ATTACHMENT 6

WATER QUALITY SWALE DESIGN ADDENDUM

12 October 2010 Project No. 073-81694.0022

Mr. Robert R. Monok
Project Manager
Energy Fuels Resource Corporation
44 Union Boulevard, Suite 600
Lakewood, Colorado 80228

RE: DESIGN ADDENDUM TO KLEINFELDER CONCEPTUAL DESIGN FOR THE WATER QUALITY SWALE, PIÑON RIDGE PROJECT, MONTROSE COUNTY, COLORADO

Dear Bob:

1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared this letter addendum to provide additional design information for the Water Quality Swale (WQS) and its associated stilling basin proposed for construction at the Piñon Ridge Project in Montrose County, Colorado. The conceptual design for the WQS was originally provided by Kleinfelder (Kleinfelder, 2009). This document is intended to supplement that design by specifying the design components of this swale and stilling basin as requested by the Colorado Department of Public Health and Environment (CDPHE) as part of the Request for Additional Information (RFI) #3 received on August 19, 2010. Maintenance recommendations are also provided.

2.0 WATER QUALITY SWALE

Water quality swales are vegetated channels that are commonly used as a permanent stormwater Best Management Practice (BMP). When built according to specified design criteria, these channels improve the water quality of flows exiting the swale primarily by promoting settling of suspended solids. These swales also have an ancillary benefit of providing some removal of trace metals and other particulates (USEPA, 1999).

2.1 Design Criteria

The U.S. Environmental Protection Agency (USEPA) provides general guidance for the design and functionality of water quality swales. For more specific design guidance, the USEPA refers engineers and designers to *Design of Stormwater Filtering Systems*, published by the Center for Watershed Protection. (CWP, 1996). Table 1 is provided to summarize the specific design criteria for water quality swales.

Golder Associates Inc.
44 Union Boulevard, Suite 300
Lakewood, CO 80228 USA
Tel: (303) 980-0540 Fax: (303) 985-2080 www.golder.com

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Table 1: Water Quality Swale Design Criteria

Parameter	Design Criteria
Channel Shape	Trapezoidal or Parabolic
Bottom Width	2 feet minimum, 6 feet maximum (widths up to 12 feet are allowable with a dividing berm or structure to prevent channel braiding)
Side Slopes	3H:1V or flatter (4H:1V preferred)
Channel Longitudinal Slope	1.0% minimum, 4.0% maximum
Water Quality Design Flow	<5 cubic feet per second (cfs)
Flow Depth	4 inches maximum for water quality flow
Manning's n Value	0.15 for depths up to 4 inches 0.15 to 0.03 for depths 4 to 12 inches 0.03 for depths over 12 inches
Flow Velocity	Maximum 1.0 foot per second (fps) for water quality flow Maximum 7.0 fps for 10-year storm
Swale Length	Length necessary for minimum 10 minute residence time
Minimum Freeboard	6 inches above 10-year water surface elevation
Stilling Basin/Forebay at Swale Entrance	Volume = 0.05 inches per impervious acre Mild (3H:1V or flatter) side slopes

2.2 Water Quality Swale

2.2.1 WQS Design Discharges

Based on previous hydrologic analyses (Kleinfelder, 2009), the 100-year, 24-hour discharge entering the WQS is estimated to be 40 cfs. Peak discharges for lower magnitude, more frequent storm events were not determined. Since designing this swale for infrequent, high magnitude peak discharges would diminish the swale's effectiveness in improving water quality, it is recommended to use the "90% Rule" in the absence of locally defined design discharge criteria (CWP, 1996). Under this rule, the average 24-hour precipitation event that is expected to occur 90% of the time on an annual basis is to be used to determine the swale's water quality design discharge. This discharge will be used to verify that flow depth, velocity and residence time criteria will be met with the proposed WQS design.

For the Piñon Ridge site, this 90% precipitation depth was determined using the recorded observations on precipitation events noted in the Piñon Ridge Surface Water Log Book. Based on this information, a design precipitation depth of 1.0 inches is used. For comparison purposes, a summary of precipitation depths at the Piñon Ridge site for various storm events is provided in Table 2.

Table 2: Piñon Ridge Precipitation

Precipitation Event	24-Hour Precipitation Depth (inches)
90% Annual Precipitation (Water Quality Design)	1.0
2-Year	1.4 (NOAA, 2006)
10-Year	2.0 (NOAA, 2006)
100-Year	3.0 (Kleinfelder, 2009)

Using the total drainage area of 0.25 square miles reporting to the WQS and an effective Curve Number (CN) of 67 (Kleinfelder, 2009), the WQS design discharge is estimated at 4.8 cfs. The design criteria also dictate using the 10-year discharge to check maximum flow depths and velocities through the WQS. A 10-year, 24-hour discharge of 9.4 cfs reporting to the WQS is estimated using the SCS method (NRCS,

1986). Additional information regarding the determination of the WQS design discharge and 10-year discharge is provided as Attachment A to this report.

The 0.25 square-mile watershed area and corresponding discharges apply to the Phase 1 operating condition of the mill facility. When the facility expands to the proposed full build-out, additional area within the WQS contributing watershed will become zero-discharge facilities (i.e., evaporation ponds and tailings cells) and will no longer contribute to runoff. Although the ultimate footprint of the mill facility will result in reduced flows being directed to the WQS, the Phase 1 layout is taken to be the prevailing condition for this design.

2.2.2 WQS Design

For this design, the water quality discharge of 4.8 cfs is used to determine the required swale cross section in order to meet flow depth and velocity criteria. The 10-year discharge of 9.4 cfs is used to verify that maximum velocities are not exceeded and to establish the minimum total channel depth necessary. A summary of the WQS design for Piñon Ridge is provided in Table 3.

