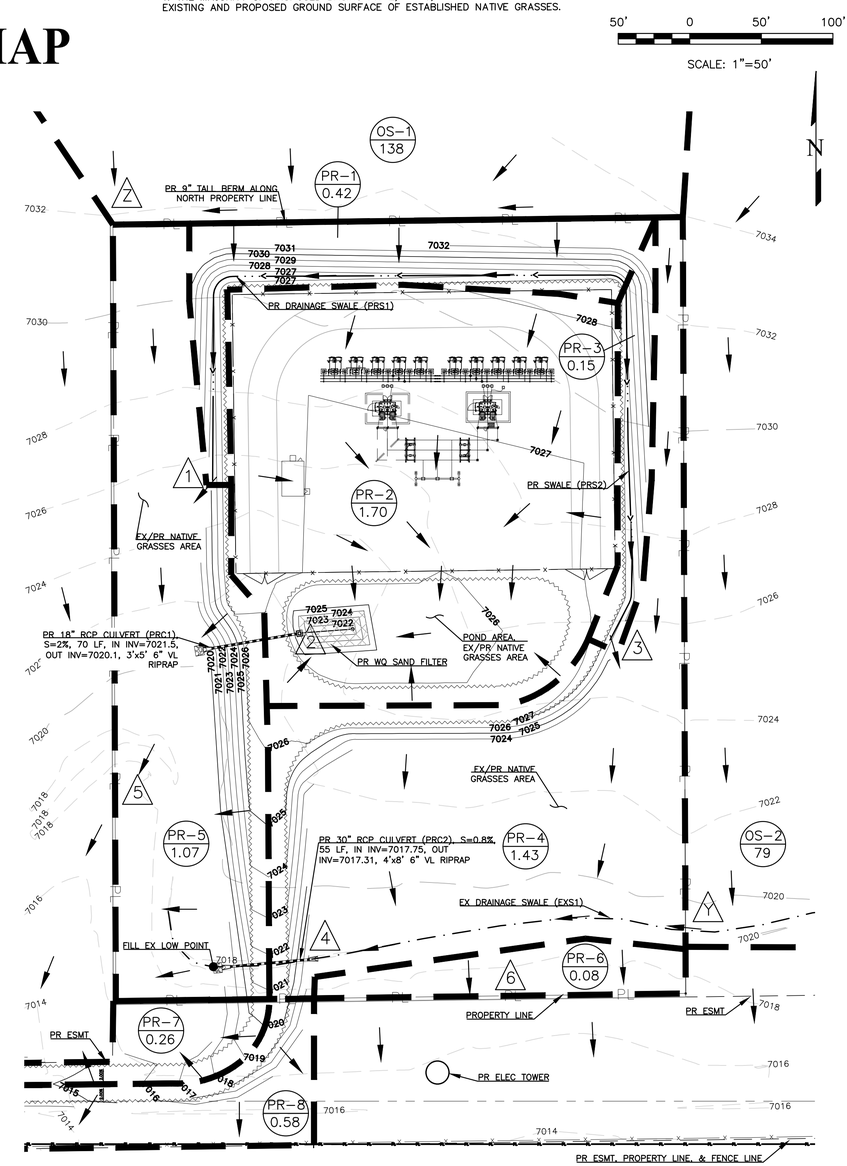


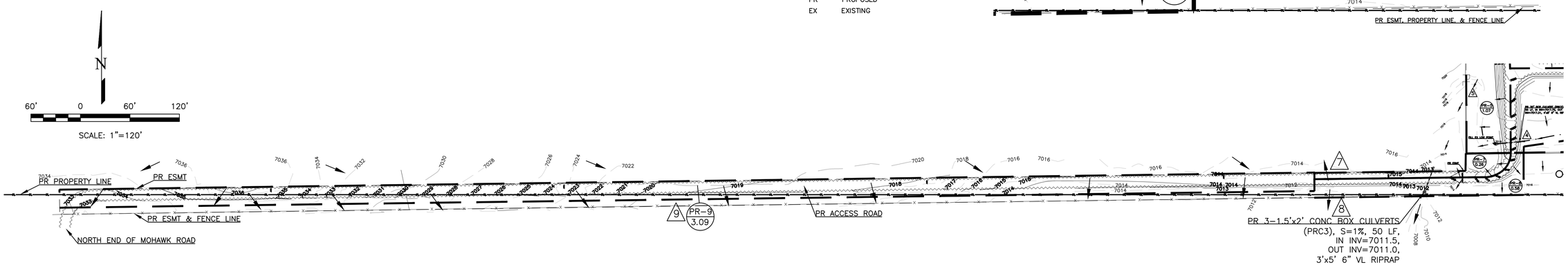

Q = 0.4 CFS
SLOPE = 0.8%
n VALUE = 0.13
DEPTH = 0.51'
VELOCITY = 0.40 FT/S

**SWALE CROSS SECTION – PRS2 (TYP)**

### LEGEND

| | |
|---|---|
| P-7 / 12.22 | BASIN DESIGNATION / AREA IN BASIN (AC) |
| D | DESIGN POINT |
| | BASIN BOUNDARY |
| 7262 | EXISTING 2' CONTOUR |
| 7260 | EXISTING 10' CONTOUR |
| | FLOW DIRECTION |
| | SURFACE FLOW CHANNEL |
| X | FENCE LINE |
| 7261 | PROPOSED 1' CONTOUR |
| 7265 | PROPOSED 5' CONTOUR |
| | PROPOSED EDGE OF GRAVEL |
| PR | PROPOSED |
| EX | EXISTING |




REVISIONS

| NO. | DESCRIPTION | DATE |
|---|---|---|
| | | |

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE APPROPRIATE REVIEWING AGENCIES, TERRA NOVA ENGINEERING, INC. APPROVES THEIR USE ONLY FOR THE PURPOSES DESIGNATED BY WRITTEN AUTHORIZATION.


