Final Drainage Report
for
Bybee 14-L Facility

Prepared For:

Extraction Oil & Gas

370 17th St. Suite #5300

Denver, CO 80202

Prepared By:

Petroleum Field Services

7535 Hilltop Circle

Denver, CO 80221

Nov 3, 2015

November 10, 2015

Mr. Adam Smith
Engineering & Utilities
Town of Frederick
401 Locust Street
Frederick, Colorado 80530

Bybee 14-L Facility Irrigation Ditch culverts

Dear Mr. Smith,

Per the comments on the final drainage report contained in the Development Review Committee Report for the Bybee 14-L facility, you requested that Extraction Oil & Gas obtain approval to install culverts in the two irrigation ditches to the east of the site from the owner of these ditches. We have identified that the Lower Boulder Ditch Company owns these ditches, and Extraction is currently in the process of obtaining a letter of approval from them. Since we have performed all necessary calculations and design work showing that these culverts will be sufficient to convey the full flow of these ditches and this information has been passed along to the ditch owner, we are requesting that you conditionally approve the Final Drainage Report for the Bybee 14-L Facility with the approval letter from the ditch owner to be included for the final approval.

Sincerely,

Petroleum Field Services, LLC.

Michael C. Welker, PE, CFM

Project Engineer

November 3, 2015

Mr. Adam Smith
Engineering & Utilities
Town of Frederick
401 Locust Street
Frederick, Colorado 80530

Re: Bybee 14-L Facility

Dear Mr. Smith,

Petroleum Field Services (PFS) has completed a final drainage report for the Bybee 14-L Facility located 2200 feet north of county road 20/Bella Rosa Parkway and 950 feet west of Silver Birch Boulevard.

This report is prepared in accordance with the *Urban Storm Drainage Criteria Manual Volumes 1-3* (USDCM). Since the Bybee 14-L Facility is located within the Godding Hollow Basin as shown in in the Basin Map located in Appendix A, the report was also prepared in accordance with the South Weld I-25 Corridor Master Drainage Plan. The site includes a WQ feature that incorporates water quality measures in accordance with the USDCM and an emergency spillway that releases stormwater from larger storms to the surrounding field following historic patterns. Therefore, the design of the proposed Bybee 14-L Facility is in compliance with the Town of Frederick, UDFCD stormwater criteria as well as the South Weld I-25 Corridor Master Drainage Plan.

We look forward to your consideration of and feedback on this Final Drainage Report. If you have any further questions or comments, please contact our office at 303-928-7128 or by email at mwelker@petro-fs.com.

Sincerely,

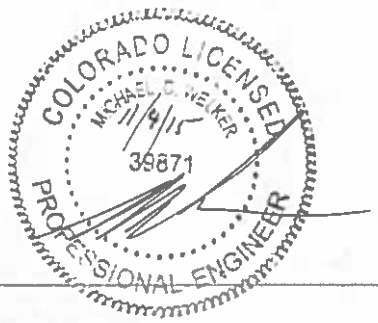
Petroleum Field Services, LLC.

Michael C. Welker, PE, CFM

Project Engineer

Certification of Engineering

I hereby certify that this report for the final drainage design of the Bybee 14-L Facility was prepared by me (or under my direct supervision) in accordance with the provisions of the Urban Drainage and Flood Control District Storm Drainage Criteria and supplemental Town of Frederick requirements for the owners thereof.



Michael C. Welker,

Registered Professional Engineer

State of Colorado No. 39871

Contents

1. General Location and Description

1.1. Location

The Bybee 14-L Facility is located in the North ½ of the Southeast ¼ of Section 14, Township 2 North, Range 68 West of the 6th Principal Meridian, Town of Frederick, County of Weld, State of Colorado. It is physically located about 2000 feet north of Weld county road 20/Bella Rosa Parkway, 900 feet west of Silver Birch Boulevard and 3800 feet east of Interstate 25 (see Vicinity Map in Appendix A for exact location).There are irrigation ditches located immediately to the north, east and west of the site and the Godding Hollow major drainageway flows from south to north approximately 350 feet to the west of the site. The main surrounding developments include a well pad approximately 50 feet to the northwest of the site, the Stone Ridge housing development 1000 feet to the northeast, a single family residence 800 feet to the northeast and farming facilities approximately 1000 feet to the southwest.

1.2. Description of the Property

The proposed site is approximately 4.02 acres in area and consists of a well pad that will be partially reclaimed. The permanent pad with an area of 4.0 acres will be repurposed to operate and maintain oil production facilities. The facilities will consist of two water tanks, 16 oil tanks, eight separators, 12 ECD's a vapor recovery tower and a sales meter. There will be a topsoil stockpile located along the south edge of the reclaimed portion of the pad.

Drainage facilities, including a water quality feature, emergency spillway and infiltration bed are proposed on the south side of the production facility pad. A combination of swales and berms are proposed along the perimeter of the production facility pad to redirect offsite stormwater around the site, and collect developed onsite stormwater.

As determined by the USDA Web Soil Survey, the historical soil on this site is Vona sandy loam. The hydrologic soil group is type A (see Hydrologic Soils Map in Appendix A). The historical site generally slopes from the east to the west with slopes ranging from 1 to 3%. The historical site has a percent imperviousness of 2%. Upon completion of development the proposed site will be a combination of native planted areas, compacted gravel and drives and walks. The composite percent imperviousness will be 51.00% (see calculations in Appendix B for details).

2. Drainage Basins and Sub-Basins

2.1. Major Basin Description

The proposed site is located within the Godding Hollow basin as defined in the South Weld I-25 Corridor Master Drainage Plan (see Basin Map in Appendix A), thus the South Weld I-25 Corridor Master Drainage Plan was consulted during the design of the drainage facilities for the proposed site. The Godding Hollow basin is located in the Southwest corner of Weld County, bounded by The Saint Vrain River to the North, Weld County Road 7 to the West and WCR 8 to

the South. The tri-town basin lies directly to the East of the Godding Hollow Basin and makes up its eastern border. The total area of the basin is 12,419 acres, 11% of which was developed as of 2000. The primary drainage feature of the basin is the Godding Hollow channel which runs through the center of the basin. This channel begins southwest of the intersection of Weld County road (WCR) 10 and I-25. From this starting point, the channel initially bears northeast, crossing under I-25, and then heads north until it drains into the Saint Vrain River (see "South Weld I-25 Corridor Master Drainage Plan" for full details of this basin).

Irrigation ditches are located directly north, east and west of the proposed site and the aforementioned Godding Hollow major drainageway is located to the west of the site approximately 350 feet. Due to the proposed swales and berms that will surround the facility pad, developed stormwater will flow away from these ditches. As indicated by the Weld County FEMA Map Index, the proposed site is within Panel Number 080266-0861C, panel 861 of 1075, dated September 28, 1982 (please see FEMA Firmette in Appendix A). The Bybee 14-L facilities are shown to be located within Zone C, which is defined by FEMA as an area of minimal flooding.

2.2. Sub-Basin Description

Stormwater historically drains from the east to west across the proposed site based upon topographic maps provided in the South Weld I-25 Corridor Master Drainage Plan. According to topographic data collected for the grading of this site, the proposed pad will be located on top of an existing low point within the field where water currently collects. Therefore, offsite stormwater will flow from all directions towards the proposed pad.

The proposed site is surrounded by a single offsite basin. This offsite basin is bounded by the high points of the irrigation ditch berms to the north and west, by existing topography to the South and by the edge of Silver Birch Boulevard/WCR 11 to the East containing a total area of 30.63 acres. Please see Appendix A8 – Basin Map for the extents of this basin. Offsite stormwater from this basin will be directed around the site by berms along all cut slopes.

The edge of the facility pad forms the extents of the onsite drainage basin for the proposed site. The developed stormwater from this basin will be collected via swales to the north, west and south and carried to a water quality feature along the south edge of the pad. From this water quality feature, stormwater will either be released through a water quality outlet structure along the western edge of the feature, or will be allowed to drain into an infiltration bed below.

2.3. Summary Table

Refer to Appendix B for the summary tables.

3. Drainage Design Criteria

3.1. Regulations

Due to the flat topography of the surrounding field, and the existing low point that the site is located in, the proposed drainage features will include a water quality feature in place of the typically required detention pond.

3.2. Development Criteria Reference and Constraints

Since the proposed site is located within the Godding Hollow major basin, the South Weld I-25 Corridor Master Drainage Plan was consulted.

In its existing condition, stormwater from the site would pool at the low point in the field. After construction of the proposed site, developed onsite stormwater will be directed to the water quality pond. Once collected in this pond, the developed stormwater will be released to the surrounding field either through the water quality structure in the event of a smaller storm, or through the emergency spillway in the event of a larger storm. Additionally, a portion of the developed flow will drain into the infiltration trench below the pond where it will infiltrate into the ground.

Prior to the partial reclamation of the well pad, the site will contain two modular large volume tanks (MLVTs), to be used for well pad operations, located on the south side of the site. Due to the existing topography, if these tanks were to fail, the released water would initially pool around the site and would be contained by the irrigation ditches that surround the field the site is to be located in. In the event that the capacity of this surrounding catchment is exceeded, the remaining water would flow out of this surrounding catchment at a point to the northwest of the site towards the Godding Hollow drainage channel due to the slope of the surrounding land. Please see Appendix C31 – MLVT Failure Analysis for further details of this analysis.

3.3. Hydrological Criteria

This proposed drainage plan follows the *Town of Frederick Design Standards and Specifications* and the *Urban Storm Drainage Criteria Manuals (USDCM Volumes 1-3).* The minor and major design storm frequencies used for the detention pond design are 10 years and 100 years respectively. As indicated in the NOAA Atlas in Appendix A, the associated one hour point rainfalls are 1.39 inches for the minor (10 year) storm and 2.73 inches for the major (100 year) storm.

As the on-site basin is less than 160 acres (8.7 acres), the rational method was used to compute the runoff. The weighted percent imperviousness and runoff coefficient were calculated for the two basins using USDCM tables RO-3 and RO-4, and equations RO-6 and RO-7. The time of concentration was calculated using USDCM table RO-2 and equations RO-2, RO-3 and RO-4. For the onsite basin, equation RO-5 was used to check the calculated value for the time of concentration since the developed site acts similar to an urban environment and the smaller of the two calculated values was used.

The volume of the water quality pond was computed using the WQCV tab of the UDFCD UD-Denteion_v2.34 Spreadsheet considering a 40 hour drain time.

Please see Hydrological Computations in Appendix B for details.

3.4. Hydraulic Criteria

The hydraulic structures proposed on-site include a water quality pond, a water quality outlet structure, an emergency spillway, an infiltration bed below the water quality pond and a combination of swales and berms to direct offsite stormwater around the site and keep developed, onsite stormwater within the site.

The sizing of the water quality pond and emergency spillway were computed using the UDFCD UD-Denteion_v2.34 Spreadsheet. These hydraulic calculations include stage storage sizing for the water quality pond and stage-discharge sizing of the spillway. Since the water quality orifice plate, as designed, does not fit the requirements of the UDFCD spreadsheet (since there is less than one foot from the lowest set of orifices to the WQCV elevation due to site constraints) the sizing of orifices was calculated by hand using Bernoulli's equation and the continuity equation for incompressible, steady flow. The Water Quality trash screen size was calculated per USDCM V3 Chapter 4 Outlet Structures**.** The capacities of the two swales along the edges of the site were calculated using the UDFCD UD-Channels_v1.05 spreadsheet. Swale 1, which runs along the north and west edges of the pad, was evaluated at its midpoint and endpoint and swale 2, which runs along the south edge of the pad, was evaluated at its midpoint to ensure that they had adequate capacity to convey the portion of the full 100-year developed flow that they are designed to convey. Due to the topography of the site and surrounding field, it would be impractical for these swales to provide 1 foot of freeboard and still have enough slope to direct water to the pond; however, these calculations indicate they will provide 3" of freeboard. The culverts for the irrigation ditch where the proposed permanent access road crosses over them were sized using the UDFCD UD-Culvert_v3.03 spread sheet. Please see Hydraulic Computations in Appendix C for details.

4. Drainage Facility Design

4.1. General Concept

As mentioned in section 3.1 - Development Criteria Reference and Constraints, under existing conditions runoff around the site flows from all directions to the low point in the field. In order to maintain this existing pattern, the water quality feature and emergency spillway will release water to the west of the site at the surrounding low point.

The water quality pond for this site was designed to collect the full water quality capture volume and release it to the surrounding field with a drain time of 40 hours. A water quality orifice plate, located along the western edge of the pond in the middle of the emergency spillway, was designed to control this release rate, with a narrow channel running down the middle of the emergency spillway to convey this flow. In the event of a larger storm which exceeds the water

quality capture volume, stormwater will be channeled through the emergency spillway to the existing low point in the field. This emergency spillway was designed to convey the 100 year developed flow without overtopping.

In addition to the water quality orifice plate, an infiltration bed is proposed beneath the water quality pond to drain the remainder of the stored volume (primarily that volume which remains in the 0.55 feet below the water quality orifices). In order to design this infiltration trench, the EPA fact sheet regarding infiltration trenches (see reference 6) was consulted to determine that this site met the requirements for an infiltration trench/bed. Due to the hydrological soil type (type A) and depth to groundwater (over 6.5 feet) it was determined that this site did meet these qualifications. Between the water quality orifice plate and this infiltration bed, the full WQCV will be drained in less than the maximum drain time of 72 hours.

4.2. Specific Details

The depth of the proposed water quality pond is 1.3 feet with the top of the pond at the pad elevation of 4889.4'. The proposed water quality pond has a calculated storage volume of 0.094 acre-ft and is graded with a 4:1 interior side slope. The emergency spillway is located along the western edge of the pond at the WQCV elevation of 4889.1'.

The owner is responsible for maintaining the operation and access of the drainage facilities including the culverts proposed beneath the access road. The proposed detention pond can be accessed from WCR 20/Bella Rosa Parkway via the proposed on-site access road. The disturbed area of the detention pond will be re-seeded. Any vegetation should be trimmed. Any debris or trash from the trash grates attached to the outlet structure should be cleaned. Any blockage in the culverts, ditches, or outlet pipes should be removed to keep the drainage facilities at full capacity. The infiltration trench should be inspected and cleaned twice a year and following major storm events. The infiltration may need to be fully rehabilitated every 5 to 15 years.

4.3. Summary Tables

Refer to Appendix B and C for the summary tables.

5. Conclusion

The hydrologic and hydraulic calculations associated with the proposed drainage plan follow the *Urban Storm Drainage Criteria Manuals* (USDCM). These calculations show that the water quality feature is designed to contain the water quality capture volume and drain within 72 hours. The emergency spillway for this site will be able to convey the full 100 year developed flow without overtopping and direct it to the low point of the surrounding field. The design of the drainage facilities for this site have also taken into account the South Weld I-25 Corridor Master Drainage Plan, specifically in regard to maintaining historical drainage patterns. Thus, the Town of Frederick's stormwater requirements have been met and stormwater impacts due to proposed development have been mitigated.

6. References

1. Town of Frederick Design Standards and Construction Specifications; Town of Frederick, Weld County; Colorado

2. Urban Storm Drainage Criteria Manual Vol. 1, 2 and 3; Urban Drainage and Flood Control District; Latest Revision

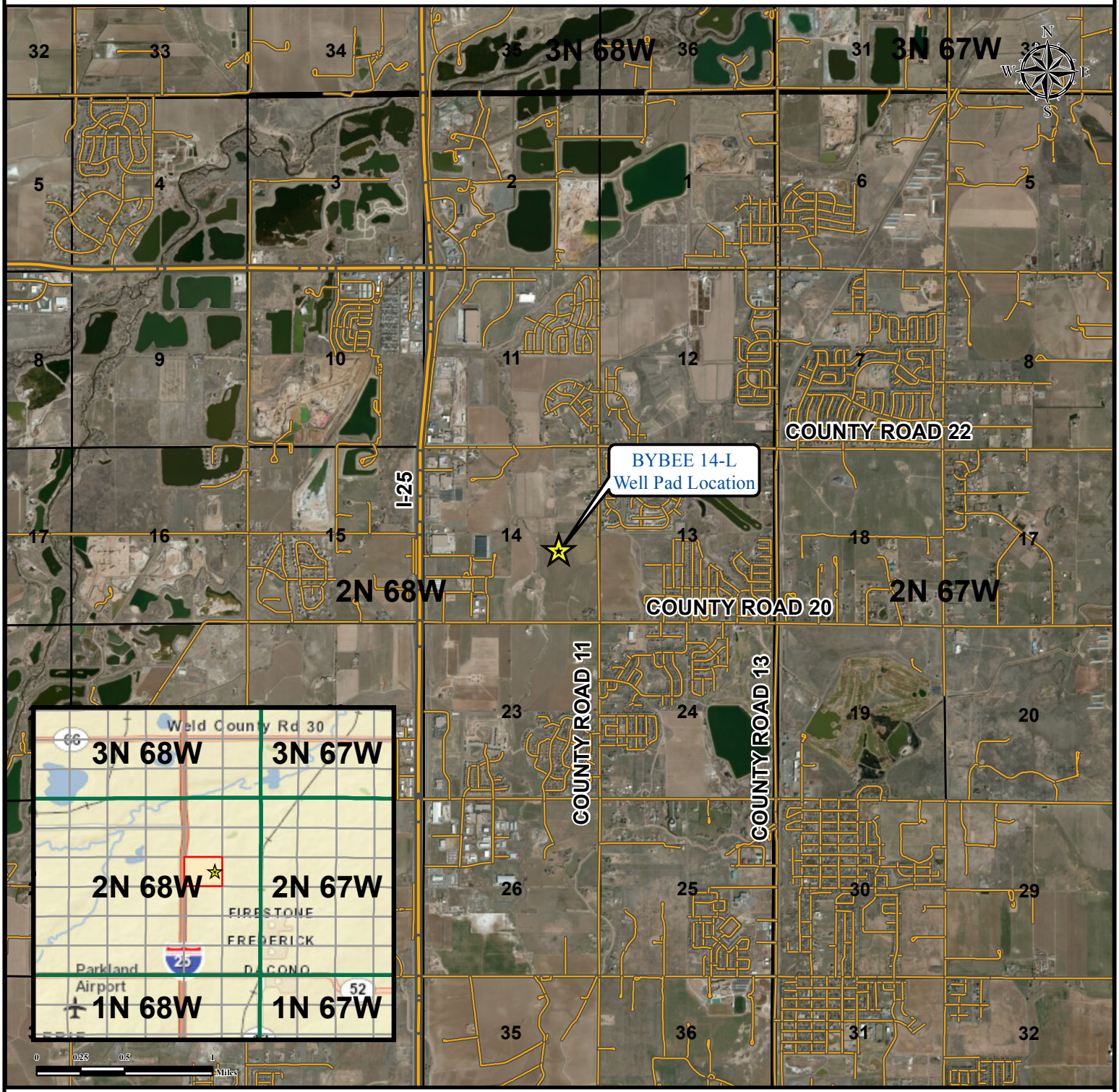
3. South Weld I-25 Corridor Master Drainage Plan; Anderson Consulting Engineers, Inc.: February 17, 2000