Table 3: Piñon Ridge WQS Design

Parameter	Design
Channel Shape	Trapezoidal
Bottom Width	16 feet total, with 4-foot dividing berm
Side Slopes	10H:1V
Channel Longitudinal Slope	1.1%
Design Discharge	4.8 cfs (water quality) 9.4 cfs (10-year)
Flow Depth	5.4 inches (water quality flow) 7.1 inches (10-year)
Manning's n Value	0.13 (water quality flow) 0.11 (10-year)
Flow Velocity	0.6 fps (water quality flow) 0.8 fps (10-year)
Minimum Channel Depth (with 6 inches minimum freeboard)	14 inches
Residence Time	18 minutes (based on 630-foot treatment length and 0.6 fps flow velocity)

For this water quality design discharge of 4.8 cfs, the design flow depth of 5.4 inches exceeds the maximum 4-inch design flow depth established in the design criteria. Due to site topographic constraints and tying into an existing downstream culvert, the longitudinal slope cannot be increased as a means of reducing the flow depth. Since the channel configuration utilizes the maximum allowable bottom width, there are limited options available to significantly reduce the flow depth. Since the design meets the maximum flow velocity and minimum swale residence time criteria, it is believed that this design will be sufficient to promote the settling of suspended solids.

2.3 Stilling Basin Design

For the WQS to function appropriately, a stilling basin or small forebay at the swale entrance is recommended to provide pre-treatment of incoming flow and enhance filtering into the treatment section of the swale. The primary design element of this basin is that it is sized to provide 0.05 inches of storage volume for each impervious acre reporting to the WQS. Previous hydrologic assessment has indicated

that approximately 4% of the 0.25-square mile area reporting to the WQS, or 6.8 acres, is impervious (Golder, 2010). Based on this impervious area, the required volume of this stilling basin is approximately 1,235 cubic feet.

2.4 Recommended Vegetation and Maintenance

It is recommended that drought-tolerant plant species be specified for the WQS due to this site being located in a semi-arid area. Recommended maintenance procedures are summarized in Table 4.

Table 4: Piñon Ridge WQS Maintenance

Activity	Schedule
Inspect vegetation along channel side slopes for erosion and formation of rills and gullies and correct Remove trash and accumulated debris in WQS and stilling basin Inspect and correct erosion problems within the channel bed	Annual (semi-annual and after significant rainfall the first 2 years)
Plant alternative vegetative species if original vegetation does not successfully establish	After 3 years
Remove sediment build-up within the swale once it has accumulated to 25% of the original design volume (approximately 3 inches) and re-vegetate disturbed areas	As needed

3.0 CONCLUSIONS

A water quality swale is provided for the Piñon Ridge site primarily to prevent excess sediment from exiting the property. The proposed swale has been designed in accordance with USEPA recommended criteria. Although the design exceeds the maximum threshold for flow depth, the design meets or is well below maximum design thresholds for flow velocity and residence time. A stilling basin is provided at the swale entrance to enhance sediment removal. The proposed WQS design is expected to meet water quality objectives related to the removal of suspended solids. Design drawings for the WQS are provided in Attachment B.

4.0 CLOSING

We appreciate the opportunity to provide continued engineering services for the Piñon Ridge project. If you have any questions regarding this document, please contact the undersigned at 303-980-0540.

Sincerely,

GOLDER ASSOCIATES INC.

Sheina P. Sadza
Senior Project Engineer

Kimberly Finke Morrison, P.E., R.G.
Associate - Senior Project Manager

Attachments: A – Water Quality Swale Design Calculations
B – Water Quality Swale Design Drawings

SPS/KFM/rjg

5.0 REFERENCES

Center for Watershed Protection (CWP). 1996. Design of Stormwater Filtering Systems. December 1996.

Golder Associates (Golder). 2010. Potential Impacts to the Dolores River from the Piñon Ridge Project, Montrose County, Colorado. May 2010

Kleinfelder (Kleinfelder). 2009. Site Drainage Analysis and Design Report, Energy Fuels Resources Corporation, Piñon Ridge Project, Montrose County, Colorado. February 2009.

National Oceanic and Atmospheric Administration (NOAA). 2006. Precipitation Frequency Atlas of the United States, NOAA Atlas 14, Volume 1, Version 4. 2006.

United States Department of Agriculture Natural Resources Conservation Service (NRCS). 1986. Urban Hydrology for Small Watersheds (TR-55), June 1986.

United States Environmental Protection Agency (USEPA). 1999. Stormwater Technology Fact Sheet: Vegetated Swales. September 1999.

ATTACHMENT A

WATER QUALITY SWALE DESIGN CALCULATIONS

OBJECTIVE:

Determine both the design flow and the 10-year discharges for the Water Quality Swale (WQS) within the Piñon Ridge Mill site. Verify that the swale configuration meets applicable conveyance criteria.

METHOD:

Based on previous site design, HEC-1 modeling was used to estimate the 100-year peak discharges within the site (Kleinfelder, 2008). In order to determine discharges for more frequent, lower magnitude storm events such as the 10-year storm, the Soil Conservation Service (SCS) method developed by the Natural Resource Conservation Service (NRCS) is used.

The U.S. Environmental Protection Agency (USEPA) provides general guidance for the design and functionality of water quality swales. For more specific design guidance, the USEPA refers to *Design of Stormwater Filtering Systems*, published by the Center for Watershed Protection. (CWP, 1996). This document provides guidance for determining the effective design discharge of the water quality swales as well as the flow conveyance criteria for these swales.

The design discharge is determined using the "90% Rule" in the absence of locally defined design discharge criteria. Under this rule the average 24-hour precipitation event that is expected to occur 90% of the time on an annual basis is to be used to determine the swale's water quality design discharge. For the Piñon Ridge site this 90% precipitation depth was determined using the recorded observations of precipitation events noted in the Piñon Ridge Surface Water Log Book for 2008 and 2009.