PREPARED FOR:
MVEA
ATTN: DAVE WALDNER
11140 E. WOODMEN RD
PEYTON, CO 80831
(719) 495-2283

Terra Nova Engineering, Inc.
Creative Civil Engineering Solutions
721 S. 23RD STREET
COLORADO SPRINGS, CO 80904
OFFICE: 719-635-6422
FAX: 719-635-6426
www.tnesinc.com


VOLLMER SUBSTATION

DEVELOPED DRAINAGE MAP

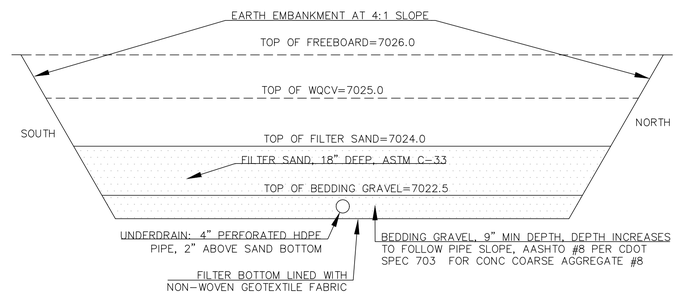
DESIGNED BY LD
DRAWN BY DLF
CHECKED BY LD
H-SCALE AS SHOWN
V-SCALE NA
JOB NO. 1845.00
DATE ISSUED 09/17/18
SHEET NO. 2 OF 3

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

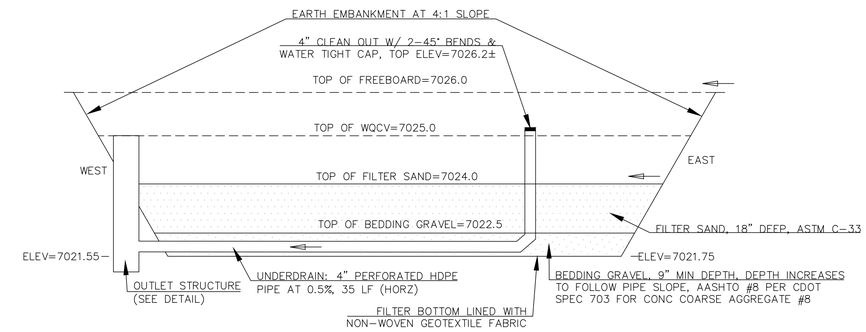
**NOTES**

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

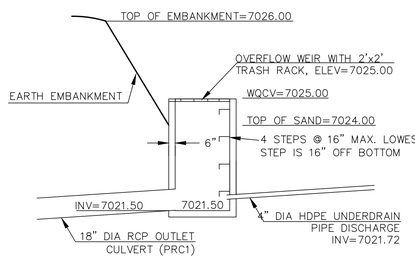



SAND FILTER – PROFILE VIEW (NORTH–SOUTH)
N.T.S.