4. Hydrologic Group Rating for Town of Frederick, Weld County, Colorado, Northern Part ; USDA-Natural Resources Conservation Services; National Cooperative Soil Survey

5. FEMA FIRM Flood Insurance Rate Map, Map Number 080266-0864C; Federal Emergency Management Agency: September 28, 1982

6. Storm Water Technology Fact Sheet: Infiltration Trench; United State Environmental Protection Agency: September, 1999

BYBEE 14-L PAD
VICINITY MAP



Legend

BYBEE 14-L Well Pad Location

Roads

FIELD DATE: 07-17-14	SITE NAME: BYBEE 14-L PAD	PREPARED FOR: EXTRACTION Oil & Gas
DRAWING DATE: 03-23-15	SURFACE LOCATION: NE1/4 SE1/4, SEC. 14, T2N, R68W, 6TH P.M. WELD COUNTY, COLORADO	
BY: CSG / CHECKED BY: FMB		

PFS llc Petroleum Field Services

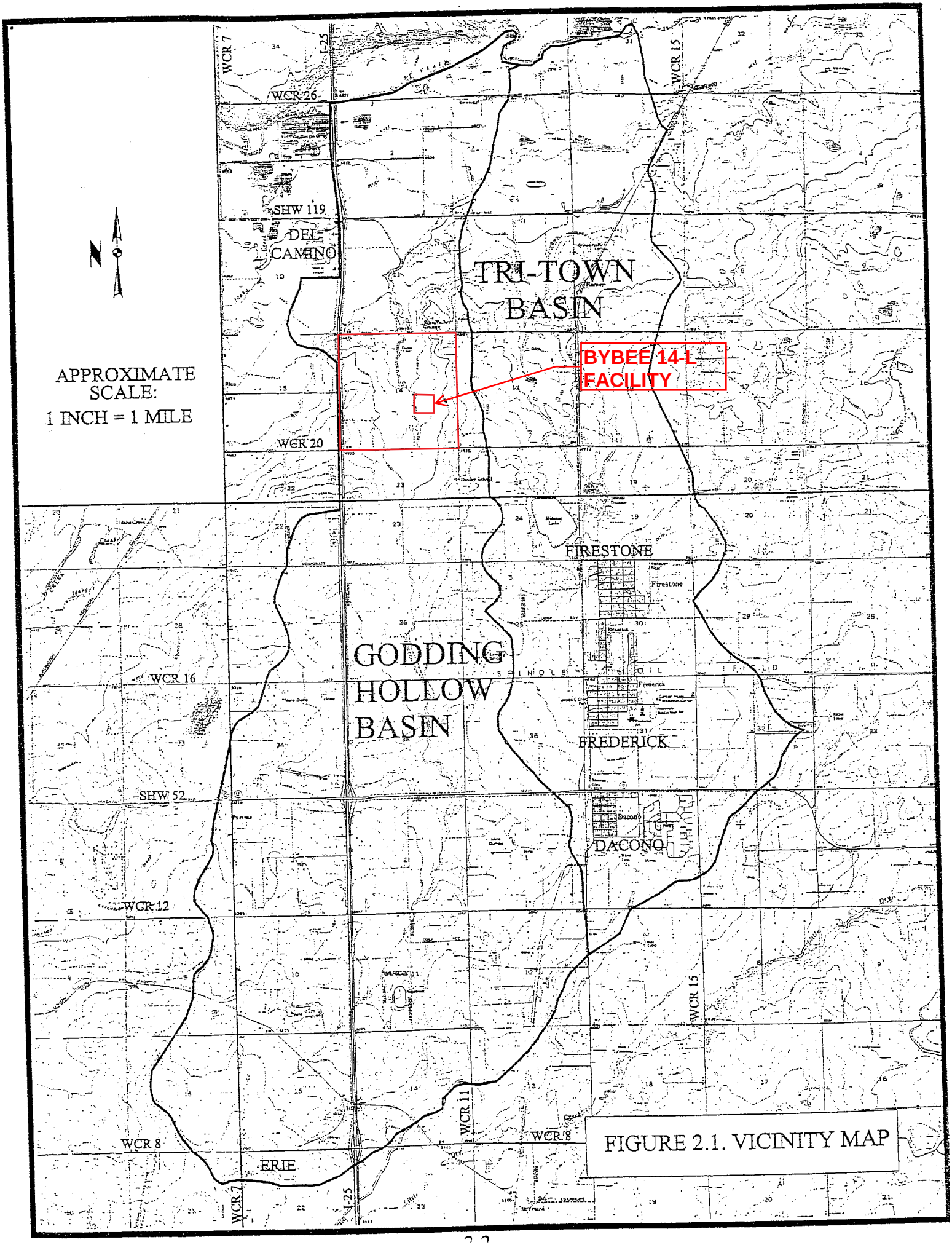
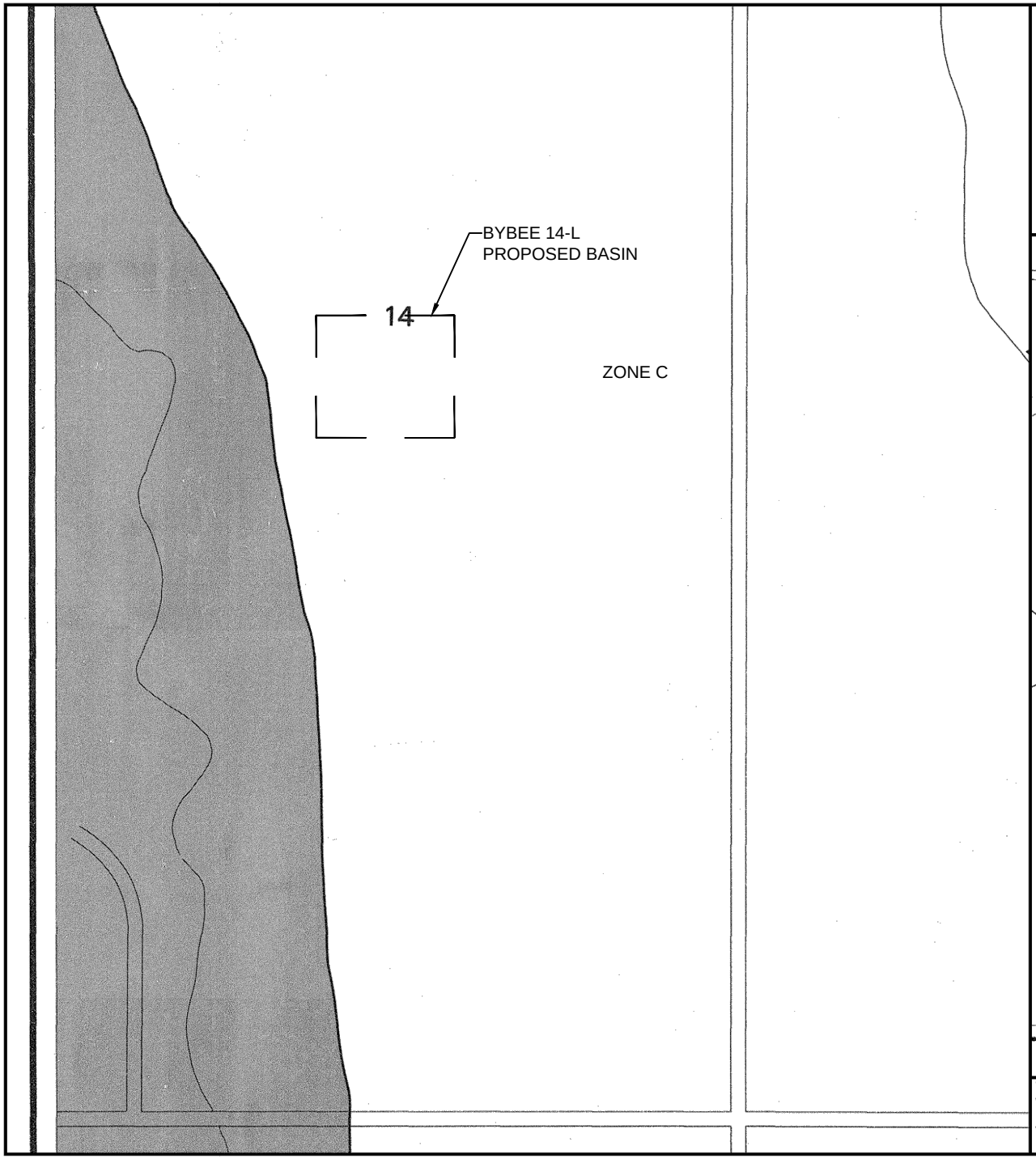


FIGURE 2.1. VICINITY MAP



APPROXIMATE SCALE

500 0

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

WELD COUNTY, COLORADO

UNINCORPORATED AREA

PANEL 861 OF 1075

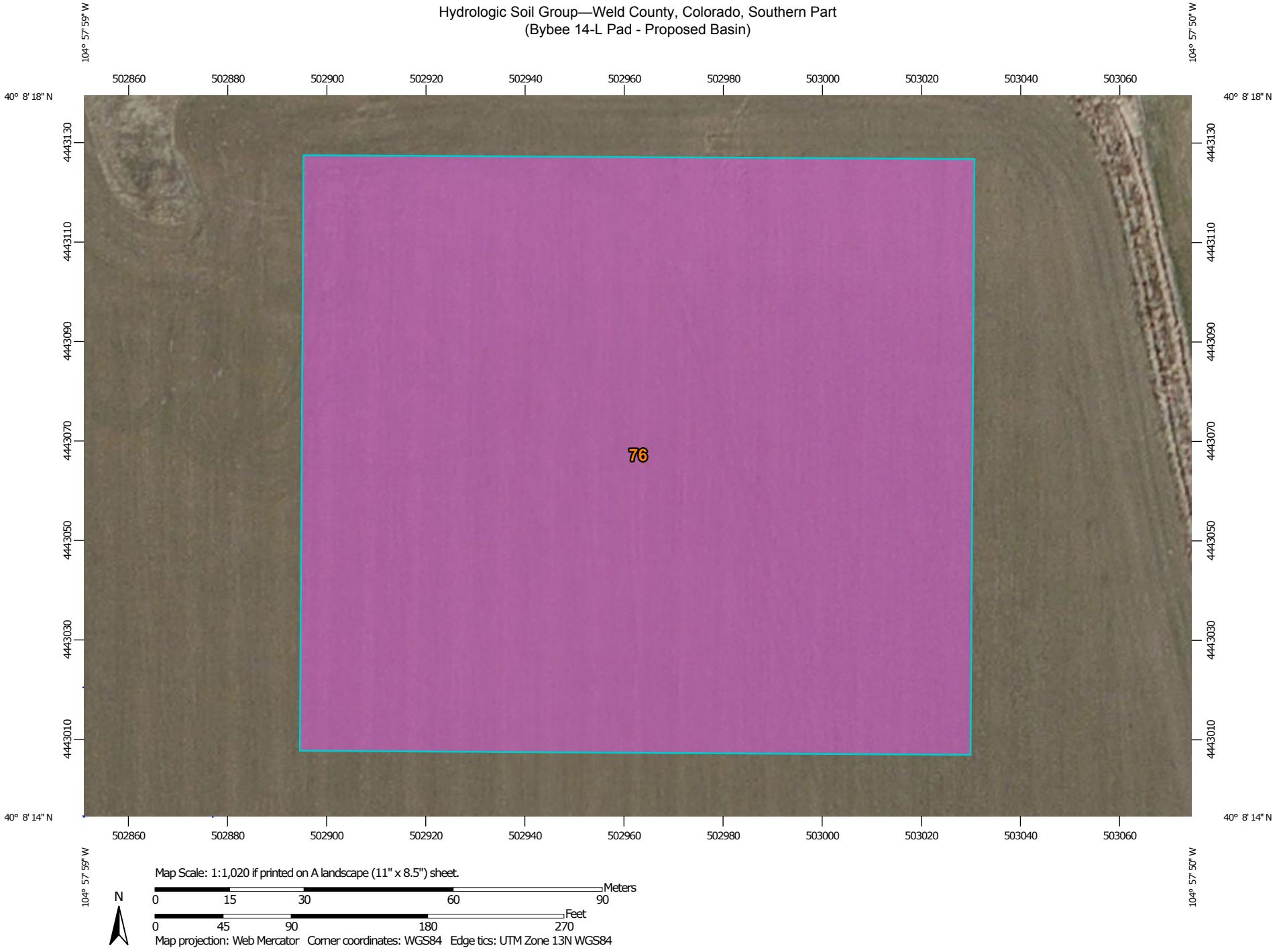
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
080266 0861 C

MAP REVISED:
SEPTEMBER 28, 1982

federal emergency management agency

Hydrologic Soil Group—Weld County, Colorado, Southern Part
(Bybee 14-L Pad - Proposed Basin)



Map Scale: 1:1,020 if printed on A landscape (11" x 8.5") sheet.

N

Meters
0 15 30 60 90

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 Rating Polygons

A
A/D
B
B/D
C
C/D
D
Not rated or not available

Soil Rating Lines

A
A/D
B
B/D
C
C/D
D
Not rated or not available

Soil Rating Points

A
A/D
B
B/D
C
C/D
D
Not rated or not available

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: http://websoilsurvey.nrcs.usda.gov
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: Weld County, Colorado, Southern Part
Survey Area Data: Version 13, Sep 23, 2014

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

Date(s) aerial images were photographed: Mar 16, 2012—Apr 13, 2012

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.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Weld County, Colorado, Southern Part (CO618)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
76	Vona sandy loam, 1 to 3 percent slopes	A	4.0	100.0%
Totals for Area of Interest			**4.0**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

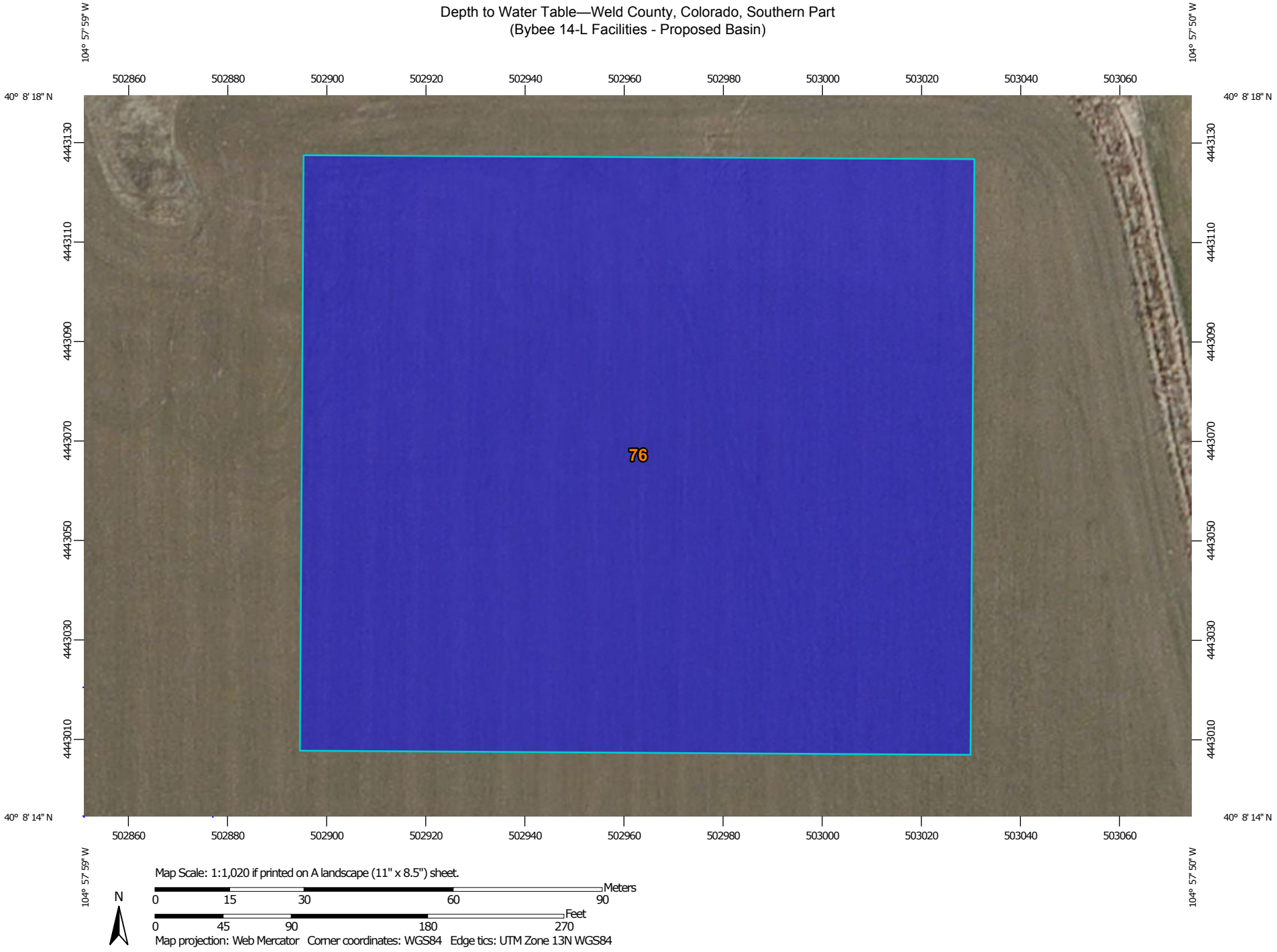
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Depth to Water Table—Weld County, Colorado, Southern Part
(Bybee 14-L Facilities - Proposed Basin)



Map Scale: 1:1,020 if printed on A landscape (11" x 8.5") sheet.

N

0 15 30 60 90 Meters

0 45 90 180 270 Feet

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 Rating Polygons
- 0 - 25
- 25 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- > 200
- Not rated or not available

Soil Rating Lines
- 0 - 25
- 25 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- > 200
- Not rated or not available

Soil Rating Points
- 0 - 25
- 25 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- > 200
- Not rated or not available

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: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

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Soil Survey Area: Weld County, Colorado, Southern Part
Survey Area Data: Version 14, Sep 22, 2015

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

Date(s) aerial images were photographed: Mar 16, 2012—Apr 13, 2012

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Depth to Water Table

Depth to Water Table— Summary by Map Unit — Weld County, Colorado, Southern Part (CO618)				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
76	Vona sandy loam, 1 to 3 percent slopes	>200	4.0	100.0%
Totals for Area of Interest			**4.0**	**100.0%**

Description

"Water table" refers to a saturated zone in the soil. It occurs during specified months. Estimates of the upper limit are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table.

This attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: centimeters

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

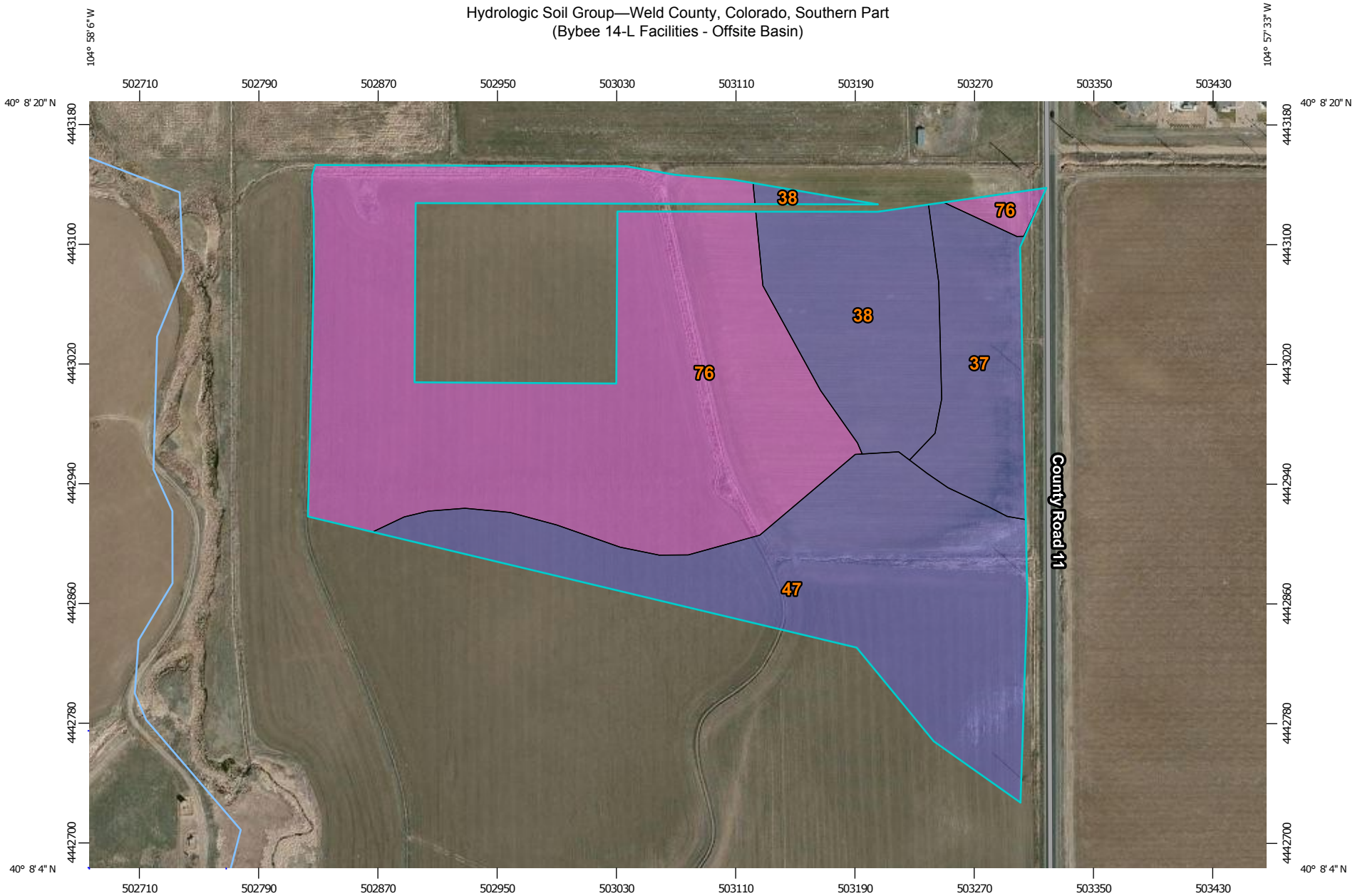
Tie-break Rule: Lower

Interpret Nulls as Zero: No

Beginning Month: January

Ending Month: December

Hydrologic Soil Group—Weld County, Colorado, Southern Part
(Bybee 14-L Facilities - Offsite Basin)



MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

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

Background
- Aerial Photography

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

Date(s) aerial images were photographed: Mar 16, 2012—Apr 13, 2012

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.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Weld County, Colorado, Southern Part (CO618)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
37	Nelson fine sandy loam, 0 to 3 percent slopes	B	2.8	9.0%
38	Nelson fine sandy loam, 3 to 9 percent slopes	B	4.0	13.0%
47	Olney fine sandy loam, 1 to 3 percent slopes	B	8.3	27.3%
76	Vona sandy loam, 1 to 3 percent slopes	A	15.5	50.7%
Totals for Area of Interest			**30.6**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

NOAA Atlas 14, Volume 8, Version 2
Location name: Longmont, Colorado, US*
Latitude: 40.1378°, Longitude: -104.9651°
Elevation: 4890 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.228** (0.176-0.296)	**0.277** (0.213-0.360)	**0.373** (0.286-0.487)	**0.469** (0.358-0.615)	**0.625** (0.473-0.882)	**0.763** (0.560-1.08)	**0.918** (0.650-1.34)	**1.09** (0.743-1.63)	**1.35** (0.881-2.07)	**1.56** (0.986-2.40)
10-min	**0.334** (0.257-0.434)	**0.405** (0.312-0.527)	**0.547** (0.419-0.713)	**0.687** (0.524-0.901)	**0.915** (0.692-1.29)	**1.12** (0.819-1.59)	**1.34** (0.952-1.96)	**1.60** (1.09-2.39)	**1.97** (1.29-3.03)	**2.28** (1.44-3.51)
15-min	**0.407** (0.314-0.529)	**0.494** (0.380-0.643)	**0.667** (0.511-0.869)	**0.838** (0.639-1.10)	**1.12** (0.844-1.57)	**1.36** (0.999-1.94)	**1.64** (1.16-2.39)	**1.95** (1.33-2.92)	**2.40** (1.57-3.70)	**2.78** (1.76-4.29)
30-min	**0.552** (0.425-0.718)	**0.668** (0.514-0.869)	**0.899** (0.689-1.17)	**1.13** (0.861-1.48)	**1.50** (1.14-2.12)	**1.83** (1.34-2.60)	**2.21** (1.56-3.21)	**2.62** (1.79-3.93)	**3.24** (2.12-4.98)	**3.75** (2.37-5.77)
60-min	**0.676** (0.520-0.878)	**0.818** (0.629-1.06)	**1.10** (0.845-1.44)	**1.39** (1.06-1.82)	**1.85** (1.40-2.61)	**2.26** (1.66-3.21)	**2.73** (1.93-3.97)	**3.25** (2.21-4.86)	**4.01** (2.63-6.17)	**4.65** (2.94-7.16)
2-hr	**0.799** (0.622-1.02)	**0.968** (0.753-1.24)	**1.30** (1.01-1.68)	**1.64** (1.27-2.13)	**2.20** (1.68-3.06)	**2.69** (2.00-3.77)	**3.24** (2.33-4.66)	**3.87** (2.66-5.71)	**4.79** (3.17-7.25)	**5.55** (3.55-8.42)
3-hr	**0.868** (0.680-1.10)	**1.05** (0.822-1.34)	**1.41** (1.10-1.81)	**1.78** (1.38-2.28)	**2.37** (1.83-3.28)	**2.91** (2.17-4.04)	**3.50** (2.53-4.99)	**4.17** (2.89-6.11)	**5.16** (3.44-7.75)	**5.98** (3.85-9.00)
6-hr	**1.03** (0.817-1.29)	**1.24** (0.978-1.55)	**1.64** (1.29-2.07)	**2.04** (1.60-2.59)	**2.69** (2.10-3.67)	**3.28** (2.47-4.48)	**3.92** (2.86-5.50)	**4.65** (3.25-6.70)	**5.72** (3.85-8.46)	**6.61** (4.30-9.79)
12-hr	**1.26** (1.01-1.57)	**1.50** (1.20-1.86)	**1.95** (1.56-2.42)	**2.38** (1.89-2.98)	**3.08** (2.41-4.10)	**3.68** (2.80-4.95)	**4.35** (3.20-5.99)	**5.10** (3.60-7.21)	**6.18** (4.20-8.99)	**7.08** (4.65-10.3)
24-hr	**1.51** (1.23-1.84)	**1.80** (1.46-2.21)	**2.33** (1.89-2.87)	**2.82** (2.27-3.48)	**3.56** (2.80-4.63)	**4.19** (3.21-5.50)	**4.86** (3.60-6.55)	**5.59** (3.98-7.75)	**6.63** (4.54-9.45)	**7.48** (4.97-10.7)
2-day	**1.73** (1.42-2.08)	**2.10** (1.73-2.54)	**2.74** (2.24-3.32)	**3.30** (2.68-4.01)	**4.10** (3.24-5.20)	**4.75** (3.66-6.10)	**5.42** (4.04-7.14)	**6.13** (4.39-8.31)	**7.10** (4.90-9.91)	**7.87** (5.28-11.1)
3-day	**1.88** (1.56-2.25)	**2.27** (1.87-2.71)	**2.92** (2.40-3.50)	**3.48** (2.85-4.20)	**4.30** (3.42-5.40)	**4.95** (3.85-6.30)	**5.63** (4.23-7.36)	**6.34** (4.58-8.53)	**7.33** (5.09-10.1)	**8.10** (5.48-11.3)
4-day	**2.01** (1.67-2.39)	**2.39** (1.99-2.85)	**3.04** (2.52-3.63)	**3.61** (2.97-4.33)	**4.42** (3.54-5.53)	**5.08** (3.97-6.43)	**5.77** (4.36-7.49)	**6.49** (4.71-8.67)	**7.49** (5.22-10.3)	**8.27** (5.62-11.5)
7-day	**2.31** (1.94-2.71)	**2.71** (2.27-3.18)	**3.38** (2.83-3.99)	**3.97** (3.30-4.70)	**4.80** (3.87-5.91)	**5.47** (4.31-6.83)	**6.16** (4.70-7.89)	**6.89** (5.04-9.07)	**7.88** (5.55-10.7)	**8.66** (5.93-11.9)
10-day	**2.56** (2.16-2.99)	**2.98** (2.52-3.48)	**3.69** (3.10-4.32)	**4.29** (3.59-5.05)	**5.15** (4.17-6.28)	**5.83** (4.62-7.21)	**6.52** (5.00-8.27)	**7.25** (5.33-9.45)	**8.23** (5.83-11.0)	**8.99** (6.20-12.3)
20-day	**3.28** (2.80-3.77)	**3.76** (3.21-4.33)	**4.56** (3.88-5.26)	**5.22** (4.42-6.06)	**6.15** (5.04-7.36)	**6.87** (5.50-8.34)	**7.60** (5.88-9.45)	**8.34** (6.20-10.7)	**9.33** (6.67-12.3)	**10.1** (7.03-13.5)
30-day	**3.85** (3.32-4.39)	**4.40** (3.79-5.02)	**5.30** (4.55-6.06)	**6.04** (5.15-6.94)	**7.05** (5.81-8.34)	**7.83** (6.31-9.40)	**8.60** (6.70-10.6)	**9.38** (7.01-11.9)	**10.4** (7.49-13.6)	**11.2** (7.84-14.8)
45-day	**4.54** (3.94-5.13)	**5.20** (4.51-5.88)	**6.26** (5.41-7.10)	**7.13** (6.13-8.12)	**8.29** (6.87-9.69)	**9.16** (7.43-10.9)	**10.0** (7.85-12.2)	**10.9** (8.17-13.6)	**12.0** (8.65-15.4)	**12.8** (9.02-16.8)
60-day	**5.10** (4.45-5.73)	**5.88** (5.12-6.61)	**7.11** (6.17-8.01)	**8.10** (6.99-9.16)	**9.41** (7.82-10.9)	**10.4** (8.45-12.2)	**11.3** (8.91-13.7)	**12.2** (9.25-15.2)	**13.4** (9.74-17.1)	**14.3** (10.1-18.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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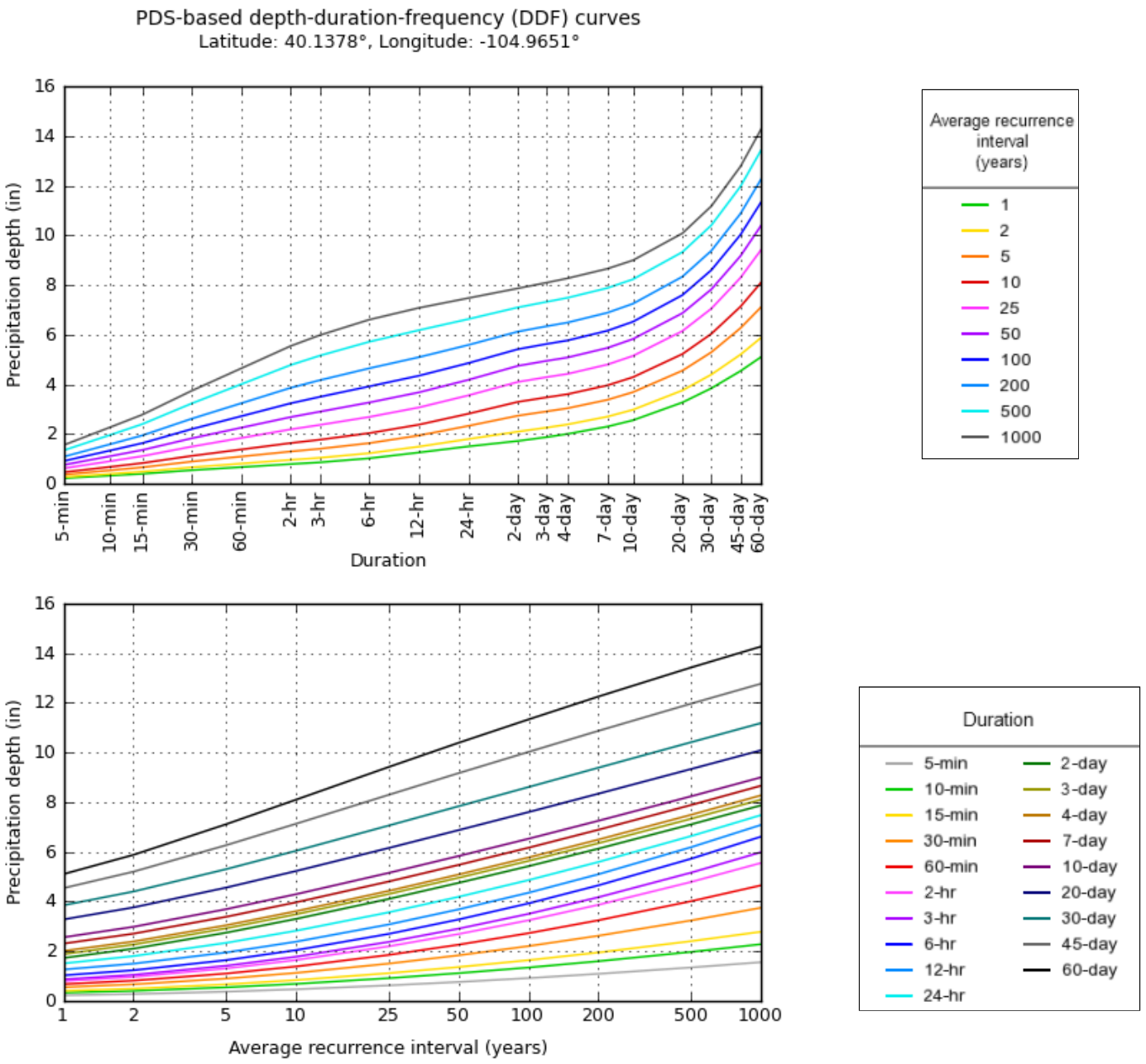
PF graphical



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Created (GMT): Mon Apr 20 15:48:41 2015

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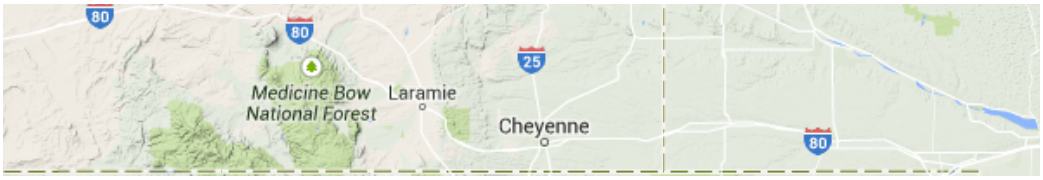
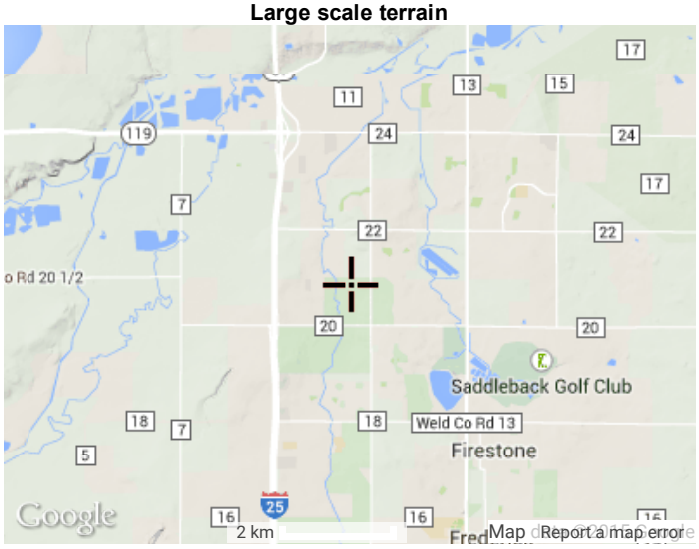
Maps & aerials