ASSUMPTIONS & DATA:

- 100-year, 24-hour rainfall depth = 3.0 inches (Kleinfelder, 2009)
- 10-year, 24-hour rainfall depth = 2.0 inches (NOAA, 2006)
- Water Quality Swale hydrologic parameters (Kleinfelder, 2009)
  - Drainage area = 0.25 square miles (160 acres)
  - Effective CN = 67
  - Length of watercourse = 0.86 miles (4,541 feet)
  - Watercourse slope = 0.020 ft/ft
- Impervious area within water quality swale watershed = 6.8 acres (Golder, 2010)

CALCULATIONS:

10-Year Discharge

The 10-year discharge is used to check that the WQS will have sufficient capacity to safely pass this flow rate. This discharge is determined using the SCS TR-55 graphical method for small watersheds (NRCS, 1986). This peak discharge is governed by the equation:

$$q_p = q_u A_m Q F_p$$

where:
q_p = peak discharge (cfs)
q_u = unit peak discharge (csm/in)
A_m = drainage area (mi2)
Q = runoff (in)
F_p = pond and swamp adjustment factor = 1 (no ponds or swamps in watershed)

The 10-year runoff volume (Q) is determined using the following equation:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where:
Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) = $\frac{1000}{CN} - 10$

Based on the available information, the runoff from this watershed can be determined:

$$S = \frac{1000}{67} - 10 = 4.925\ inches$$

$$Q = \frac{\left(2 - 0.2(4.925)\right)^2}{(2 + 0.8(4.925))} = 0.173\ inches$$

The watershed's time of concentration is used to determine the unit peak discharge (q_u) of the watershed. Using the watercourse slope, the average velocity for shallow concentrated flow over an unpaved surface is graphically estimated at 2.2 feet per second (Figure 3-1 from NRCS, 1986). Applying this velocity over the watercourse length of 4,541 feet results in a time of concentration of 0.57 hours (34 minutes).

In order to determine the unit peak discharge the ratio of initial abstraction (Ia) to total rainfall (P) is needed. This is defined as:

$$\frac{I_a}{P} = \frac{0.2S}{P} = \frac{0.2(4.925\ inches)}{2.0\ inches} = 0.49$$

Using the determined time of concentration and Ia/P ratio under SCS Type II storm conditions, the unit peak discharge (q_u) is determined graphically to be 218 csm/in (Exhibit 4-II from NRCS, 1986). The peak discharge to the WQS during the 10-year storm event is:

$$q_p = \left(218\frac{csm}{in}\right)(0.25\ mi^2)(0.173\ in)(1) = 9.4\ cfs$$

WQS Design Discharge

As noted previously, it is recommended to determine the design discharge of water quality swales using the 90% Rule in the absence of locally defined discharge criteria (CWP, 1996). The 90% precipitation depth was determined using the recorded observations on precipitation events noted in the Piñon Ridge Surface Water Log Book for 2008 and 2009, after discounting precipitation events 0.1 inches or less. The precipitation data is summarized in Tables 1a and 1b.

Table 1a: 90th Percentile Data for 2008 Precipitation Log Data

2008 Precipitation Log Data (inches observed)				
Log Date	Sampler ID			
	S1	S2	S3	S4
5/13	0.4	0.4	0.5	0.7
6/5	0.4	0.5	0.4	0.5
7/17		0.2	0.2	
7/23				0.15
8/5	0.15			
8/7	0.6	0.5	0.5	0.4
8/26	0.2	0.2	0.2	0.2
9/17	0.4	0.4	0.4	0.3
9/28	0.6	0.5	0.5	0.3
10/4	0.3	0.3	0.3	0.3
10/6	0.7	0.8	0.8	0.8
11/27	0.4	0.3	0.3	0.4
11/28	0.6	0.6	0.6	0.6
90th Percentile (each sampler)	0.6	0.6	0.62	0.7
90th Percentile (average over all samplers)	0.63			

Table 1b: 90th Percentile Data for 2009 Precipitation Log Data

2009 Precipitation Log Data (inches observed)				
Log Date	Sampler ID			
	S1	S2	S3	S4
5/2	0.4	0.4	0.4	0.4
5/23		0.3	0.4	0.6
5/26	1.2	1.2	1.2	1.3
6/11	0.3	0.3	0.3	0.4
6/21	0.3	0.3	0.4	0.4

2009 Precipitation Log Data (inches observed)				
Log Date	Sampler ID			
	S1	S2	S3	S4
6/28	1.0			1.0
6/29		0.8	0.8	
7/3	0.3	0.25	0.35	0.6
7/13	0.4	0.4	0.4	0.5
7/28	0.2	0.2	0.25	0.7
90th Percentile (each sampler)	1.06	0.88	0.88	1.06
90th Percentile (average over all samplers)	0.97			

Based on this information, a design precipitation depth of 1.0 inches is used. For comparison purposes a summary of precipitation depths at the Piñon Ridge site for various storm events is provided in Table 2.

Table 2: Piñon Ridge Precipitation

Precipitation Event	24-Hour Precipitation Depth (inches)
90% Annual Precipitation (Water Quality Design)	1.0
2-Year	1.4 (NOAA, 2006)
10-Year	2.0 (NOAA, 2006)
100-Year	3.0 (Kleinfelder, 2009)

The water quality volume generated by the watershed is determined using the 90% Rule rainfall, such that:

$$WQV = P * R_v$$

where:
WQV = Water Quality Volume (inches of runoff per unit watershed area)
P = 90% Rule Rainfall = 1.0 inches; and,

$$R_v = 0.05 + 0.009(I)$$

where I = site percent impervious

$$WQV = (1.0\ in)\left[\left(0.05 + 0.009\left(\frac{6.8\ ac}{160\ ac} * 100\right)\right)\right] = 0.088\ inches$$

Using this volume per unit area and the effective curve number for the watershed (CN = 67), the peak water quality design discharge is determined using:

$$q_p = q_u A_m WQV = \left(218 \frac{csm}{in}\right)(0.25\ mi^2)(0.088\ in) = 4.8\ cfs$$

Swale Design

The design criteria for water quality swales, referenced from the Design of Stormwater Filtering Systems (CWP, 1996), are summarized in Table 3.

Table 3: Piñon Ridge WQS Design Criteria

Parameter	Design
Channel Shape	Trapezoidal or Parabolic
Bottom Width	2 feet minimum, 6 feet maximum (widths up to 12 feet are allowable with a dividing berm or structure to prevent channel braiding)
Side Slopes	3:1 or flatter (4:1 preferred)
Channel Longitudinal Slope	1.0% minimum, 4.0% maximum
Water Quality Design Flow	<5 cfs
Flow Depth	4" maximum for water quality flow
Manning's n Value	0.15 for depths up to 4" 0.15 to 0.03 for depths 4" to 12" 0.03 for depths over 12"
Flow Velocity	Maximum 1.0 fps for water quality flow Maximum 4-5 fps for 2-year storm Maximum 7.0 fps for 10-year storm
Swale Length	Length necessary for minimum 10 minute residence time

The primary conveyance criteria for the channel are the maximum flow depth and maximum flow velocity. These maximums, in addition to the total swale length, are established to allow for sufficient water treatment to take place. For the purpose of this evaluation, water treatment refers primarily to sediment removal.