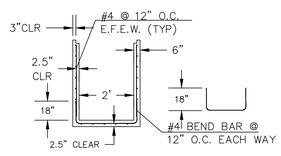



SAND FILTER – PROFILE VIEW (WEST–EAST)
N.T.S.

PRELIMINARY
NOT FOR CONSTRUCTION




**OUTLET STRUCTURE (CONCRETE & STEEL)**

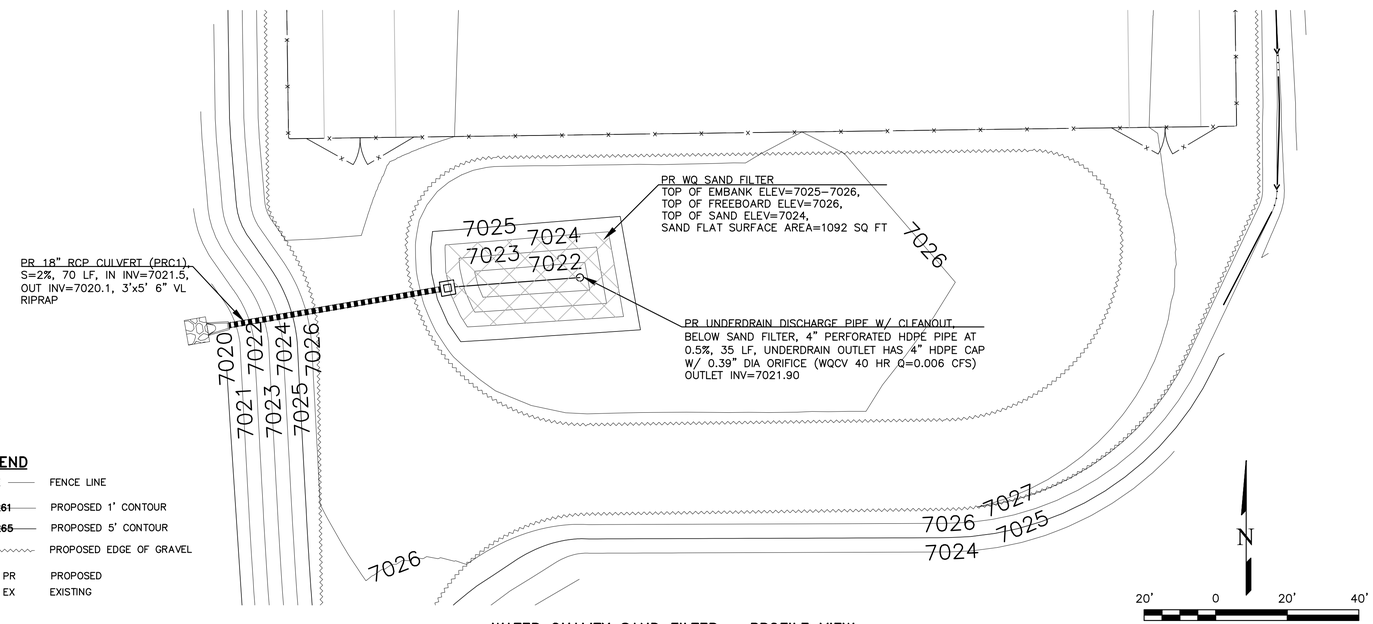



**2'x2' OUTLET BOX STRUCTURAL DETAIL**

**SAND FILTER OUTLET OVERALL DETAIL**
**N.T.S**

**LEGEND**

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




**WATER QUALITY SAND FILTER – PROFILE VIEW**
**SCALE: 1"=20'**

| REVISIONS | | |
|---|---|---|
| NO. | DESCRIPTION | DATE |

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE APPROPRIATE REVIEWING AGENCIES, TERRA NOVA ENGINEERING, INC. APPROVES THEIR USE ONLY FOR THE PURPOSES DESIGNATED BY WRITTEN AUTHORIZATION.

PREPARED FOR:
MVEA
ATTN: DAVE WALDNER
11140 E. WOODMEN RD
PEYTON, CO 80831
(719) 495-2283


Terra Nova Engineering, Inc.
"Creative Civil Engineering Solutions"
721 S. 23RD STREET
COLORADO SPRINGS, CO 80904
OFFICE: 719-635-6422
FAX: 719-635-6426
www.tnesinc.com


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 |