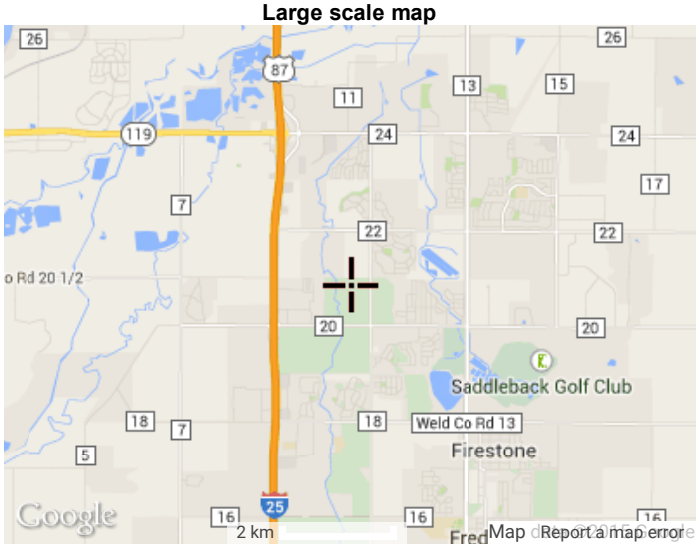
Small scale terrain



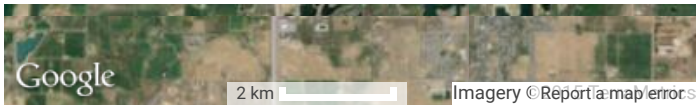
Large scale terrain



Large scale map



Large scale aerial



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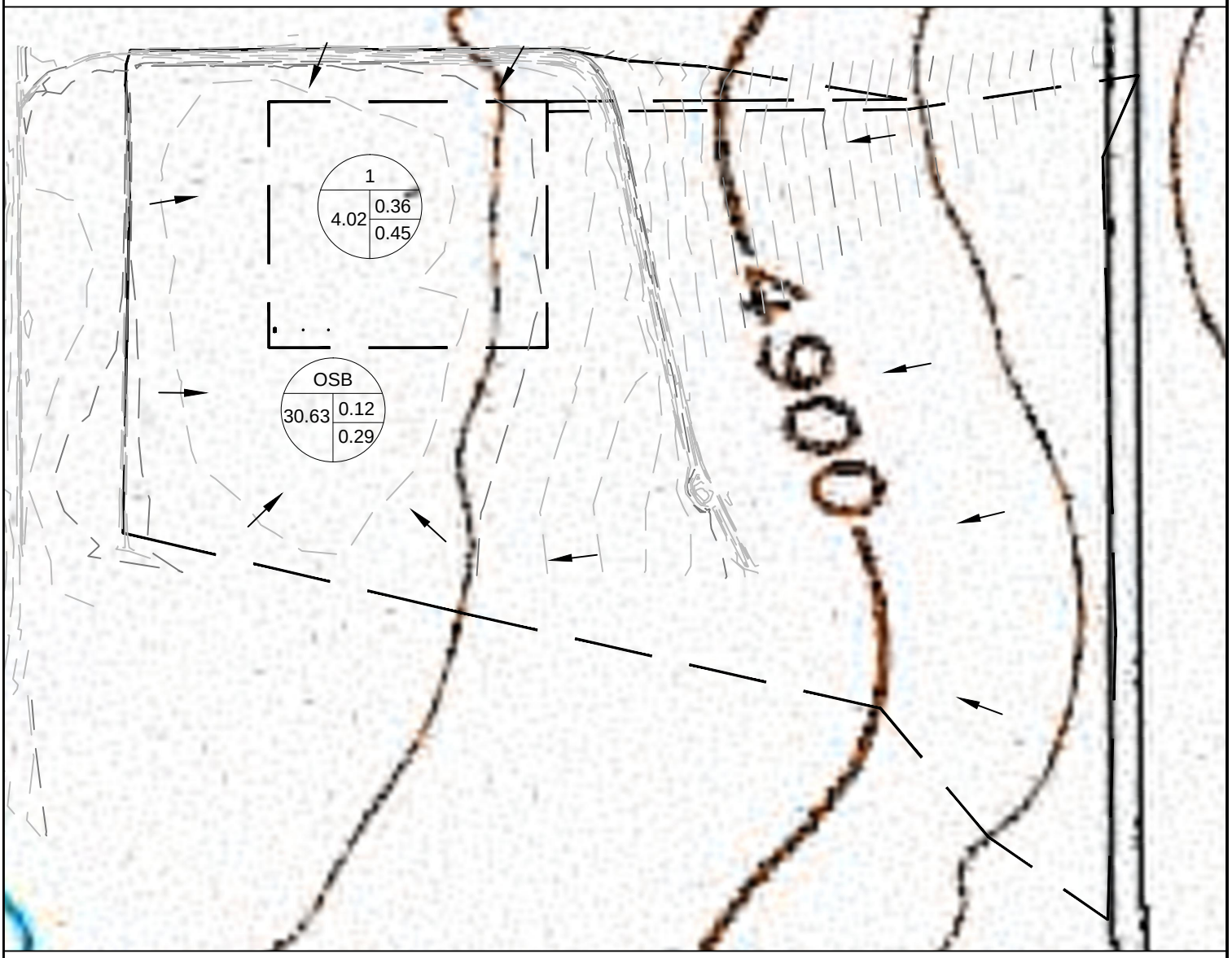
National Oceanic and Atmospheric Administration
National Weather Service
Office of Hydrologic Development
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

BYBEE 14-L FACILITY
BASIN MAP



N

0 150' 250'

SCALE: 1"=250'

LEGEND

- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONOUR
- BASIN BOUNDARY
- SUBBASIN BOUNDARY
- FLOW ARROW

A
B C
D

A = BASIN DESIGNATION
B = AREA IN ACRES
C = 10 - YR COMPOSITE RUNOFF COEFFICIENTS
D = 100 - YRCOMPOSITE RUNOFF COEFFICIENTS

PREPARED BY:
PFS llc
Petroleum Field Services, LLC
7535 Hilltop Circle
Denver, CO 80221

DRAWING DATE: 11-02-15

BY: SWW | CHECKED BY: MCW

SITE NAME: BYBEE 14-L FACILITY

SURFACE LOCATION:
N 1/2 SE 1/4 SEC. 14, T2N, R68W, 6TH P.M.
WELD COUNTY, COLORADO

PREPARED FOR:
EXTRACTION Oil & Gas

COMPOSITE BASIN -WEIGHTED "% IMPERVIOUS" CALCULATIONS

-REFERENCE : UDFCD V.1 Chapter 5 Runoff Table RO-3 Recommended Percentage Imperviousness Values

	Undeveloped areas			Street									
	Historic flow analysis	**Greenbelts, Agricultural**	**Off-site flow analysis (when land use not defined)**	**Paved**	**Gravel**	**Recycled asphalts**	**Dives and walks**	**Roofs**					
% Imperv.	2.00%	2.00%	45.00%	100.00%	40.00%	75.00%	90.00%	90.00%					
												Total	**Percent**
BASIN	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Imperv.**
Proposed Basin					3.17		0.85					4.02	51.00%
												0.00	0.00%
												0.00	0.00%
												0.00	0.00%
												0.00	0.00%
												0.00	0.00%
												0.00	0.00%
												4.02	**51.00%**
Offsite Basin		30.63										30.63	2.00%
												0.00	0.00%
												0.00	0.00%
													#DIV/0!
												0.00	0.00%
												0.00	0.00%
												0.00	0.00%
													#DIV/0!
												0.00	0.00%
												0.00	0.00%
												0.00	**#DIV/0!**

COMPOSITE BASIN -WEIGHTED "C" CALCULATIONS

REFERENCE UDFCD V.1 Chapter 5 Runoff

$C_A = K_A + (1.31i^3 - 1.44i^2 + 1.135i - 0.12)$ for C_A > or + 0, otherwise $C_A = 0$ (RO-6)

$C_B = (C_A + C_{CD})/2$

$C_{CD} = K_{CD} + (0.858i^3 - 0.786i^2 + 0.774i + 0.04)$ (RO-7)

i = % imperviousness/100 expressed as a decimal

K_A = Correction factor for Type A soils

K_{CD} = Correction factor for Type C and Type D soils

Correction Factors, K_A & K_{CD}

Soil Type	Storm Return Period		
	5-Year	**10-Year**	**100-Year**
A	$-0.08i + 0.09$	$-0.14i + 0.17$	$-0.25i + 0.32$
C or D	$-0.10i + 0.11$	$-0.18i + 0.21$	$-0.39i + 0.46$

Basin ID	**% Imperv.**	***i***	**Soil Type**	**Correction Factors, K_A & K_{CD}**			**Runoff Coefficients, C**			**Basin Area**	**Total Area**	**Weighted Runoff Coefficients, C**		
				5-Year	**10-Year**	**100-Year**	**5-Year**	**10-Year**	**100-Year**			**5-Year**	**10-Year**	**100-Year**
Proposed Basin	51.00%	0.51	A	0.05	0.10	0.19	0.31	0.36	0.45	4.02	4.02	0.31	0.36	0.45
			B	-	-	-	0.36	0.41	0.53	0.00				
			C or D	0.06	0.12	0.26	0.40	0.46	0.61	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	51.00%	0.51	A	0.05	0.10	0.19	0.31	0.36	0.45	0.00	0.0	-	-	-
			B	-	-	-	0.36	0.41	0.53	0.00				
			C or D	0.06	0.12	0.26	0.40	0.46	0.61	0.00				
Offsite Basin	2.00%	0.02	A	0.09	0.17	0.32	0.00	0.07	0.22	15.52	30.63	0.04	0.12	0.29
			B	-	-	-	0.08	0.17	0.36	15.11				
			C or D	0.11	0.21	0.45	0.16	0.26	0.507	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.00	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.00	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.00	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.00	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.00	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				
0	0.00%	0.00	A	0.09	0.17	0.32	0.00	0.05	0.20	0.00	0.0	-	-	-
			B	-	-	-	0.08	0.15	0.35	0.00				
			C or D	0.11	0.21	0.46	0.15	0.25	0.50	0.00				

Time of Concentration

REFERENCE UDFCD V.1 Chapter 5 Runoff Table RO-2 Conveyance Coefficient, C_v

Heavy Meadow	2.50	Short Grass Pasture & Lawns	7.00	Grassed Waterway	15.00
Tillage/field	5.00	Nearly Bare Ground	10.00	Paved Area & Shallow Gutter	20.00

	SUB-BASIN DATA			INITIAL / OVERLAND TIME			TRAVEL TIME T(t)					T(c) CHECK (URBANIZED BASINS)			FINAL T(c)
DESIGN POINT	DRAIN BASIN	AREA ac.	C(5)	Length ft.	Slope %	T(i) min	Length ft.	Slope %	Coeff.	Velocity fps	T(t) min.	COMP. T(c)	TOTAL LENGTH	L/180+10	min.
1	Proposed Basin	4.02	0.31	240	0.0	102.4	580	0.2	10.00	0.4	24.2	126.6	820	14.6	14.6
2	Offsite Basin	30.63	0.04	500	3.0	29.6	1330	1.2	10.00	1.1	20.2	49.8			49.8

Rational Method Procedure

10-yr Rainfall Depth-Duration-Frequency (1-hr) = 1.39

REFERENCE USDCM V.1 RUNOFF

Design Storm** **10 Year

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	Proposed Basin	4.02	0.36	14.6	1.43	3.17	4.54	14.6	1.43	3.17	4.54	
2	Offsite Basin	30.63	0.12	49.8	3.58	1.57	5.62	49.8	3.58	1.57	5.62	

Rational Method Procedure

100-yr Rainfall Depth-Duration-Frequency (1-hr) = 2.73

REFERENCE USDCM V.1 RUNOFF

Design Storm ***100 Year***

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	Proposed Basin	4.02	0.45	14.6	1.81	6.22	11.26	14.6	1.81	6.22	11.26	
2	Offsite Basin	30.63	0.29	49.8	8.84	3.08	27.28	49.8	8.84	3.08	27.28	

STAGE-DISCHARGE SIZING OF THE WATER QUALITY CAPTURE VOLUME (WQCV) OUTLET

Project: **Bybee 14-L Facility**
Basin ID: **Proposed Basin 1**

WQCV Design Volume (Input):

Catchment Imperviousness, I_a = 51.0 percent
Catchment Area, A = 4.02 acres
Depth at WQCV outlet above lowest perforation, H = 1 feet
Vertical distance between rows, h = 12.00 inches
Number of rows, NL = 1.00
Orifice discharge coefficient, C_o = 0.65
Slope of Basin Trickle Channel, S = 0.001 ft / ft
Time to Drain the Pond = 40 hours

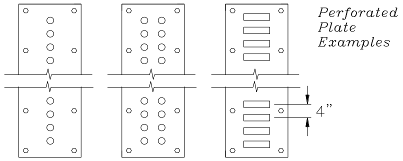
Diameter of holes, D = ______ inches
Number of holes per row, N = ______

OR

Height of slot, H = ______ inches
Width of slot, W = ______ inches

Watershed Design Information (Input):

Percent Soil Type A = 100 %
Percent Soil Type B = ______ %
Percent Soil Type C/D = ______ %



Outlet Design Information (Output):

Water Quality Capture Volume, WQCV = 0.220 watershed inches
Water Quality Capture Volume (WQCV) = 0.074 acre-feet
Design Volume (WQCV / 12 * Area * 1.2) Vol = 0.088 acre-feet
Outlet area per row, Ao = ______ square inches
Total opening area at each row based on user-input above, Ao = ______ square inches
Total opening area at each row based on user-input above, Ao = ______ square feet

***Sheet used to determine WQCV only, see appendix C3 for orifice sizing**

Central Elevations of Rows of Holes in feet / **Collection Capacity for Each Row of Holes in cfs**

	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8	Row 9	Row 10	Row 11	Row 12	Row 13	Row 14	Row 15	Row 16	Row 17	Row 18	Row 19	Row 20	Row 21	Row 22	Row 23	Row 23	Σ Flow
4886.10																									0.00
4886.20																									0.00
4886.30																									0.00
4886.40																									0.00
4886.50																									0.00
4886.60																									0.00
4886.70																									0.00
4886.80																									0.00
4886.90																									0.00
4887.00																									0.00
4887.10																									0.00
4887.20																									0.00
4887.30																									0.00
4887.40																									0.00
4887.50																									0.00
4887.60																									0.00
4887.70																									0.00
4887.80																									0.00
4887.90																									0.00
4888.00																									0.00
4888.10																									0.00
4888.20																									0.00
4888.30																									0.00
4888.40																									0.00
4888.50																									0.00
4888.60																									0.00
4888.70																									0.00
4888.80																									0.00
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Override Area Row 1	Override Area Row 2	Override Area Row 3	Override Area Row 4	Override Area Row 5	Override Area Row 6	Override Area Row 7	Override Area Row 8	Override Area Row 9	Override Area Row 10	Override Area Row 11	Override Area Row 12	Override Area Row 13	Override Area Row 14	Override Area Row 15	Override Area Row 16	Override Area Row 17	Override Area Row 18	Override Area Row 19	Override Area Row 20	Override Area Row 21	Override Area Row 22	Override Area Row 23	Override Area Row 24

COMPOSITE BASIN -WEIGHTED "% IMPERVIOUS" CALCULATIONS REF:

Weld County Engineering and Construction Criteria Table 5-3 Recommended Percentage Imperviousness Values

Table 5-3 Recommended Percentage Imperviousness Values

Land Use or Surface Characteristics	Percentage Impervious
Business:	
Commercial areas	95
Neighborhood area	85
Residential:	
Single-family	See UDFCD Manual
Multi-family (detached)	60
Multi-family (attached)	75
Half-acre lot or larger	See UDFCD Manual
Apartments	80
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	5
Playgrounds	10
Schools	50
Railroad yard areas	15
Undeveloped areas*:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel	40
Recycled asphalt	75
Drives and walks	90
Roofs	90

Obtained from the runoff chapter of the UDFCD Manual (Volume 1), Table RO-3

COMPOSITE BASIN -WEIGHTED WEIGHTED "C" CALCULATIONS REF:

USDCM V.1 Runoff Table RO-3 Recommended Percentage Imperviousness Values

$$C_A = K_A + \left(1.31i^3 - 1.44i^2 + 1.135i - 0.12\right) \text{ for } C_A \geq 0, \text{ otherwise } C_A = 0 \qquad \text{(RO-6)}$$

$$C_{CD} = K_{CD} + \left(0.858i^3 - 0.786i^2 + 0.774i + 0.04\right) \qquad \text{(RO-7)}$$

$$C_B = \left(C_A + C_{CD}\right)/2$$

in which:

i = % imperviousness/100 expressed as a decimal (see Table RO-3)

C_A = Runoff coefficient for Natural Resources Conservation Service (NRCS) Type A soils

C_B = Runoff coefficient for NRCS Type B soils

C_{CD} = Runoff coefficient for NRCS Type C and D soils

K_A = Correction factor for Type A soils defined in Table RO-4

K_{CD} = Correction factor for Type C and D soils defined in Table RO-4

Table RO-4—Correction Factors K_A and K_{CD} for Use with Equations RO-6 and RO-7

NRCS Soil Type	Storm Return Period					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
C and D	0	-0.10i + 0.11	-0.18i + 0.21	-0.28i + 0.33	-0.33i + 0.40	-0.39i + 0.46
A	0	-0.08i + 0.09	-0.14i + 0.17	-0.19i + 0.24	-0.22i + 0.28	-0.25i + 0.32

COMPOSITE DEVELOPED BASIN -Rational Method Procedure

REFERENCE USDCM VOL.1 RUNOFF

$$t_c = t_i + t_t \quad \text{(RO-2)}$$

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L}}{S^{0.33}} \quad \text{(RO-3)}$$

$$V = C_v S_w^{0.5} \quad \text{(RO-4)}$$

in which:

V = velocity (ft/sec)

C_v = conveyance coefficient (from Table RO-2)

S_w = watercourse slope (ft/ft)

$$t_c = \frac{L}{180} + 10 \quad \text{(RO-5)}$$

in which:

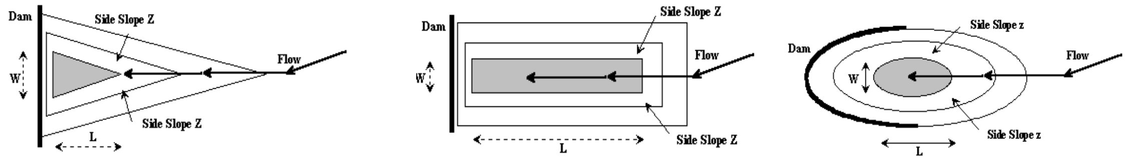
t_c = maximum time of concentration at the first design point in an urban watershed (minutes)

Table RO-2—Conveyance Coefficient, C_v

Type of Land Surface	Conveyance Coefficient, C_v
Heavy meadow	2.5
Tillage/field	5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas and shallow paved swales	20

STAGE-STORAGE SIZING FOR WATER QUALITY POND

Project: **Bybee 14-L Facility**
Basin ID: **Proposed Basin 1**



Design Information (Input):

Width of Basin Bottom, W =		ft
Length of Basin Bottom, L =		ft
Dam Side-slope (H:V), Z_d =	4.00	ft/ft

Check Basin Shape

Right Triangle		OR…
Isosceles Triangle		OR…
Rectangle		OR…
Circle / Ellipse		OR…
Irregular	X	(Use Overide values in cells G32:G52)

Stage-Storage Relationship:

	MINOR	MAJOR	
Storage Requirement from Sheet 'Modified FAA':			acre-ft.
Storage Requirement from Sheet 'Hydrograph':			acre-ft.
Storage Requirement from Sheet 'Full-Spectrum':			acre-ft.