A 630-foot long swale with an effective bottom width of 12 feet and 10H:1V side slopes is selected to meet the design parameters. The flow depth and flow velocities were determined using Bentley FlowMaster (Bentley, 2009) and the variable Manning's n graph provided on Figure 7.5 in Design of Stormwater Filtering Systems (CWP, 1996). It is recommended to use a variable Manning's n value as flow depth varies to account for the optimal height of vegetation that will be established in the swales. The channel flow parameters are summarized in Table 4.

Table 4: Proposed Piñon Ridge WQS Design

	Design Discharge (cfs)	Swale Slope (ft/ft)	Flow Depth (inches)	Flow Velocity (fps)	Manning's n
Water Quality Design	4.8	0.011	5.4	0.7	0.128
10-Year	9.4	0.011	7.2	0.8	0.11

DISCUSSION:

For the water quality design discharge of 4.8 cfs, the design flow depth of 5.4 inches exceeds the maximum 4-inch depth established in the design criteria. Due to site topographic constraints and

tying into an existing downstream culvert, the longitudinal slope cannot be increased as a means of reducing the flow depth. Because the channel configuration utilizes the maximum allowable bottom width, there are limited options available to significantly reduce the flow depth. Since the design meets the maximum flow velocity and minimum swale residence time criteria, it is believed that this design will be sufficient to promote the settling of suspended solids.

The 10-year discharge of 9.4 cfs is the maximum flow that the swale is anticipated to convey safely. The flow velocity at this maximum discharge is estimated to be 0.8 fps. Although the procedure recommends checking that the velocity of the 2-year storm discharge does not exceed a 4-5 fps erosion threshold, the 10-year velocity is well below this threshold.

CONCLUSION:

Using the TR-55 method, the 10-year discharge reporting to the Water Quality Swale is estimated at 9.4 cfs. Using USEPA recommended procedures, the design discharge for water quality treatment is estimated to be 4.8 cfs. A 630-foot long swale with a 12-foot effective bottom width and 10H:1V side slopes is proposed for this site. The proposed swale design is expected to meet water quality objectives related to the removal of suspended solids.

REFERENCES:

Bentley Systems Inc (Bentley), Bentley FlowMaster, Version 8. 2009.

Golder Associates (Golder). 2010. Potential Impacts to the Dolores River from the Piñon Ridge Project, Montrose County, Colorado. May 2010.

Center for Watershed Protection (CWP). 1996. Design of Stormwater Filtering Systems. December 1996.

Kleinfelder (Kleinfelder). 2009. Site Drainage Analysis and Design Report, Energy Fuels Resources Corporation, Piñon Ridge Project, Montrose County, Colorado. February 2009.

National Oceanic and Atmospheric Administration (NOAA). 2006. Precipitation Frequency Atlas of the United States, NOAA Atlas 14, Volume 1, Version 4. 2006.

United States Department of Agriculture Natural Resources Conservation Service (NRCS). 1986. Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55). June 1986.

United States Environmental Protection Agency (USEPA). 1999. Stormwater Technology Fact Sheet: Vegetated Swales. September 1999.

SUPPORTING DATA

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Colorado 38.245 N 109.06 W 6414 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 4
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2006

Extracted: Mon Sep 20 2010

Confidence Limits | Seasonality | Related Info | GIS data | Maps | Docs | Return to State Map

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.13	0.20	0.25	0.34	0.41	0.50	0.56	0.70	0.89	1.11	1.28	1.51	1.78	2.00	2.62	3.23	3.93	4.68
2	0.17	0.26	0.32	0.43	0.53	0.63	0.70	0.87	1.10	1.38	1.59	1.88	2.23	2.50	3.27	4.01	4.88	5.80
5	0.23	0.35	0.43	0.58	0.72	0.84	0.91	1.09	1.36	1.73	1.98	2.35	2.78	3.11	4.02	4.90	5.95	7.00
10	0.28	0.43	0.53	0.71	0.88	1.03	1.09	1.29	1.57	2.02	2.30	2.74	3.23	3.62	4.62	5.60	6.79	7.92
25	0.36	0.55	0.68	0.91	1.13	1.32	1.37	1.58	1.88	2.42	2.75	3.29	3.87	4.32	5.40	6.53	7.87	9.09
50	0.43	0.65	0.81	1.08	1.34	1.58	1.63	1.82	2.12	2.75	3.11	3.73	4.36	4.87	6.00	7.23	8.68	9.95
100	0.50	0.77	0.95	1.28	1.58	1.88	1.93	2.10	2.39	3.10	3.50	4.20	4.88	5.46	6.62	7.94	9.49	10.80
200	0.59	0.90	1.12	1.50	1.86	2.23	2.28	2.46	2.69	3.48	3.90	4.69	5.43	6.07	7.23	8.64	10.29	11.62
500	0.73	1.11	1.37	1.85	2.29	2.78	2.83	3.02	3.23	4.00	4.46	5.39	6.18	6.92	8.04	9.56	11.32	12.66
1000	0.85	1.29	1.60	2.15	2.67	3.29	3.33	3.53	3.73	4.43	4.92	5.95	6.79	7.61	8.65	10.26	12.09	13.43

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

*** Upper bound of the 90% confidence interval Precipitation Frequency Estimates (inches)**

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.15	0.23	0.29	0.39	0.48	0.57	0.63	0.78	0.97	1.23	1.41	1.67	1.97	2.21	2.89	3.53	4.31	5.12
2	0.20	0.30	0.37	0.50	0.62	0.72	0.79	0.97	1.21	1.53	1.76	2.09	2.46	2.77	3.60	4.38	5.36	6.36
5	0.27	0.40	0.50	0.68	0.83	0.96	1.02	1.21	1.49	1.91	2.18	2.61	3.07	3.44	4.44	5.36	6.53	7.68
10	0.33	0.50	0.62	0.83	1.03	1.17	1.23	1.43	1.73	2.23	2.54	3.04	3.58	4.01	5.10	6.13	7.45	8.69
25	0.42	0.65	0.80	1.08	1.33	1.50	1.55	1.75	2.07	2.68	3.05	3.66	4.28	4.80	5.99	7.17	8.67	10.01
50	0.51	0.77	0.96	1.29	1.60	1.81	1.84	2.03	2.35	3.06	3.46	4.17	4.85	5.44	6.69	7.97	9.60	11.00
100	0.61	0.93	1.16	1.56	1.93	2.17	2.19	2.36	2.65	3.47	3.92	4.73	5.47	6.12	7.40	8.80	10.54	11.99
200	0.74	1.12	1.39	1.87	2.32	2.60	2.62	2.78	3.01	3.92	4.41	5.33	6.14	6.87	8.14	9.64	11.48	12.97
500	0.94	1.43	1.77	2.38	2.95	3.31	3.34	3.47	3.66	4.59	5.15	6.23	7.12	7.97	9.16	10.80	12.78	14.27
1000	1.13	1.72	2.13	2.87	3.56	3.98	4.02	4.10	4.26	5.16	5.77	6.99	7.93	8.88	9.95	11.69	13.79	15.26

* The upper bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are greater than.
** These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.

Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

*** Lower bound of the 90% confidence interval Precipitation Frequency Estimates (inches)**

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.12	0.18	0.22	0.29	0.36	0.45	0.50	0.64	0.81	1.01	1.17	1.37	1.60	1.81	2.37	2.94	3.59	4.27
2	0.15	0.23	0.28	0.38	0.47	0.56	0.63	0.80	1.00	1.25	1.45	1.71	2.01	2.26	2.96	3.66	4.46	5.29
5	0.20	0.31	0.38	0.51	0.63	0.74	0.81	0.99	1.24	1.57	1.80	2.12	2.50	2.82	3.64	4.47	5.43	6.38
10	0.25	0.38	0.47	0.63	0.78	0.90	0.97	1.16	1.43	1.82	2.08	2.47	2.91	3.26	4.16	5.09	6.18	7.20
25	0.31	0.48	0.59	0.80	0.99	1.14	1.21	1.41	1.69	2.18	2.47	2.94	3.45	3.87	4.85	5.92	7.13	8.24