Labels for WQCV, Minor, & Major Storage Stages (input)	Water Surface Elevation ft (input)	Side Slope (H:V) ft/ft Below El.	Basin Width at Stage ft (output)	Basin Length at Stage ft (output)	Surface Area at Stage ft^2 (output)	Surface Area at Stage ft^2 User Overide	Volume Below Stage ft^3 (output)	Surface Area at Stage acres (output)	Volume Below Stage acre-ft (output)	Target Volumes for WQCV, Minor, & Major Storage Volumes (for goal seek)
	4888.10	(input)				3,325		0.076	0.000	
	4888.20		0.00	0.00		3,473	340	0.080	0.008	
	4888.30		0.00	0.00		3,622	695	0.083	0.016	
	4888.40		0.00	0.00		3,773	1,064	0.087	0.024	
	4888.50		0.00	0.00		3,926	1,449	0.090	0.033	
	4888.60		0.00	0.00		4,080	1,850	0.094	0.042	
	4888.70		0.00	0.00		4,235	2,265	0.097	0.052	
	4888.80		0.00	0.00		4,392	2,697	0.101	0.062	
	4888.90		0.00	0.00		4,551	3,144	0.104	0.072	
	4889.00		0.00	0.00		4,711	3,607	0.108	0.083	
WQCV	4889.10		0.00	0.00		4,873	4,086	0.112	0.094	
	4889.20		0.00	0.00		5,037	4,582	0.116	0.105	
	4889.30		0.00	0.00		5,202	5,094	0.119	0.117	
	4889.40		0.00	0.00		5,369	5,622	0.123	0.129	
							#N/A		#N/A	
							#N/A		#N/A	
							#N/A		#N/A	
							#N/A		#N/A	
							#N/A		#N/A	
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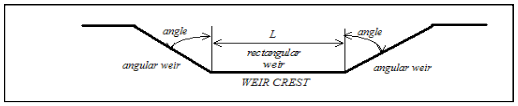
							#N/A		#N/A	
							#N/A		#N/A	
							#N/A		#N/A	

STAGE-DISCHARGE SIZING OF THE SPILLWAY

Project: **Bybee 14-L Facilities**
Basin ID: **Proposed Basin 1**



Design Information (input):

Bottom Length of Weir	L =	24.41	feet
Angle of Side Slope Weir	Angle =	75.96	degrees
Elev. for Weir Crest	EL. Crest =	4,889.10	feet
Coef. for Rectangular Weir	C_w =	3.00	
Coef. for Trapezoidal Weir	C_t =	2.51	

Calculation of Spillway Capacity (output):

Water Surface Elevation ft. (linked)	Rect. Weir Flowrate cfs (output)	Triangle Weir Flowrate cfs (output)	Total Spillway Release cfs (output)	Total Pond Release cfs (output)
4888.10	0.00	0.00	0.00	0.00
4888.20	0.00	0.00	0.00	0.00
4888.30	0.00	0.00	0.00	0.00
4888.40	0.00	0.00	0.00	0.00
4888.50	0.00	0.00	0.00	0.00
4888.60	0.00	0.00	0.00	0.00
4888.70	0.00	0.00	0.00	0.00
4888.80	0.00	0.00	0.00	0.00
4888.90	0.00	0.00	0.00	0.00
4889.00	0.00	0.00	0.00	0.00
4889.10	0.00	0.00	0.00	0.00
4889.20	2.32	0.03	2.35	2.35
4889.30	6.55	0.18	6.73	6.73
4889.40	12.03	0.49	12.53	12.53
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A

WQ Orifice Sizing

The following is an analysis of the required size of the WQ orifices.
This analysis was performed by hand since the UDFCD spreadsheets do not work for the given configuration (less than 1.0 feet from the lowest, and only, orifice row to the WQCV elevation of 4889.1')

Properties

Height at WQCV, h_i	0.45 ft
Height at Orifice, h_0	0.0 ft
Area at WQCV, A(h = 0.45)	4873.40 sq ft
Area at Orifice, A(h = 0)	4157.15 sq ft
Coefficient of Discharge for Orifice, C_D	0.65
Required Drain Time, t	40 hrs

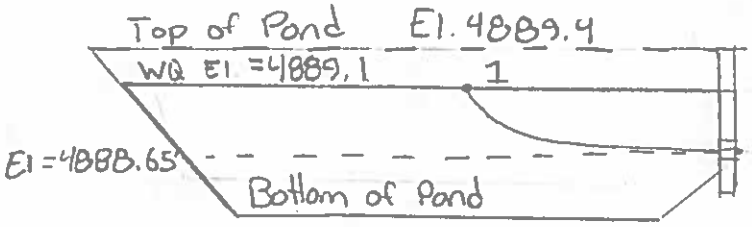
Results

Number of Orifices:	3	4
Required Radius:	0.346 in	0.300 in

Analysis

The above properties of the basin and orifice plate were used to calculate the required size of the orifices. Please refer to appendicies C4 and C5 for the complete calculations. From this calculation it was determined that four 3/5" diameter holes would be sufficient to drain the portion of the WQCV above these orifices in 40 hours. The remainder of the pond will drain through the infiltration trench within the next 32 hours (given that the entire pond needs to drain in 72 hours).

WQ Orifice Sizing



$V_1 << V_2 \rightarrow \frac{V_1^2}{2g} \approx 0$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$ Bernoulli's Equation

$$h = \frac{V_2^2}{2g}$$

$$V_2 = \sqrt{2gh}$$

$Q_1 = V_1 A$

$Q_2 = C_d V_1 A$ C_d = coefficient of discharge = 0.65

$Q_1 = Q_2$

$V_1 A_1 = C_d V_2 A$ $V_1 = -\frac{dh}{dt}$

Area of Pond

$A(h)$ = Area, function of height

$A(0.45') = 4873.40\ ft^2$

$A(0) = 4157.15\ ft^2$

→ roughly linear

$A(h) = m \cdot h + A_0$

$A_0 = 4157.15\ ft^2$

$4873.4\ ft^2 = m(0.45\ ft) + 4157.15\ ft^2$

$m = 1591.7\ ft$

$A(h) = (1591.7\ ft)h + 4157.15\ ft^2$

$$-\frac{dh}{dt}\left[(1591.7\,ft)h + (4157.15\,ft^2)\right] = \sqrt{2gh}\ 0.65\ A, \quad K = 0.65\ A\sqrt{2g}$$

$$-\frac{1}{K}\int_{h_0 = 0.45\,ft}^{h_f = 0\,ft}\left[(1591.7\,ft)h^{1/2} + (4157.15\,ft^2)h^{-1/2}\right]dh = \int_0^t dt$$

$$-\frac{1}{K}\left[(1591.7\,ft)\frac{2h^{3/2}}{3} + (4157.15\,ft^2)2h^{1/2}\right]_{0.45}^{0} = t$$

$$-\frac{1}{K}\left[-(1591.7\,ft)^2\cdot\frac{(0.45\,ft)^{3/2}}{3} - (4157.15\,ft^2)\cdot 2(0.45\,ft)^{1/2}\right] = t$$

$$-\frac{1}{K}\left[-320.3\,ft^{5/2} - 5577.4\,ft^{5/2}\right] = t$$

WQ Orifice Sizing (continued)

$$t = \frac{5897.4\ ft^{5/2}}{K} = \frac{5897.4\ ft^{5/2}}{0.65 A \sqrt{2 \cdot 32.2\ ft/s^2}}$$

$$t = \frac{1130.6\ ft^2/s}{A}$$

For 40 hr = 144000 s drain time

$$144000 s = \frac{1130.6\ ft^2/s}{A}$$

$$A = 0.00785\ ft^2 \cdot \left(\frac{144\ in^2}{ft^2}\right) = 1.13\ in^2$$

$$A = n \cdot \pi R^2$$

$n = 3$ $\quad 1.13\ in^2 = 3 \cdot \pi R^2$ $\quad R = 0.346$ in

$D \approx 7/10$ in

$n = 4$ $\quad 1.13\ in^2 = 4 \cdot \pi R^2$ $\quad R = 0.300$ in

$D = 3/5$ in

Water Quality Trash Screen Sizing

Ref: UDFCD V3 Chapter 4 T-12 Outlet Structures Table OS-2a and OS-2b
The Diameter from WQCV Outlet Spreadsheet = 0.754 " < 1.25 "

Table OS-2a. Trash Rack Sizing for Small Circular Orifices (up to 1-1/4" diameter)[1,3]

Number of Columns	Diameter of Circular Orifice (in)	Width of Trash Rack Opening ($W_{opening}$) as a Function of Water Depth H Above Lowest Perforation				
		H=2.0'	H=3.0'	H=4.0'	H=5.0'	H=6.0'
1	≤ 1-1/4	12"[2]	12"[2]	12"[2]	12"	13"

For D < 1.25" and WQCV Depth H <2', the Min recommended width is 12"

[1] For use with Johnson VEE WireTM Stainless Steel Screen1 (or equivalent screen with 60% open area). Assumes inundation of well screen into the permanent pool 2'4".

[2] Represents the minimum recommended width of 12 inches, otherwise width is calculated based on Figure OS-1.

[3] This table provides the minimum opening in the concrete, not the minimum width of the well screen. Ensure the well screen is wide enough to properly attach to the structure.

Concrete opening = 2 ft > minimum 1 ft ==> OK

Table OS-2b. Trash Rack Specifications for Circular Orifice Plates

Max. Width of Opening (in)	Screen #93 VEE Wire Slot Opening (in)	Support Rod Type	Support Rod, On Center, Spacing	Total Screen Thickness	Carbon Steel Frame Type
≤18	0.139	TE 0.074"x0.50"	1"	0.655"	¾" x 1.0 angle
≤24	0.139	TE 0.074"x0.75"	1"	1.03"	1.0" x 1½" angle
≤27	0.139	TE 0.074"x0.75"	1"	1.03"	1.0" x 1½" angle
≤30	0.139	TE 0.074"x1.0"	1"	1.155"	1 ¼"x 1½" angle
≤36	0.139	TE 0.074"x1.0"	1"	1.155"	1 ¼"x 1½" angle
≤42	0.139	TE 0.105"x1.0"	1"	1.155"	1 ¼"x 1½" angle

[1] Johnson Screens, St. Paul, Minnesota, USA (1-800-833-9473)

Analysis of Open Channels

The following is an analysis of the flow capacity of the perimeter swales as they are graded.

Given the following calculated values for the proposed basin's 100-YR flow rate

Calculated Values: (See Appendix B-5)

Proposed basin 100-YR Developed flow rate: 11.26 cfs

Swale 1 Analysis

Swale 1 is designed to convey a portion of the developed flow from the proposed basin to the water quality pond equal to approximately one third of the total 100 year developed flow rate (assuming 1/3rd of developed flow is collected by each swale, and the final third flows across the pad directly into the pond). Swale 1 was evaluated at two points to account for the varying cross section that will be neccessary due to the need for a sloped swale across an essentially flat ground surface. These two points are the midpoint, where the required capacity is approximately 1/6th of the total developed flow, and at its endpoint where the required capacity is 1/3rd of the developed flow.

As was discussed with Adam Smith (representing the town of Frederick) the swales will not be able to provide the typically required 1.0 feet of freeboard due to site constraints.

The characteristics of swale 1 as designed are shown below:

Characteristics:	**Midpoint**	**Endpoint**
Depth of swale =	0.45 ft (3" of freeboard)	0.94 ft (3" of freeboard)
Slope of the swales =	0.0015 ft/ft	0.0015 ft/ft
Bottom width: B =	4.0 ft	4.0 ft
Slope of Swale sides =	4 ft/ft	4 ft/ft
Manning's Coefficient: n =	0.03	0.03
Required capacity =	1/6(11.26cfs)	1/3(11.26 cfs)
	= 1.88 cfs	= 3.75 cfs
Calculated Flow Capacity =	2.44 cfs	10.21 cfs

Conclusion

The above parameters were entered into the UD-Channels Spreadsheets to determine the water depth at the 100-YR flow rate. Please refer to Appendix C-9 , the Normal Flow Analysis Trapezoidal Channel: Swale 1 - Midpoint, and C-10, the Normal Flow Analysis Trapezoidal Channel: Swale 1 - Endpoint, for details. Based on this analysis, the flow capacity of swale 1 meets the required capacity at both design points with 3" of freeboard.

Swale 2 Analysis

Swale 2 is designed to convey a portion of the developed flow from the proposed basin to the water quality pond equal to approximately one third of the total 100 year developed flow rate (assuming 1/3rd of developed flow is collected by each swale, and the final third flows across the pad directly into the pond). Swale 1 was evaluated at its midpoint where the required capcity was considered to be the full 1/3rd of the proposed basin's flow.

As was discussed with Adam Smith (representing the town of Frederick) the swales will not be able to provide the typically required 1.0 feet of freeboard due to site constraints.

The characteristics of swale 2 as designed are shown below:

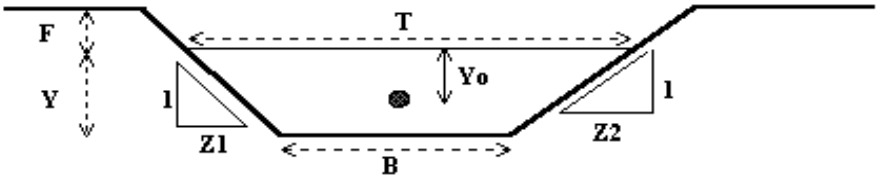
Characteristics:	**Midpoint**
Depth of swale =	0.6 ft (+3" freeboard)
Slope of the swales =	.002 ft/ft
Bottom width: B =	4 ft
Slope of Swale sides =	4 ft/ft
Manning's Coefficient: n =	0.030
Required capacity =	1/3(11.26 cfs)
	= 3.75 cfs
Calculated Flow Capacity =	4.85 cfs

Conclusion

The above parameters were entered into the UD-Channels Spreadsheets to determine the water depth at the 100-YR flow rate. Please refer to Appendix C-11 , the Normal Flow Analysis Trapezoidal Channel: Swale 2 for details. Based on this analysis, the flow capacity of swale 1 meets the required capacity at the design point with 3" of freeboard.

Normal Flow Analysis - Trapezoidal Channel

Project: Bybee 14-L Facilities
Channel ID: Swale 1 - Midpoint

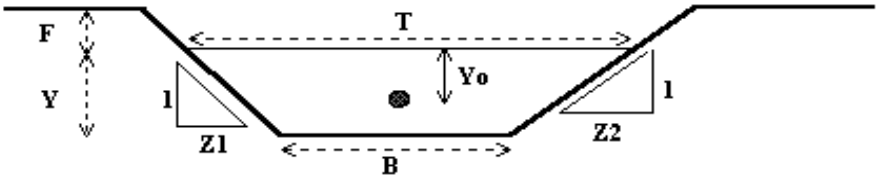


Design Information (Input)			
Channel Invert Slope	So =	0.0015	ft/ft
Manning's n	n =	0.030	
Bottom Width	B =	4.00	ft
Left Side Slope	Z1 =	4.00	ft/ft
Right Side Slope	Z2 =	4.00	ft/ft
Freeboard Height	F =	0.25	ft
Design Water Depth	Y =	**0.45**	ft

Normal Flow Condtion (Calculated)			
Discharge	**Q =**	**2.44**	cfs
Froude Number	**Fr =**	**0.28**	
Flow Velocity	**V =**	**0.93**	fps
Flow Area	A =	2.61	sq ft
Top Width	T =	7.60	ft
Wetted Perimeter	P =	7.71	ft
Hydraulic Radius	R =	0.34	ft
Hydraulic Depth	D =	0.34	ft
Specific Energy	Es =	0.46	ft
Centroid of Flow Area	Yo =	0.20	ft
Specific Force	Fs =	0.04	kip

Normal Flow Analysis - Trapezoidal Channel

Project: Bybee 14-L Facilities
Channel ID: Swale 1 - Endpoint

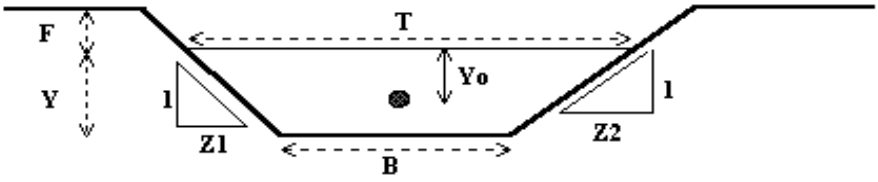


Design Information (Input)			
Channel Invert Slope	So =	0.0015	ft/ft
Manning's n	n =	0.030	
Bottom Width	B =	4.00	ft
Left Side Slope	Z1 =	4.00	ft/ft
Right Side Slope	Z2 =	4.00	ft/ft
Freeboard Height	F =	0.25	ft
Design Water Depth	Y =	**0.94**	ft

Normal Flow Condtion (Calculated)			
Discharge	**Q =**	**10.21**	cfs
Froude Number	**Fr =**	**0.31**	
Flow Velocity	**V =**	**1.40**	fps
Flow Area	A =	7.29	sq ft
Top Width	T =	11.52	ft
Wetted Perimeter	P =	11.75	ft
Hydraulic Radius	R =	0.62	ft
Hydraulic Depth	D =	0.63	ft
Specific Energy	Es =	0.97	ft
Centroid of Flow Area	Yo =	0.39	ft
Specific Force	Fs =	0.21	kip

Normal Flow Analysis - Trapezoidal Channel

Project: Bybee 14-L Facilities
Channel ID: Swale 2 - Midpoint



Design Information (Input)			
Channel Invert Slope	So =	0.0020	ft/ft
Manning's n	n =	0.030	
Bottom Width	B =	4.00	ft
Left Side Slope	Z1 =	4.00	ft/ft
Right Side Slope	Z2 =	4.00	ft/ft
Freeboard Height	F =	0.25	ft
Design Water Depth	Y =	**0.60**	ft

Normal Flow Condtion (Calculated)			
Discharge	**Q =**	**4.85**	cfs
Froude Number	**Fr =**	**0.34**	
Flow Velocity	**V =**	**1.26**	fps
Flow Area	A =	3.84	sq ft
Top Width	T =	8.80	ft
Wetted Perimeter	P =	8.95	ft
Hydraulic Radius	R =	0.43	ft
Hydraulic Depth	D =	0.44	ft
Specific Energy	Es =	0.62	ft
Centroid of Flow Area	Yo =	0.26	ft
Specific Force	Fs =	0.07	kip

Analysis of Culverts

Analysis of Irrigation Ditch Culverts

The proposed culverts for the Irrigation ditches where the proposed permanent access road crosses them (at the northeast corner of the site) were sized to convey the full flow of the ditches. In order to calculate the full flow of the irrigation ditches, their cross sections and flow path were measured and entered into the UD-Channels Spreadsheet. Using these calculated flow rates, the culverts were then sized. Using the information from the sizing of the culverts, the required outlet protection was then determined.

Characteristics:	**Northeast Irrigation Ditch 1**	**Northeast Irrigation Ditch 2**
Depth of swale =	1.10 ft	1.31 ft
Slope of Ditch Flow Path =	0.0018 ft/ft	.0020 ft/ft
Bottom width: B =	0.7 ft	1.66 ft
Slope of West Side =	2 ft/ft	1.35 ft/ft
Slope of East Side =	1.5 ft/ft	1.31 ft/ft
Manning's Coefficient: n =	0.030	0.030
Calculated Full Flow capacity =	4.14 cfs	8.10 cfs
	NE IRD 1 Culvert	**NE IRD 2 Culvert**
Diameter of Culvert =	15"	15"
Inlet Edge Type =	Square Edge Projection	Square Edge Projection
Number of Barrels =	2	2
Inlet Elevation =	4891.6'	4894.1'
Outlet Elevation =	4891.46'	4893.8'
Length =	52.5 ft	37.5 ft
Manning's Roughness =	0.013	0.013
Elevation of top of Ditch at Inlet =	4892.7'	4895.46'
Calculated Capacity at top of Ditch HW Elevation =	5.37 cfs	8.38 cfs
Rip Rap Sizing =	Type M, 4' X 4'	Type M, 4' X 4'

Conclusion

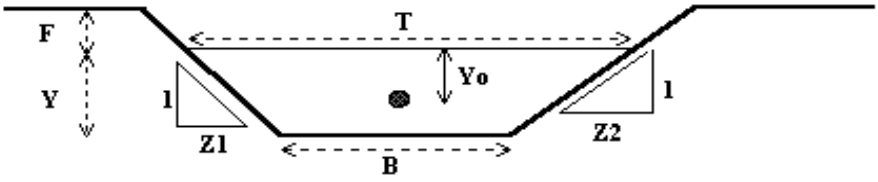
The above parameters were entered into the UD-Channels Spreadsheets to determine the full flow capacity of the irrigation ditches. Please refer to Appendix C-13, the Normal Flow Analysis Trapezoidal Channel: Northeast Irrigation Ditch 1, and C-16, the Normal Flow Analysis Trapezoidal Channel: Northeast Irrigation Ditch 2, for details. These values for the required design capacity along with the above values for the culverts were entered into the UD-Culverts spreadsheet to determine the culverts flow capacity. Please refer to Appendix C-14 , the Culvert Stage-Discharge Sizing - Northeast Irrigation Ditch 1, and C-17, the Culvert Stage-Discharge Sizing - Northeast Irrigation Ditch 2, for details. Based on this analysis, the proposed culverts are sufficiently sized to convey the full flow of the irrigation ditches.

The culvert properties were then entered into the UD-Culvert Outlet protection spreadsheet to determine the required Rip Rap sizing. Since the required rip rap type was calculated to be Type VL, Type M will be proposed instead for safety considerations. Please refer to Appendix C-15 , Determination of Culvert Headwater and Outlet Protection - Northeast Irrigation Ditch 1, and C-18, Determination of Culvert Headwater and Outlet Protection - Northeast Irrigation Ditch 2, for details.

This analysis shows that the culverts, as designed, are sufficient to convey the full capacity of the irrigation ditches.

Normal Flow Analysis - Trapezoidal Channel

Project: Bybee 14-L Facilities
Channel ID: Northeast Irrigation Ditch 1

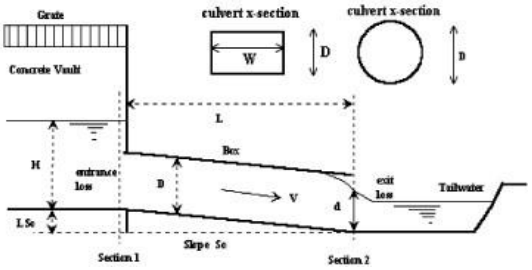


Design Information (Input)			
Channel Invert Slope	So =	0.0018	ft/ft
Manning's n	n =	0.030	
Bottom Width	B =	0.70	ft
Left Side Slope	Z1 =	2.00	ft/ft
Right Side Slope	Z2 =	1.50	ft/ft
Freeboard Height	F =	0.00	ft
Design Water Depth	Y =	**1.10**	ft

Normal Flow Condtion (Calculated)			
Discharge	**Q =**	**4.14**	cfs
Froude Number	**Fr =**	**0.32**	
Flow Velocity	**V =**	**1.43**	fps
Flow Area	A =	2.89	sq ft
Top Width	T =	4.55	ft
Wetted Perimeter	P =	5.14	ft
Hydraulic Radius	R =	0.56	ft
Hydraulic Depth	D =	0.63	ft
Specific Energy	Es =	1.13	ft
Centroid of Flow Area	Yo =	0.41	ft
Specific Force	Fs =	0.09	kip

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

Project: Bybee 14-L Facilities
Basin ID: Northeast Irrigation Ditch 1
Status:



Design Information (Input):

Circular Culvert:	Barrel Diameter in Inches	D =	15	inches
	Inlet Edge Type (choose from pull-down list)		Square End Projection	
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 =	2	
	Inlet Elevation at Culvert Invert	Inlet Elev =	4891.6	ft. elev.
	Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)	Outlet Elev =	4891.46	ft. elev.
	Culvert Length in Feet	L =	52.5	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 =	0.50
Friction Loss Coefficient	K_f =	1.21
Sum of All Loss Coefficients	K_s =	2.71
Orifice Inlet Condition Coefficient	C_d =	0.85
Minimum Energy Condition Coefficient	KE_{low} =	0.0560

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
4891.60		0.00	0.00	**0.00**	No Flow (WS < inlet)	N/A
4891.70		0.20	1.57	**0.20**	Min. Energy. Eqn.	INLET
4891.80		0.40	2.20	**0.40**	Min. Energy. Eqn.	INLET
4891.90		0.80	2.84	**0.80**	Min. Energy. Eqn.	INLET
4892.00		1.20	3.40	**1.20**	Min. Energy. Eqn.	INLET
4892.10		1.80	3.97	**1.80**	Min. Energy. Eqn.	INLET
4892.20		2.60	4.50	**2.60**	Min. Energy. Eqn.	INLET
4892.30		3.20	4.90	**3.20**	Regression Eqn.	INLET
4892.40		4.00	4.94	**4.00**	Regression Eqn.	INLET
4892.50		4.80	5.04	**4.80**	Regression Eqn.	INLET
4892.60		5.60	5.17	**5.17**	Regression Eqn.	OUTLET
4892.70		6.60	5.37	**5.37**	Regression Eqn.	OUTLET
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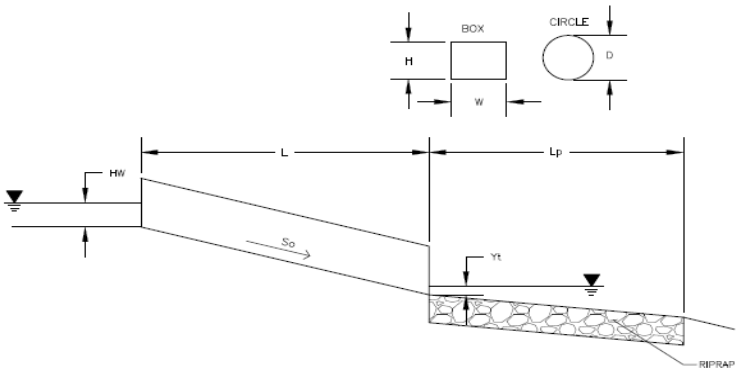
Determination of Culvert Headwater and Outlet Protection

Project: Bybee 14-L Facilities
Basin ID: Northeast Irrigation Ditch 1



Soil Type:
Choose One:
○ Sandy
◉ Non-Sandy

Design Information (Input):

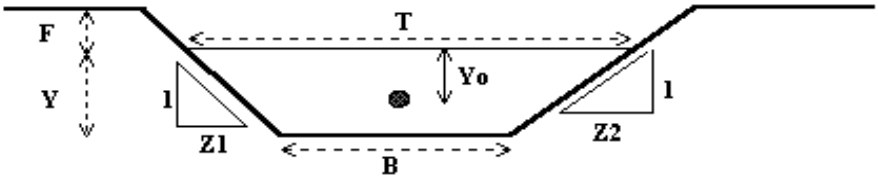
	Design Discharge	Q = 4.14	cfs
Circular Culvert:			
	Barrel Diameter in Inches	D = 15	inches
	Inlet Edge Type (Choose from pull-down list)	Square End Projection	
Box Culvert:		**OR**	
	Barrel Height (Rise) in Feet	Height (Rise) =	ft
	Barrel Width (Span) in Feet	Width (Span) =	ft
	Inlet Edge Type (Choose from pull-down list)		
	Number of Barrels	No = 2	
	Inlet Elevation	Elev IN = 4891.6	ft
	Outlet Elevation **OR** Slope	Elev OUT = 4891.46	ft
	Culvert Length	L = 52.5	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 = 7	ft/s

Required Protection (Output):

	Tailwater Surface Height	Y_t = 0.50	ft
	Flow Area at Max Channel Velocity	A_t = 0.30	ft^2
	Culvert Cross Sectional Area Available	A = 1.23	ft^2
	Entrance Loss Coefficient	k_e = 0.50	
	Friction Loss Coefficient	k_f = 1.21	
	Sum of All Losses Coefficients	k_s = 2.71	ft
	Culvert Normal Depth	Y_n = 0.71	ft
	Culvert Critical Depth	Y_c = 0.57	ft
	Tailwater Depth for Design	d = 0.91	ft
	Adjusted Diameter **OR** Adjusted Rise	D_a = -	ft
	Expansion Factor	1/(2*tan(Θ)) = 6.53	
	Flow/Diameter$^{2.5}$ **OR** Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 = 1.18	$ft^{0.5}/s$
	Froude Number	Fr = 0.66	
	Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise	Yt/D = 0.40	
	Inlet Control Headwater	HW_I = 0.83	ft
	Outlet Control Headwater	HW_O = 0.89	
	Design Headwater Elevation	**HW = 4,892.49**	**ft**
	Headwater/Diameter OR Headwater/Rise Ratio	**HW/D = 0.71**	
	Minimum Theoretical Riprap Size	d_{50} = 1	in
	Nominal Riprap Size	d_{50} = 6	in
	UDFCD Riprap Type	**Type = VL**	**Use Type M**
	Length of Protection	**L_p = 4**	**ft**
	Width of Protection	**T = 2**	**ft**

Normal Flow Analysis - Trapezoidal Channel

Project: Bybee 14-L Facilities
Channel ID: Northeast Irrigation Ditch 2

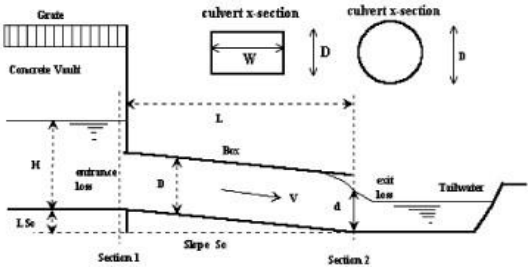


Design Information (Input)			
Channel Invert Slope	So =	0.0020	ft/ft
Manning's n	n =	0.030	
Bottom Width	B =	1.66	ft
Left Side Slope	Z1 =	1.35	ft/ft
Right Side Slope	Z2 =	1.31	ft/ft
Freeboard Height	F =	0.00	ft
Design Water Depth	Y =	**1.31**	ft

Normal Flow Condtion (Calculated)			
Discharge	**Q =**	**8.10**	cfs
Froude Number	**Fr =**	**0.34**	
Flow Velocity	**V =**	**1.82**	fps
Flow Area	A =	4.46	sq ft
Top Width	T =	5.14	ft
Wetted Perimeter	P =	6.02	ft
Hydraulic Radius	R =	0.74	ft
Hydraulic Depth	D =	0.87	ft
Specific Energy	Es =	1.36	ft
Centroid of Flow Area	Yo =	0.54	ft
Specific Force	Fs =	0.18	kip

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

Project: Bybee 14-L Facilities
Basin ID: Northeast Irrigation Ditch 2
Status:



Design Information (Input):

Circular Culvert:	Barrel Diameter in Inches	D =	15	inches
	Inlet Edge Type (choose from pull-down list)		Square End Projection	
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 =	2	
	Inlet Elevation at Culvert Invert	Inlet Elev =	4894.1	ft. elev.
	Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)	Outlet Elev =	4893.8	ft. elev.
	Culvert Length in Feet	L =	37.5	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 =	0.50
Friction Loss Coefficient	K_f =	0.87
Sum of All Loss Coefficients	K_s =	2.37
Orifice Inlet Condition Coefficient	C_d =	0.85
Minimum Energy Condition Coefficient	KE_{low} =	0.0560

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
4894.10		0.00	0.00	**0.00**	No Flow (WS < inlet)	N/A
4894.20		0.20	3.70	**0.20**	Min. Energy. Eqn.	INLET
4894.30		0.40	4.28	**0.40**	Min. Energy. Eqn.	INLET
4894.40		0.80	4.80	**0.80**	Min. Energy. Eqn.	INLET
4894.50		1.20	4.91	**1.20**	Min. Energy. Eqn.	INLET
4894.60		1.80	5.03	**1.80**	Min. Energy. Eqn.	INLET
4894.70		2.60	5.14	**2.60**	Min. Energy. Eqn.	INLET
4894.80		3.20	5.32	**3.20**	Regression Eqn.	INLET
4894.90		4.00	5.60	**4.00**	Regression Eqn.	INLET
4895.00		4.80	5.89	**4.80**	Regression Eqn.	INLET
4895.10		5.80	6.30	**5.80**	Regression Eqn.	INLET
4895.20		6.60	6.70	**6.60**	Regression Eqn.	INLET
4895.30		7.60	7.16	**7.16**	Regression Eqn.	OUTLET
4895.40		8.40	7.86	**7.86**	Regression Eqn.	OUTLET
4895.46		8.80	8.38	**8.38**	Regression Eqn.	OUTLET
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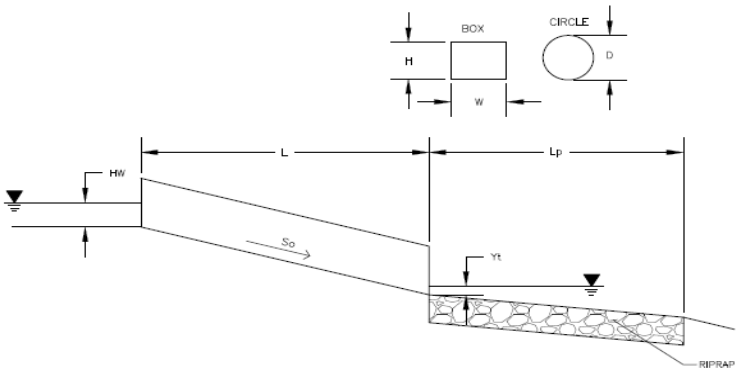
Determination of Culvert Headwater and Outlet Protection

Project: Bybee 14-L Facilities

Basin ID: Northeast Irrigation Ditch 2



Soil Type:

Supercritical Flow! Using Da to calculate protection type.

Design Information (Input):

	Design Discharge	Q =	8.1	cfs
Circular Culvert:				
	Barrel Diameter in Inches	D =	15	inches
	Inlet Edge Type (Choose from pull-down list)			
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 =	2	
	Inlet Elevation	Elev IN =	4894.1	ft
	Outlet Elevation **OR** Slope	Elev OUT =	4893.8	ft
	Culvert Length	L =	37.5	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 =	5.5	ft/s

Required Protection (Output):

Tailwater Surface Height	Y_t =	0.50	ft
Flow Area at Max Channel Velocity	A_t =	0.74	ft^2
Culvert Cross Sectional Area Available	A =	1.23	ft^2
Entrance Loss Coefficient	k_e =	0.50	
Friction Loss Coefficient	k_f =	0.87	
Sum of All Losses Coefficients	k_s =	2.37	ft
Culvert Normal Depth	Y_n =	0.77	ft
Culvert Critical Depth	Y_c =	0.81	ft
Tailwater Depth for Design	d =	1.03	ft
Adjusted Diameter **OR** Adjusted Rise	D_a =	1.01	ft
Expansion Factor	1/(2*tan(Θ)) =	6.35	
Flow/Diameter$^{2.5}$ **OR** Flow/(Span * Rise$^{1.5}$)	Q/D^2.5 =	2.32	$ft^{0.5}/s$
Froude Number	Fr =	1.11	**Supercritical!**
Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise	Yt/D =	0.50	
Inlet Control Headwater	HW_I =	1.28	ft
Outlet Control Headwater	HW_O =	1.13	
Design Headwater Elevation	**HW =**	**4,895.38**	**ft**
Headwater/Diameter OR Headwater/Rise Ratio	**HW/D =**	**1.02**	
Minimum Theoretical Riprap Size	d_{50} =	3	in
Nominal Riprap Size	d_{50} =	6	in
UDFCD Riprap Type	**Type =**	**VL**	**Use Type M**
Length of Protection	**L_p =**	**4**	**ft**
Width of Protection	**T =**	**2**	**ft**

MLVT Failure Analysis

The following is an analysis of the routing and flow rate of water in the event of a failure of an MLVT on the Bybee 14-L drill pad.

MLVT Properties:

Diameter: D= 157 ft
Capacity: Vol = 42,000 Barrels = 1,764,000 Gallons
= 235,813 cubic feet = 7.21 acre-ft

Size of Onsite and Surrounding Basin at time of MLVT use

Stage Elevation	Surface Area at Stage	Volume Below Stage	Volume Below Stage
ft	ft^2	ft^3	acre-ft
4888.5	6695		
4889.0	128224	33729.75	0.77
4889.3	189194	81342.45	1.87
4889.5	470245	147286.35	3.38
4889.7	496288	218438.85	5.01

The final elevation in the above table, 4889.7', represents the highest connected contour around the pad during the time in which the MLVTs will be on site. This indicates that the first 5.01 acre-ft released from the MLVTs will pond around the site. Once this elevation is reached, the remaining water released from the tanks would flow between the irrigation ditches at the Northwest corner of the field (this is the low point of the surrounding contours) and from there would flow towards the Godding Hollow Drainage Channel. Please see Drainage plan DP1 for this location.

In the event of MLVT failure, the assumption is shown as follows:

Assumption:

MLVT Drain Time: T= 10 min = 600 Sec

Discharge Calculation:

Q = Vol / T
= 235,813 ft^3 / 600 Sec
= 393.02 cfs

100 yr Flowrate of Godding Hollow = 9,730 cfs to 10,500 cfs*

The above calculations show that the flow rate from the MLVTs in the event of a failure would be approximately 1/25th of the 100 year storm flow rate in the Godding Hollow Channel.

*Taken from South Weld I-25 Corridor Master Drainage Plan Table 4.4 - Major Drainageway Peak Discharges for Existing Conditions. Values represent those for the nearest road crossings (WCR 20 and WCR 22 respectively)

DETENTION POND EMERGENCY SPILLWAY REF:

REFERENCE UDFCD VOL.2 STORAGE

Broad-Crested Weir: The equation typically used for a broad-crested weir is:

$$Q = C_{BCW} L H^{1.5} \qquad \text{(SO-18)}$$

in which:

Q = discharge (cfs)

C_{BCW} = broad-crested weir coefficient (This ranges from 2.38 to 3.32 as per Brater and King (1976). A value of 3.0 is often used in practice.)