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow

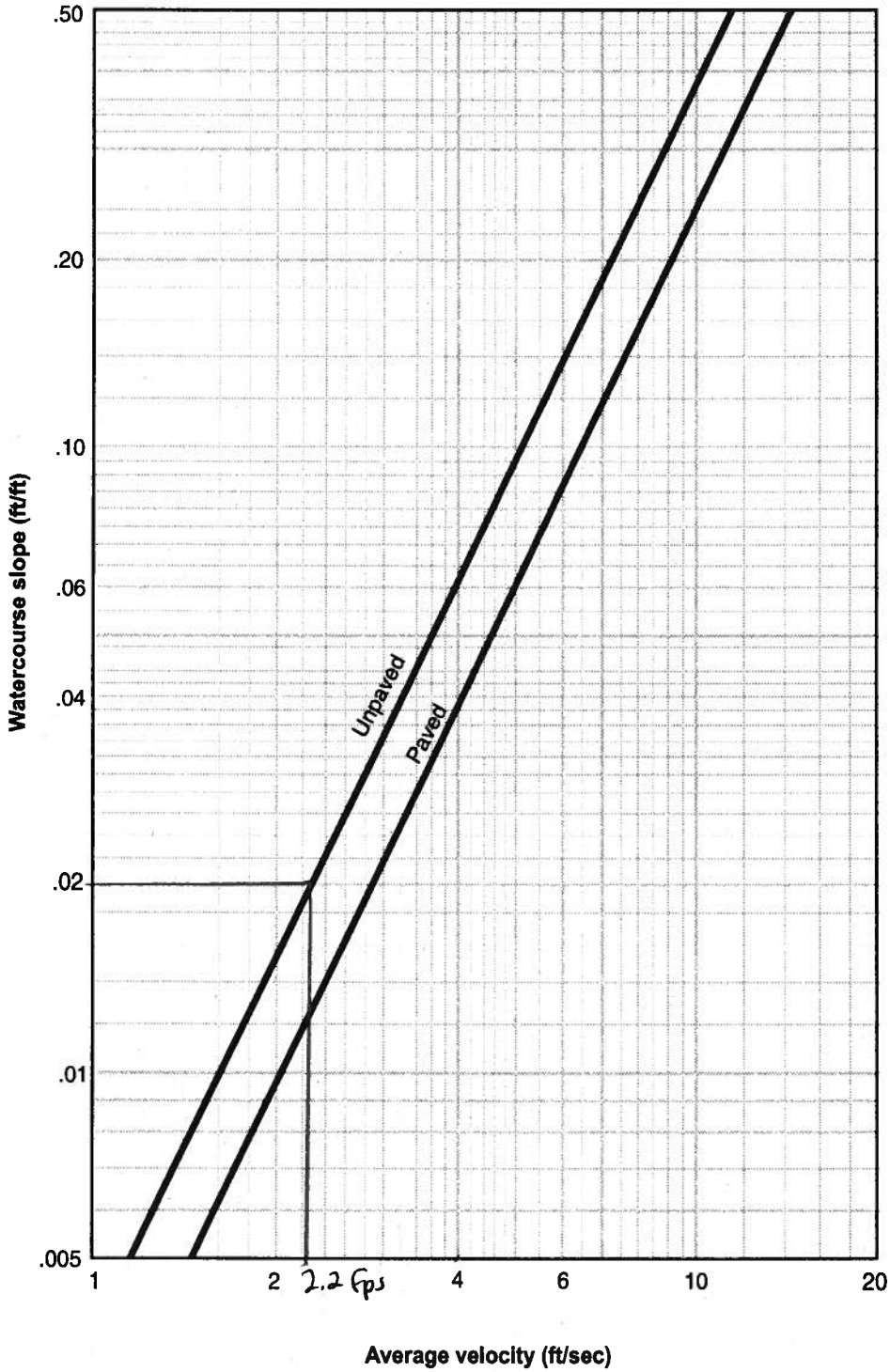


Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution

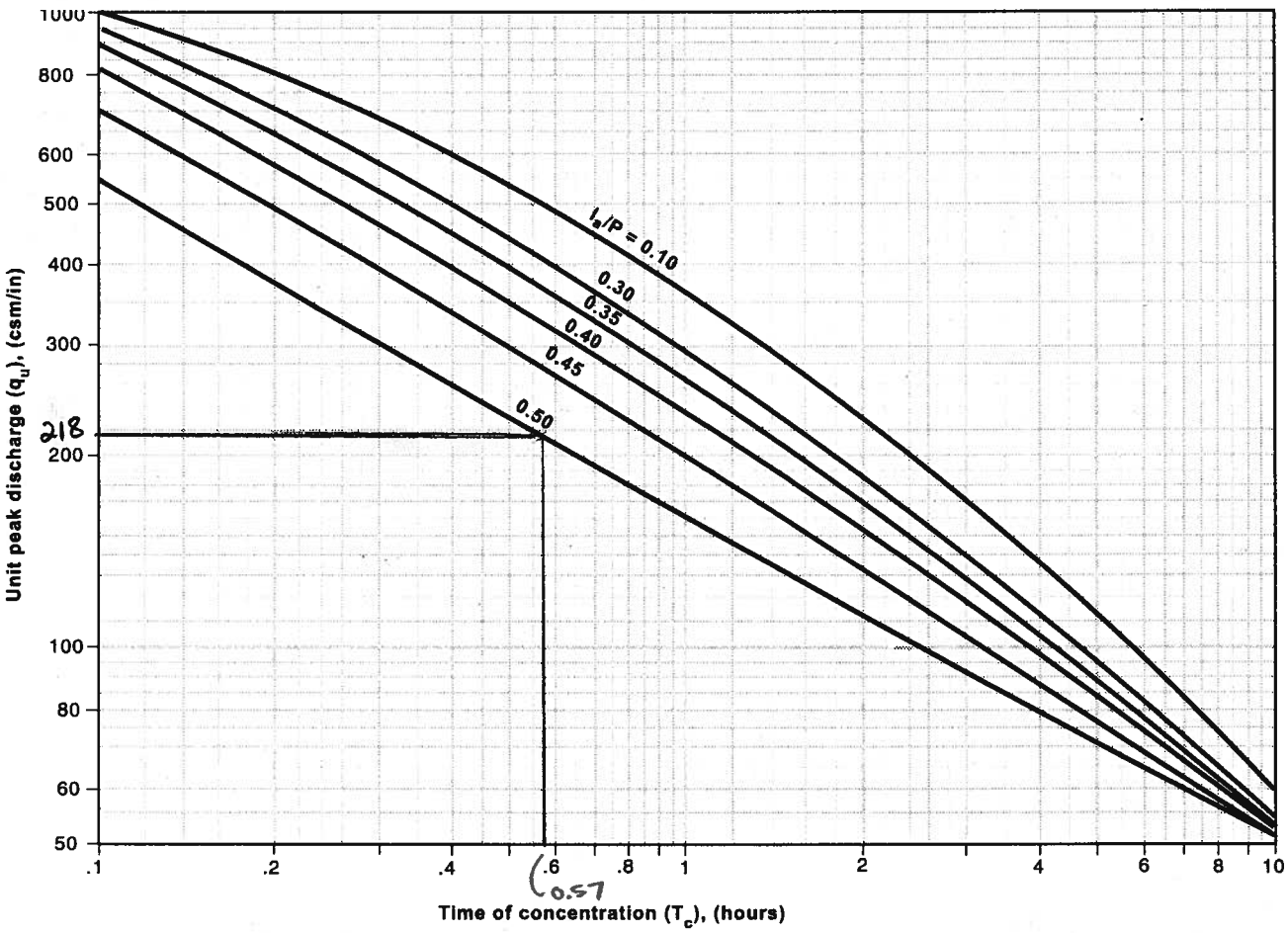
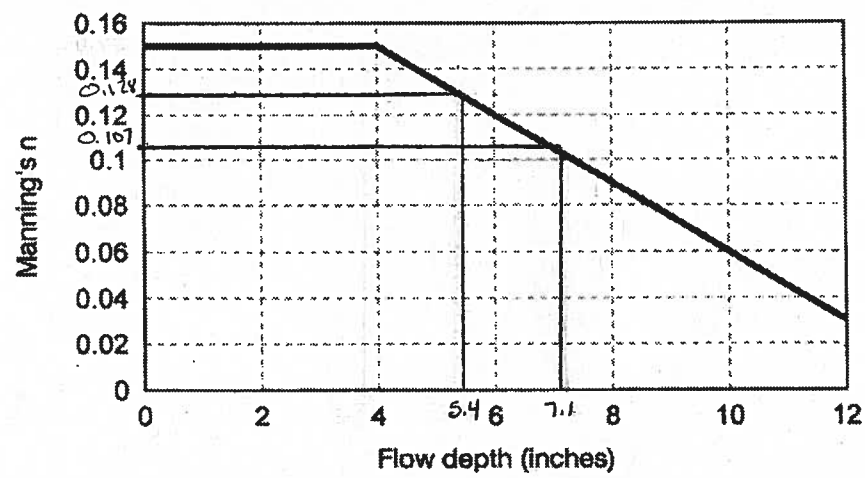


FIGURE 7.5: VARIABLE MANNING'S N WITH VARYING FLOW DEPTH



GRASSED CHANNEL DESIGN PROCEDURE

- Use the 90% Rule to select rainfall for the Water Quality Storm (refer to Chapter 2, Section 2.5)
- Compute the peak rate of discharge (Q_p) for the Water Quality Storm based on the procedures identified in Chapter 2, Section 2.8, Small Storm Hydrology.
- Utilize Q_p to size the channel, maintain design criteria parameters noted in Table 7.2
  - Utilize the design charts (Figures 7.6-7.8) for channel widths 2, 4, and 6 feet, or
  - Utilize computer model which solves Manning's equation, or other open channel flow equations.
- Compute 2 year and 10 year frequency storm event peak discharges using SCS, TR-55.
- Check 2 year velocity for erosive potential (adjust geometry, if necessary and re-evaluate WQV design parameters).
- Check 10 year depth and velocity for capacity (adjust geometry, if necessary and re-evaluate WQV and 2 year design parameters).
- Provide minimum freeboard above 10 year storm water surface elevation (6 inches minimum, recommended).