L = broad-crested weir length (ft)

H = head above weir crest (ft)

V-Notch Weir: The discharge through a V-notch or triangular weir is shown in Figure SO-5 and can be calculated from the following equation:

$$Q = C_t \tan\left(\frac{\theta}{2}\right) H^{2.5} \qquad \text{(SO-20)}$$

in which:

C_t = Coefficient for Triangular Weir taken from the table below

Q = discharge (cfs)

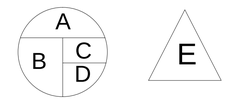
θ = angle of V-notch in degrees

H = head above the apex of V-notch (ft)

SPECIAL USE REVIEW USRXX-XXXX
EXTRACTION OIL & GAS. BYBEE 14-L FACILITY

SUMMARY RUNOFF TABLE

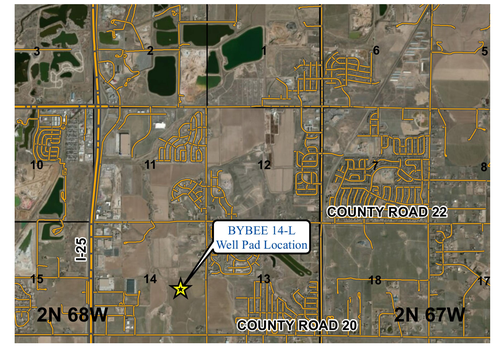
DESIGN POINT	CONTRIBUTING AREA (ACRES)	DIRECT RUNOFF 10-YR (CFS)	TOTAL RUNOFF 10-YR (CFS)	DIRECT RUNOFF 100-YR (CFS)	TOTAL RUNOFF 100-YR (CFS)
1	4.02	4.54	4.54	11.26	11.26
2	30.63	5.62	5.62	27.28	27.28



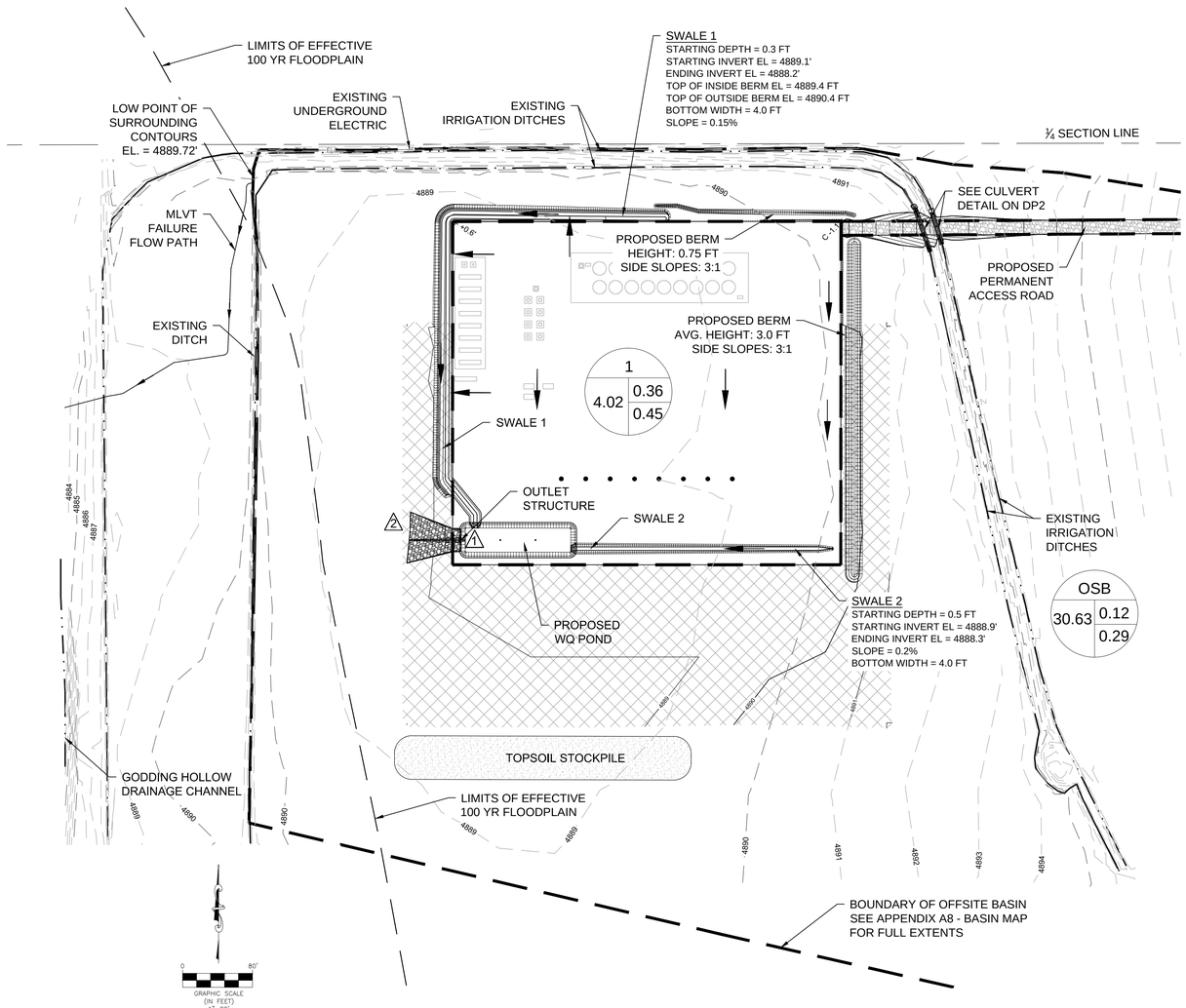
A = BASIN DESIGNATION
B = AREA IN ACRES
C = 10 - YR COMPOSITE RUNOFF COEFFICIENTS
D = 100 - YRCOMPOSITE RUNOFF COEFFICIENTS
E = DESIGN POINT DESIGNATION

LEGEND

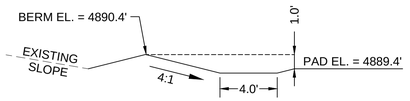
- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONOUR
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- BASIN BOUNDARY
- PROPOSED WELL
- FLOW ARROW



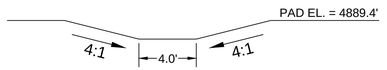
VICINITY MAP
NOT TO SCALE



PROPOSED DRAINAGE PLAN



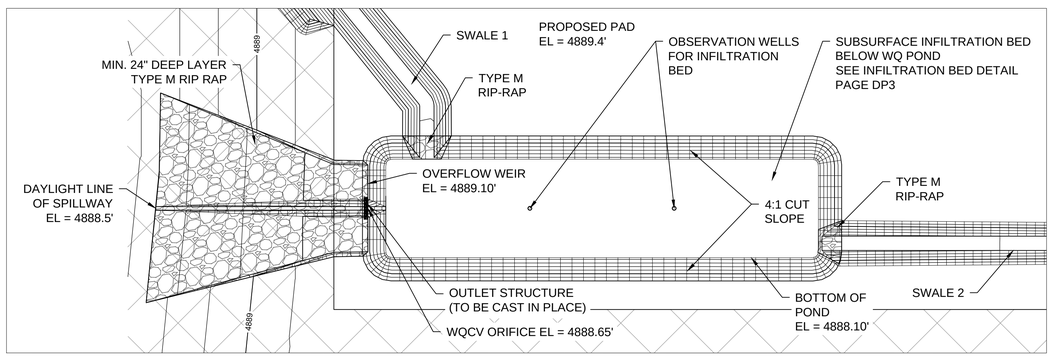
SWALE 1 SECTION
N.T.S.



SWALE 2 SECTION
N.T.S.

WATER QUALITY POND SUMMARY TABLE

DESIGN WQCV VOLUME (ACRE-FEET)	WQCV ELEVATION (FEET)	DESIGN DRAIN TIME - ORIFICE PLATE (HR)	DESIGN DRAIN TIME - TOTAL (HR)
0.088	4889.1	40	72



DETAILED WQ POND
(PROPOSED CONTOURS AT 0.2' INTERVALS)

NOTE: THE EXISTING TOPOGRAPHY INFORMATION WAS COLLECTED BY PETROLEUM FIELD SERVICES ON 08-27-2014.

811 Know what's below. Call before you dig.

NO.	DATE:	REVISION DESCRIPTION	NAME

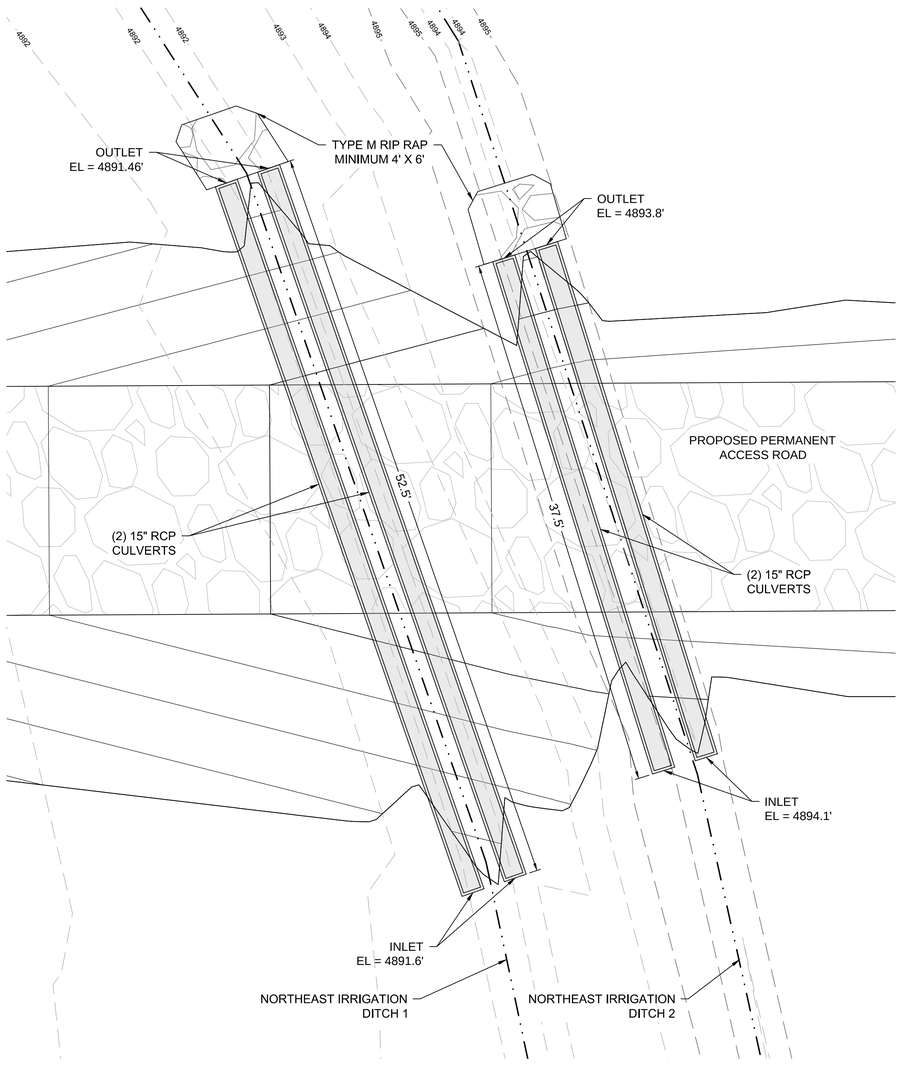
PREPARED FOR:
EXTRACTION Oil & Gas
EXTRACTION OIL & GAS

PREPARED BY:
PFS Petroleum Field Services, LLC
7535 Hilltop Circle
Denver, CO 80221

EXTRACTION OIL & GAS

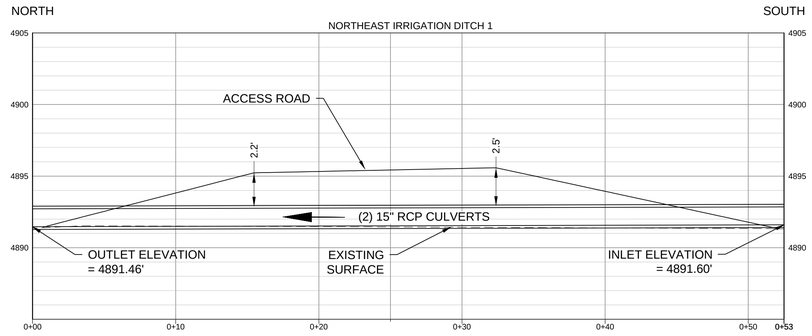
DRAWING DATE: 11-03-15	DRAWING NAME: DRAINAGE PLAN
DRAWN BY: SWW	SURFACE LOCATION: SECTION 14, TOWNSHIP 2 NORTH RANGE 68 WEST, 6TH P.M. FREDERICK, COLORADO
CHECK BY: MCW	DP1

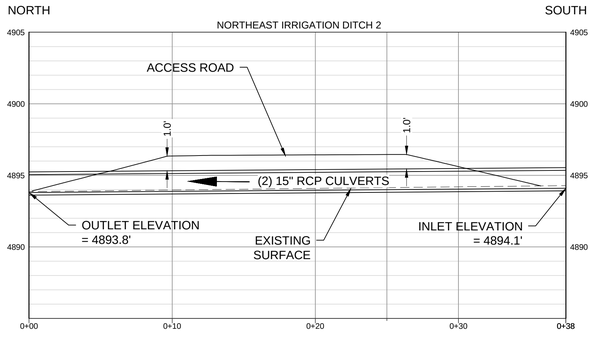
SPECIAL USE REVIEW USRXX-XXXX
EXTRACTION OIL & GAS. BYBEE 14-L FACILITY



LEGEND

- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONOUR
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- BASIN BOUNDARY
- PROPOSED WELL
- FLOW ARROW





CULVERT DETAIL

NOTE: THE EXISTING TOPOGRAPHY INFORMATION WAS COLLECTED BY PETROLEUM FIELD SERVICES ON 08-27-2014.

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PREPARED FOR:
EXTRACTION Oil & Gas
EXTRACTION OIL & GAS

PREPARED BY:
PFS Inc.
Petroleum Field Services, LLC
7535 Hilltop Circle
Denver, CO 80221

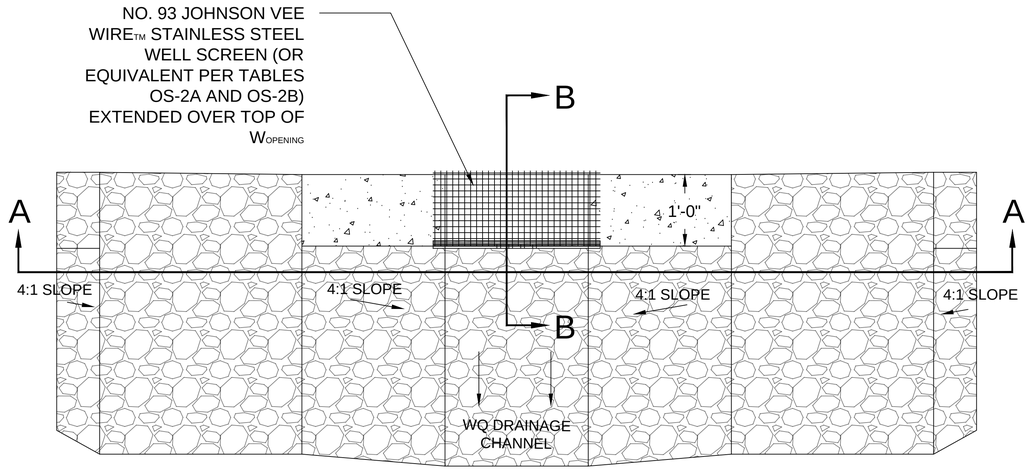
EXTRACTION OIL & GAS

DRAWING DATE: 10-30-15
DRAWN BY: SWW
CHECK BY: MCW

DRAWING NAME: DRAINAGE PLAN - DETAIL 1
SURFACE LOCATION: SECTION 14, TOWNSHIP 2 NORTH RANGE 68 WEST, 6TH P.M. FREDERICK, COLORADO

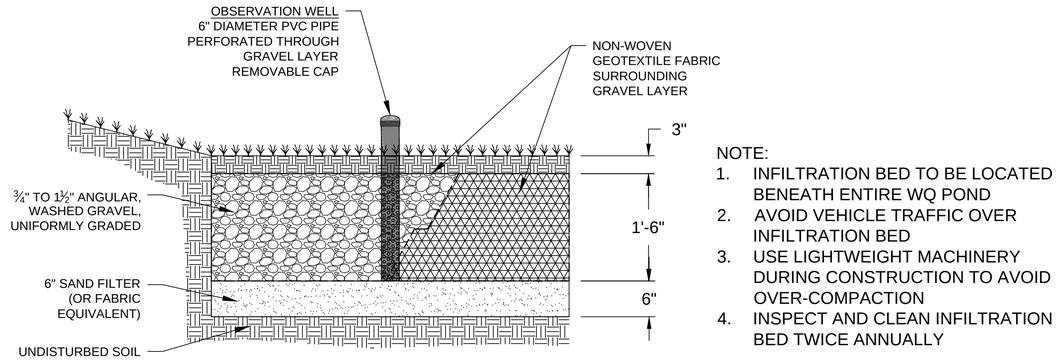
DP2

SPECIAL USE REVIEW USRXX-XXXX
EXTRACTION OIL & GAS. BYBEE 14-L FACILITY



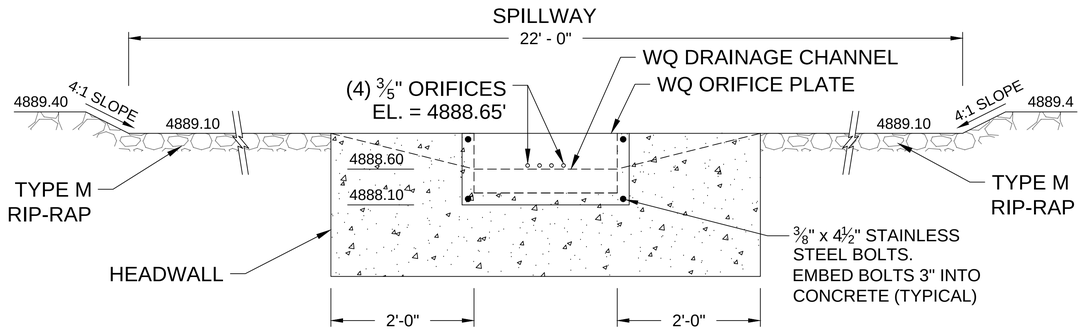
WQ ORIFICE PLATE AND HEADWALL

PLAN VIEW

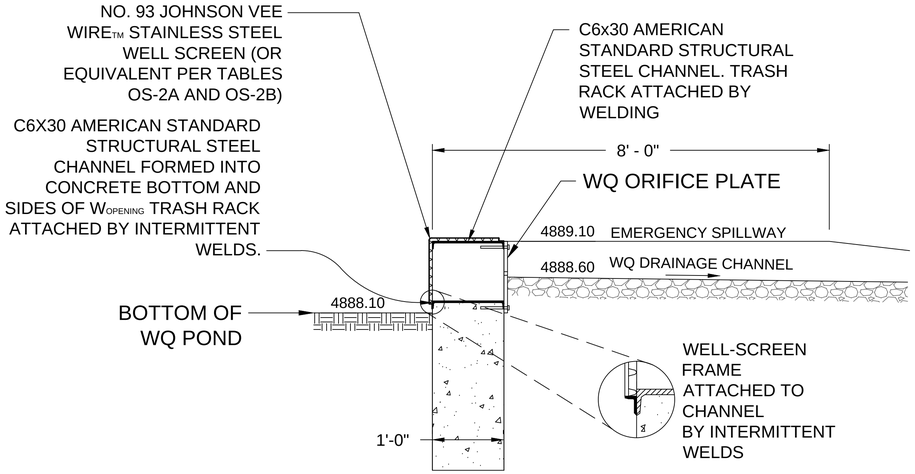


NOTE:
1. INFILTRATION BED TO BE LOCATED BENEATH ENTIRE WQ POND
2. AVOID VEHICLE TRAFFIC OVER INFILTRATION BED
3. USE LIGHTWEIGHT MACHINERY DURING CONSTRUCTION TO AVOID OVER-COMPACTION
4. INSPECT AND CLEAN INFILTRATION BED TWICE ANNUALLY