The design charts provided (Figures 7.6 - 7.8) solve Manning's equation for various slopes and discharges. The charts were adapted from the U.S. Department of Transportation, Federal Highway Administration's, Hydraulic Design Series "Design Charts for Open-Channel Flow," reprinted 1980.

Worksheet for Water Quality Swale (Design)

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01100	ft/ft
Discharge	4.80	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	1.17
0+12	0.00
0+18	0.00
0+19	0.50
0+20	0.50
0+22	0.00
0+28	0.00
0+38	1.17

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 1.17)	(0+38, 1.17)	0.128

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	0.45	ft
Elevation Range	0.00 to 1.17 ft	
Flow Area	8.04	ft²
Wetted Perimeter	23.62	ft
Hydraulic Radius	0.34	ft

Worksheet for Water Quality Swale (Design)

Results

Top Width		23.42	ft
Normal Depth		0.45	ft
Critical Depth		0.16	ft
Critical Slope		0.45817	ft/ft
Velocity		0.60	ft/s
Velocity Head		0.01	ft
Specific Energy		0.46	ft
Froude Number		0.18	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.45	ft
Critical Depth	0.16	ft
Channel Slope	0.01100	ft/ft
Critical Slope	0.45817	ft/ft

Cross Section for Water Quality Swale (Design)

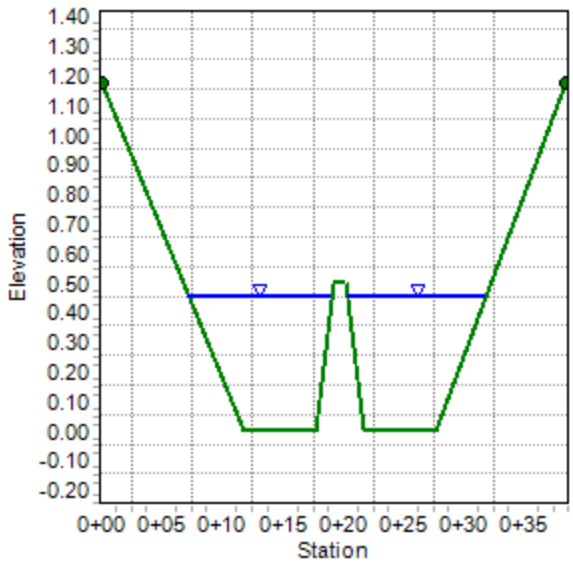
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01100	ft/ft
Normal Depth	0.45	ft
Discharge	4.80	ft³/s

Cross Section Image



Worksheet for Water Quality Swale (10-Year Q)

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.01100	ft/ft
Discharge	9.40	ft³/s

Section Definitions

Station (ft)	Elevation (ft)
0+00	1.17
0+12	0.00
0+18	0.00
0+19	0.50
0+20	0.50
0+22	0.00
0+28	0.00
0+38	1.17

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+00, 1.17)	(0+38, 1.17)	0.107

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	0.59	ft
Elevation Range	0.00 to 1.17 ft	
Flow Area	11.52	ft²
Wetted Perimeter	27.52	ft
Hydraulic Radius	0.42	ft

Worksheet for Water Quality Swale (10-Year Q)

Results

Top Width		27.30	ft
Normal Depth		0.59	ft
Critical Depth		0.24	ft
Critical Slope		0.28613	ft/ft
Velocity		0.82	ft/s
Velocity Head		0.01	ft
Specific Energy		0.60	ft
Froude Number		0.22	
Flow Type	Subcritical		

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.59	ft
Critical Depth	0.24	ft
Channel Slope	0.01100	ft/ft
Critical Slope	0.28613	ft/ft

Cross Section for Water Quality Swale (10-Year Q)

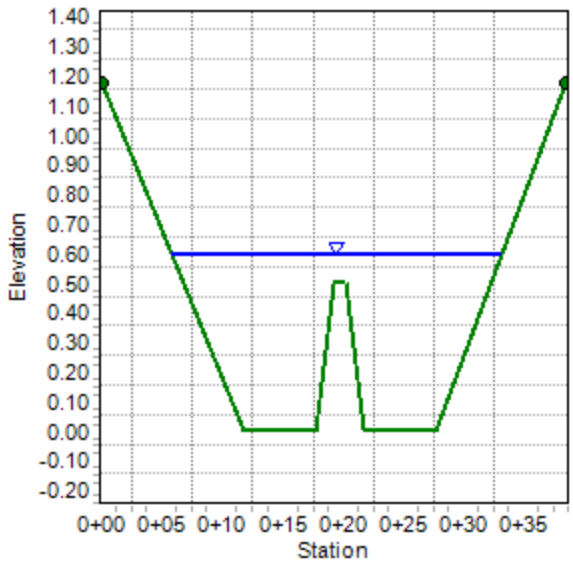
Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

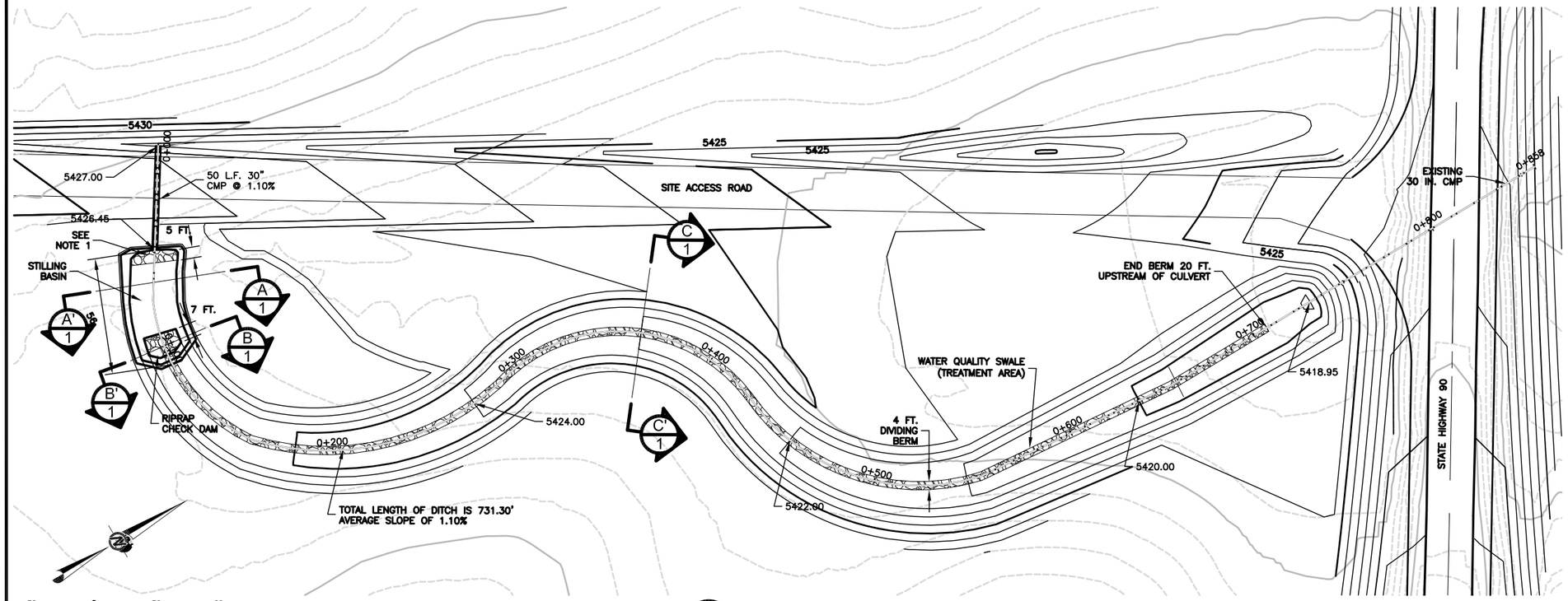
Channel Slope	0.01100	ft/ft
Normal Depth	0.59	ft
Discharge	9.40	ft³/s

Cross Section Image



ATTACHMENT B

WATER QUALITY SWALE DESIGN DRAWINGS



1/1 WATER QUALITY SWALE LAYOUT

SCALE: 1 IN.= 30 FT.

LEGEND

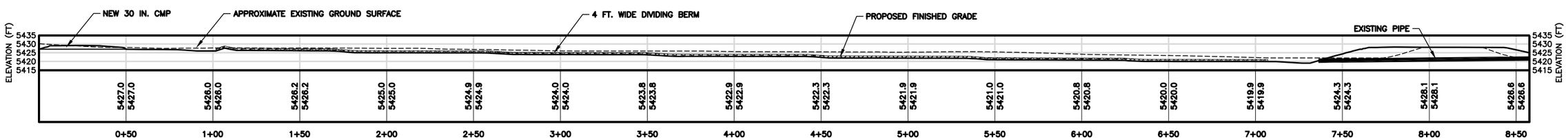
- EXISTING GROUND TOPOGRAPHY (SEE REFERENCE 1)
- PROPOSED FINISHED GRADE TOPOGRAPHY
- CROSS SECTION IDENTIFIER
- SHEET WHERE SECTION IS LOCATED

NOTES

1. DUMPED RIPRAP (D_{50} = 6 IN., THICKNESS = 1 FT.) TO BE PROVIDED AT CULVERT OUTLET.

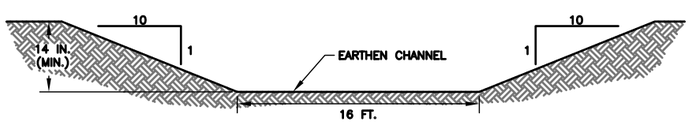
REFERENCES

1. TWO-FOOT CONTOUR BASE MAP PROVIDED BY KLEINFELDER IN JUNE 2008, CREATED FROM DRAWING BY ACCURATE SURVEY & ENGINEERING DATED 9/6/2007.



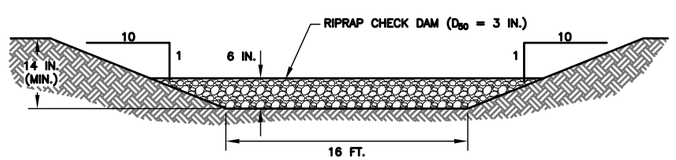
2/1 WATER QUALITY SWALE PROFILE

SCALE: 1 IN.= 30 FT.



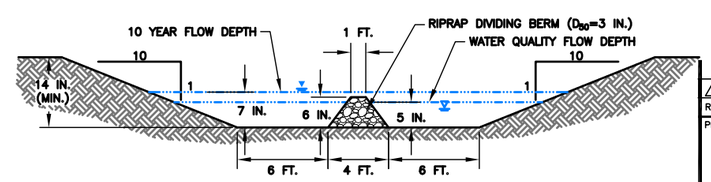
A-A' 1 STILLING BASIN

NTS



B-B' 1 RIPRAP CHECK DAM

NTS



C-C' 1 WATER QUALITY SWALE TREATMENT AREA

NTS

IF THE ABOVE BAR DOES NOT SCALE 1 INCH THE DRAWING SCALE IS ALTERED

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
A	10/8/10	SPS	ISSUED FOR WQS ADDENDUM	AW/MTM	SPS	KFM

PROJECT

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

TITLE

WATER QUALITY SWALE LAYOUT, SECTIONS, AND DETAILS

Golder Associates
DENVER, COLORADO

PROJECT No.	073-81694		FILE No.	07381694A097	
DESIGN	SPS	10/10	SCALE	AS SHOWN	REV. A
CADD	AW/MTM	10/10	DRAWING		
CHECK	SPS	10/10	1		
REVIEW	KFM	10/10			

Plot Time: 10/11/10 16:05

Drawing File: N:\07\073-81694\ 07381694A097.dwg | Layout: 22x34 Landscape | Modified: Oct 08, 2010 13:56 MTMarks | Plotted: 10/11/10 4:05pm MTMarks