INFILTRATION BED DETAIL



CROSS SECTION A-A



CROSS SECTION B-B

NOTE:
1. OUTLET STRUCTURE TO BE CAST IN PLACE
2. SEE CDOT DETAIL M-601-1 FOR REINFORCEMENT

811 Know what's below. Call before you dig.

NO.	DATE:	REVISION DESCRIPTION	NAME

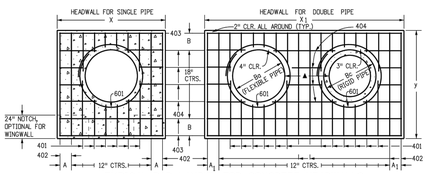
PREPARED FOR:
EXTRACTION Oil & Gas
EXTRACTION OIL & GAS

PREPARED BY:
PFS Petroleum Field Services, LLC
7535 Hilltop Circle
Denver, CO 80221

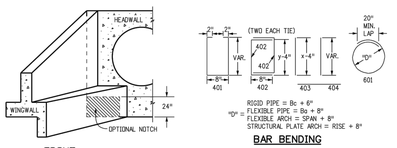
EXTRACTION OIL & GAS

DRAWING DATE: 10-30-15	DRAWING NAME: DRAINAGE STURCUTRES DETAIL SHEET 1
DRAWN BY: SWW	SURFACE LOCATION: SECTION 14, TOWNSHIP 2 NORTH RANGE 68 WEST, 6TH P.M. FREDERICK, COLORADO
CHECK BY: MCW	DP3

SPECIAL USE REVIEW USRXX-XXXX
EXTRACTION OIL & GAS. BYBEE 14-L FACILITY



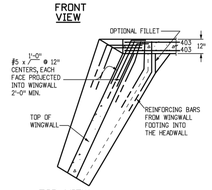
TYPICAL BAR LAYOUT FOR CONCRETE HEADWALLS



FRONT VIEW

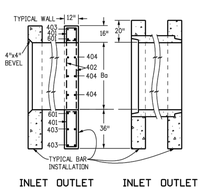
RIGID PIPE = Bc + 6"
"D" = FLEXIBLE PIPE = Ba + 8"
FLEXIBLE ARCH = SPAN + 8"
STRUCTURAL PLATE ARCH = RISE + 8"

BAR BENDING



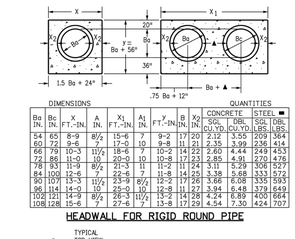
TOP VIEW

WINGWALL CONNECTION



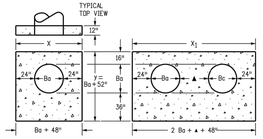
INLET OUTLET
ENDS OF
FLEXIBLE PIPE

INLET OUTLET
ENDS OF
RIGID PIPE



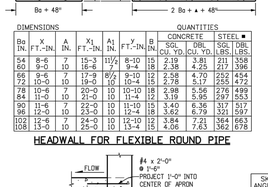
DIMENSIONS										QUANTITIES		
Ba IN.	Bc IN.	X FT.-IN.	A IN.	X_1 FT.-IN.	A_1 IN.	Y_1 FT.-IN.	B IN.	X_2 IN.	CONCRETE SQL CU. YD.	CONCRETE DBL CU. YD.	STEEL ■ SQL LBS.	STEEL ■ DBL LBS.
54	65	8-9	8½	15-6	7	9-2	17	20	2.12	3.55	209	364
60	72	9-6	7	17-0	10	9-8	11	21	2.35	3.99	236	414
66	79	10-3	11½	18-6	7	10-2	14	22	2.60	4.44	249	453
72	86	11-0	10	20-0	10	10-8	17	23	2.85	4.91	270	476
78	93	11-9	8½	21-3	11	11-2	11	24	3.11	5.29	306	527
84	100	12-6	7	22-6	7	11-8	14	25	3.38	5.88	333	572
90	107	13-3	11½	23-9	8½	12-2	17	26	3.66	6.08	335	593
96	114	14-0	10	25-0	10	12-8	11	27	3.94	6.48	379	649
102	121	14-9	8½	26-3	11½	13-2	14	28	4.24	6.89	400	664
108	128	15-6	7	27-6	7	13-8	17	29	4.54	7.30	424	707

HEADWALL FOR RIGID ROUND PIPE



DIMENSIONS											QUANTITIES		
EQUIV. Ba IN.	SPAN IN.	RISE IN.	X FT.-IN.	A IN.	X_1 FT.-IN.	A_1 IN.	Y_1 FT.-IN.	B IN.	CONCRETE SQL CU. YD.	CONCRETE DBL CU. YD.	STEEL ■ SQL LBS.	STEEL ■ DBL LBS.
72	81	59	10-9	8½	20-6	7	9-3	17½	2.72	5.10	250	467
78	87	63	11-3	11½	21-6	7	9-7	10½	2.85	5.34	275	531
84	95	67	11-9	8½	22-10	9	9-11	12½	3.08	5.79	290	547
90	103	71	12-7	7½	24-2	11	10-3	15	3.30	6.21	321	591
96	112	75	13-4	12	25-8	8	10-7	16½	3.52	6.65	314	606
102	117	79	13-9	8½	26-6	7	10-11	9½	3.63	6.86	356	672
108	128	83	14-8	8	28-4	12	11-3	11½	3.96	7.51	376	699

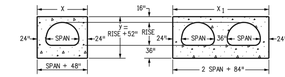
HEADWALL FOR FLEXIBLE PIPE ARCH



DIMENSIONS							QUANTITIES	
Ba IN.	X FT.-IN.	A IN.	X_1 FT.-IN.	A_1 IN.	Y_1 FT.-IN.	B IN.	CONCRETE SQL CU. YD.	CONCRETE DBL CU. YD.	STEEL ■ SQL LBS.	STEEL ■ DBL LBS.
54	8-6	7	15-3	11½	8-10	15	2.19	3.81	211	358
60	9-0	10	16-6	7	9-4	18	2.38	4.25	217	396
66	9-6	7	17-9	8½	9-10	12	2.58	4.70	252	454
72	10-0	10	19-0	10	10-4	15	2.78	5.17	255	472
78	10-6	7	20-0	10	10-10	18	2.98	5.56	276	499
84	11-0	10	21-0	10	11-4	12	3.19	5.95	297	553
90	11-6	7	22-0	10	11-10	15	3.40	6.36	317	517
96	12-0	10	23-0	10	12-4	18	3.62	6.79	321	597
102	12-6	7	24-0	10	12-10	12	3.84	7.21	364	663
108	13-0	10	25-0	10	13-4	15	4.06	7.63	362	678

HEADWALL FOR FLEXIBLE ROUND PIPE

WHEN APRON IS REQUIRED



DIMENSIONS												QUANTITIES		
EQUIV. Ba IN.	SPAN FT.-IN.	RISE FT.-IN.	X FT.-IN.	A IN.	X_1 FT.-IN.	A_1 IN.	Y_1 FT.-IN.	B IN.	X_2 IN.	Y_2 FT.-IN.	CONCRETE SQL CU. YD.	CONCRETE DBL CU. YD.	STEEL ■ SQL LBS.	STEEL ■ DBL LBS.
66	6-1	4-7	10-1	10½	19-2	11	8-11	15½	22	7-10½	2.52	4.70	232	424
75	7-0	5-1	11-0	10	21-0	10	9-5	9½	23	8-4½	2.80	5.25	282	509
84	7-11	5-7	11-11	9½	22-10	9	9-11	12½	24	8-10½	3.08	5.79	291	540
93	8-10	6-1	12-10	9	24-8	8	10-5	15½	25	9-4½	3.36	6.33	309	622
102	9-9	6-7	13-9	8½	26-6	7	10-11	9½	26	9-10½	3.63	6.86	379	673
111	10-11	7-1	14-11	9½	28-10	9	11-5	12½	27	10-4½	4.05	7.87	377	711
120	11-10	7-7	15-10	9	30-8	8	11-11	15½	28	10-10½	4.36	8.28	395	731
132	12-10	8-4	16-10	9	32-8	8	12-8	11	29	11-4½	4.75	9.03	441	839
141	14-1	8-9	18-1	10½	35-2	11	13-1	13½	29	11-4½	5.17	9.86	448	931
150	15-4	9-3	19-4	12	37-8	8	13-7	16½	29	11-4½	5.69	10.88	490	953
159	15-10	9-10	19-10	9	38-8	8	14-2	11	29	11-4½	5.89	11.25	534	1019

HEADWALL FOR STRUCTURAL PLATE ARCH

SKEW ANGLE A°	90	85	80	75	70	65	60	55	50	45	40	35	30
FACTOR (cosecA°)	1.000	1.004	1.015	1.035	1.064	1.103	1.155	1.221	1.305	1.414	1.556	1.743	2.000

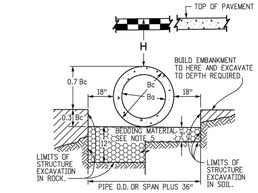
SKEW FACTOR TABLE

GENERAL NOTES

1. CONCRETE SHALL BE CLASS B.
2. HEADWALL SHALL BE PERPENDICULAR TO THE PIPE ℄ UNLESS OTHERWISE SHOWN ON THE PLANS. TABULATED DIMENSIONS AND QUANTITIES MUST BE ADJUSTED FOR SKEWED INSTALLATIONS.
3. FOR WINGWALL DETAILS, SEE STANDARD PLAN M-601-20.
4. VOLUME OCCUPIED BY PIPE HAS BEEN DEDUCTED FROM STEEL AND CONCRETE QUANTITIES.
5. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED ¾ IN.
6. ALL REINFORCING BARS SHALL HAVE A 2 IN. MINIMUM CLEARANCE.

▲ WHEN TWO OR MORE PIPES ARE LAID SIDE BY SIDE, THEY SHALL BE PLACED SO THAT THE ADJACENT PIPES WILL BE ½ INSIDE DIAMETER APART, OR ½ INSIDE SPAN APART, OR 3 FT. APART (INCLUDING WALL THICKNESS), WHICHEVER IS LESS.

■ ADD 0.89 x (X OR X_1) (LB.) WHEN APRON IS REQUIRED.



NOTE: Bc IS THE OUTSIDE DIMENSION FOR DIAMETER, SPAN OR RISE.

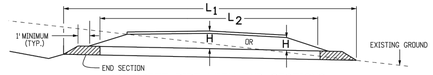
PIPE INSTALLATION
(WITH 0.7 PROJECTION RATIO)

△ PIPE SIZE= Ba (INSIDE DIA)	WALL THICKNESS	0.3 Bc (OUTSIDE DIA)
IN.		FT.
12	2	0.40
15	2-¼	0.49
18	2-½	0.58
21	2-¾	0.66
24	3	0.75
27	3-¼	0.84
30	3-½	0.92
33	3-¾	1.01
36	4	1.10
42	4-½	1.28
48	5	1.45
54	5-½	1.62
60	6	1.80
66	6-½	1.97
72	7	2.15
78	7-½	2.32
84	8	2.50
90	8-½	2.68
96	9	2.85
102	9-½	3.02
108	10	3.20

CIRCULAR (CIR)			VERTICAL ELLIPTICAL (VE)				HORIZONTAL ELLIPTICAL (HE)			
SPAN	RISE	WALL THICKNESS	SPAN	RISE	WALL THICKNESS	0.3 OUTSIDE RISE	SPAN	RISE	WALL THICKNESS	0.3 OUTSIDE RISE
IN.			IN.			FT.	IN.			FT.
							23	14	2-¾	0.49
							30	19	3-¼	0.66
							34	22	3-½	0.73
							38	24	3-¾	0.79
							45	29	4-½	0.95
29	45	4-½	1.35							
34	53	5	1.58				53	34	5	1.10
38	60	5-½	1.78				60	38	5-½	1.23
43	68	6	2.00				68	43	6	1.38
48	76	6-½	2.23				76	48	6-½	1.53
53	83	7	2.43				83	53	7	1.68
58	91	7-½	2.65				91	58	7-½	1.83
63	98	8	2.85				98	63	8	1.98
68	106	8-½	3.08				106	68	8-½	2.13
72	113	9	3.28				113	72	9	2.25
77	121	9-½	3.50				121	77	9-½	2.40
82	128	9-¾	3.69				128	82	9-¾	2.54
87	136	10	3.90				136	87	10	2.68

△ ALSO EQUIVALENT ROUND DIMENSION FOR ELLIPTICAL PIPE.

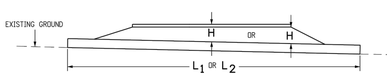
DIMENSIONS FOR REINFORCED CONCRETE PIPE
(FOR INFORMATION ONLY)



CONCRETE PIPE WITH END SECTIONS

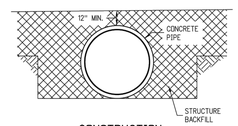
NOTE: USE THE H THAT IS GREATER FOR MAXIMUM ALLOWABLE FILL HEIGHT.

H = HEIGHT OF FILL OVER TOP OF PIPE, INCLUDING PAVEMENT THICKNESS.
L_1 = LENGTH OF PIPE TO BE MEASURED WHEN PLACED IN ACCORDANCE WITH SECTION 624.
L_2 = LENGTH OF PIPE TO BE MEASURED WHEN PLACED IN ACCORDANCE WITH SECTION 603.



CONCRETE PIPE WITHOUT END SECTIONS

NOTE: USE THE H THAT IS GREATER FOR MAXIMUM ALLOWABLE FILL HEIGHT.



CONSTRUCTION
MINIMUM COVER FOR RIGID PIPE

TYPE OF PIPE	HEIGHT OF FILL OVER TOP OF PIPE, H (FEET)				
	CLASS OF PIPE		(0.01 IN. CRACK D-LOAD)		
	CLASS CIR II CLASS VE II CLASS HE II 1000 D	CLASS CIR III CLASS VE III CLASS HE III 1350 D	CLASS CIR IV CLASS VE IV CLASS HE IV 2000 D	CLASS CIR V CLASS VE V ——— 3000 D	——— CLASS VE VI ——— 4000 D
CIRCULAR (CIR)	1 TO 18	1 TO 25	± 25 TO 37	± 37 TO 45	
VERTICAL ELLIPTICAL (VE)	1 TO 18	1 TO 25	± 25 TO 37	± 37 TO 45	± 45 TO 62
HORIZONTAL ELLIPTICAL (HE)	1 TO 18	1 TO 25	± 25 TO 37		

ALLOWABLE RANGE OF HEIGHTS FOR FILL
OVER REINFORCED CONCRETE PIPE
(ALL SIZES)

GENERAL NOTES

REINFORCED CONCRETE PIPE

1. FILL HEIGHTS GREATER THAN MAXIMUM ALLOWED IN THE HEIGHTS OF FILL TABLE ON THIS SHEET REQUIRE SPECIAL DESIGN OF STRUCTURE.
2. PIPE DESIGN IS BASED ON SAFETY FACTOR OF 1.33 ON ULTIMATE STRENGTH.
3. THE HEIGHTS OF FILL OVER TOP OF PIPE ARE BASED ON UNIT WEIGHT OF SOIL AT 135 LBS. PER CUBIC FT.
4. PIPE CLASS IS DETERMINED FROM 0.01 IN. CRACK D-LOAD.
5. BEDDING IS CLASS B (MODIFIED) (FROM CONCRETE PIPE DESIGN MANUAL-AMERICAN CONCRETE PIPE ASSOCIATION) WITH SETTLEMENT RATIO $R = 0.0_{SD}$ (YIELDING BED). BEDDING MATERIAL FOR RIGID PIPE IN SOIL SHALL BE 3 IN. LOOSE THICKNESS STRUCTURE BACKFILL CLASS 2. BEDDING MATERIAL FOR RIGID PIPE IN ROCK SHALL BE 12 IN. LOOSE THICKNESS STRUCTURE BACKFILL CLASS 1.
6. CHANGES IN DESIGN FACTORS REQUIRE COMPENSATING CHANGES IN PIPE DESIGN.
7. MINIMUM WALL THICKNESS DIMENSIONS ARE BASED ON AASHTO M 170 (WALL B) FOR CIRCULAR PIPE, AND AASHTO M 207 FOR ELLIPTICAL PIPE.
8. SPACING FOR MULTIPLE PIPE INSTALLATIONS SHALL CONFORM TO THE DETAILS SHOWN ON STANDARD PLAN M-206-1.
9. WHEN A PIPE IS TO BE EXTENDED, THE SAME PIPE MATERIAL AND SIZE AS IN THE ORIGINAL PIPE INSTALLATION SHALL BE USED.

NONREINFORCED CONCRETE PIPE

1. AT THE OPTION OF THE CONTRACTOR, NONREINFORCED CONCRETE PIPE CONFORMING TO AASHTO M 86 MAY BE USED IN LIEU OF REINFORCED CONCRETE PIPE FOR ALL SIZES 36 INCHES IN DIAMETER AND SMALLER. THE NONREINFORCED CONCRETE PIPE SHALL MEET THE SAME D-LOAD TO PRODUCE THE ULTIMATE LOAD UNDER THE THREE-EDGE BEARING METHOD AS SPECIFIED FOR REINFORCED CONCRETE PIPE IN CONFORMANCE WITH AASHTO M 170. THE CONTRACTOR SHALL PROVIDE WRITTEN CERTIFICATION OF CONFORMANCE. THE WALL THICKNESS OF THE NONREINFORCED PIPE MAY BE INCREASED AS REQUIRED TO MEET D-LOAD REQUIREMENT.
2. ALL REQUIREMENTS FOR REINFORCED CONCRETE PIPE, EXCEPT THOSE REFERRING TO REINFORCEMENT, SHALL APPLY TO NONREINFORCED CONCRETE PIPE.

Computer File Information	
Creation Date: 07/04/12	Initials: DD
Last Modification Date: 07/04/12	Initials: LTA
Full Pathtwww.coloradodot.info/business/designsupport	
Drawing File Name: 601000101.dgn	
CAD Ver.: MicroStation V8 Scale: Not to Scale	Units: English

Sheet Revisions	
Date:	Comments

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Project Development Branch DD/LTA

HEADWALL FOR PIPES

Issued By: Project Development Branch July 4, 2012

STANDARD PLAN NO.
M-601-10
Sheet No. 1 of 1

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Sheet Revisions	
Date:	Comments
3/25/14	Made Min. Cover for Rigid Pipe detail like others. Deleted Gen Note 9 & renumbered.
4/11/14	Changed "Min." to ≤ in Heights table.

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REINFORCED CONCRETE PIPE

Issued By: Project Development Branch on July 4, 2012

STANDARD PLAN NO.
M-603-2
Sheet No. 1 of 1

811 Know what's below. Call before you dig.

NO.	DATE:	REVISION DESCRIPTION	NAME

PREPARED FOR:
EXTRACTION
Oil & Gas
EXTRACTION OIL & GAS

PREPARED BY:
PFS
Petroleum Field Services, LLC
7535 Hilltop Circle
Denver, CO 80221

EXTRACTION OIL & GAS

DRAWING DATE: 09-27-15
DRAWN BY: SWW
CHECK BY: MCW

DRAWING NAME: DRAINAGE STURCUTRES DETAIL SHEET 2
SURFACE LOCATION: SECTION 14, TOWNSHIP 2 NORTH RANGE 68 WEST, 6TH P.M. FREDERICK, COLORADO

DP4