ATTACHMENT C

Design Analysis for Erosion Protection Cover for Piñon Ridge Tailing Cells

TAILING CELL CLOSURE DESIGN REPORT
ENERGY FUELS RESOURCE CORPORATION
PIÑON RIDGE PROJECT

Summary

The primary purpose of the tailing cell erosion cover is to protect the tailing cell cover from erosion by runoff of precipitation and by wind. Of these two, runoff presents the greater hazard. As suggested in NUREG-1620 (USNRC, 2003), the tailing cell erosion cover is designed to withstand the Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP). The methods used for determining the PMF, top and side slope cover design, and tailing cell toe protection follow guidelines suggested by the Nuclear Regulatory Commission in NUREG-1623, *Design of Erosion Protection for Long-Term Stabilization* (USNRC, 2002). The following discusses the basic approach, methodology, and key parameters used in the tailing cell cover erosion design. Full calculations (Kleinfelder document DEN8R197, December 9, 2008) are included following this summary.

PMP and PMF Calculations

The PMP was calculated using procedures outlined in Hydrometeorological Report No. 49 (HMR 49). Each tailing cell has an approximate footprint of 0.05 square miles so no areal reduction was applied to the rainfall depth calculation. A 6-hr Local Storm depth was calculated and applied to the appropriate HMR-49 storm distribution. The maximum 1-hour rainfall depth increment for the 6-hr Local Storm distribution was determined to be 7.6 inches.

NOAA Atlas 2 Volume III (Miller et al., 1973) was followed to create an intensity-duration curve for tailing cell drainages shown below in Table 1.

Table 1
Intensity-Duration Values for Piñon Ridge Mill Site, Montrose County, Colorado

Duration (min)[1] =	0	5	10	15	30	60
Intensity (in/hr) =	26.4	26.4	20.5	17.3	12.0	7.6

[11]Miller et al, 1973

The times of concentration for the tailing cell drainages were calculated using Kirpich's method, Equation (1) (Barfield et al., 1981)

$$T_c = 0.0078\left(\frac{L^{0.77}}{S^{0.385}}\right) \qquad (1)$$

where T_c is time of concentration in minutes, L is the maximum length of flow in feet, and S is the slope of the drainage in feet/foot.

The Rational Method (Barfield et al., 1981) was used to calculate the PMF for each drainage on the tailing cell configuration. Based on the magnitude of the design event and anticipated soil and vegetation conditions, a conservative runoff coefficient value of 0.8 was chosen. A flow concentration factor of 3.0 was selected for top and side slope cover designs to account for concentrated sheet flow conditions. The Rational Method is given below in Equation (2)

$$Q = FCiA \tag{2}$$

where Q is the maximum discharge in cubic feet per second (cfs), F is a flow concentration factor (only used for sheet flow conditions), C is a runoff coefficient, i is rainfall intensity in inches/hour, and A is the drainage area in acres.

A unit discharge rate was used in designing the top and side covers while a conventional peak discharge for a given area was calculated for the riprap channel rundowns.

Top and Side Slope Covers

PMF unit discharges were used in the Safety Factor method (Barfield et al., 1981) to determine an appropriate rock size for the tailing cell top cover. The Maximum Permissible Velocity (MPV) method (Chow, 1959) was used to design a stable vegetated soil/rock mulch cover. PMF unit discharges were also used in the Stephenson Method to design a rock cover for the steeper tailing cell outslopes. The Safety Factors method was used for slopes less than 10% while the Stephenson Method was used for slopes of 10% or greater (NUREG-1623, 2002).

The Safety Factors method is given in Equation (3)

$$SF_b = \frac{\cos(\theta)\tan(\varphi)}{\sin(\theta) + \eta_b \tan(\varphi)} \tag{3}$$

$$\eta_b = \frac{\tau}{\tau_c} = \frac{21\tau}{\gamma(SG-1)D_{50}} = \frac{21dS}{(SG-1)D_{50}}$$

where SF_b is the safety factor, θ is the slope angle in degrees, φ is the materials friction angle in degrees, η_b is a stability parameter, τ is applied tractive force in psf, τ_c is the critical tractive force in psf, γ is the specific weight of water in pcf, SG is the specific gravity of the cover material, d is flow depth in feet, S is longitudinal slope in feet/foot, and D_{50} is the representative material size in feet.

A safety factor of 1.0 indicates the moment of incipient motion for a representative cover particle; therefore, a safety factor of 1.1 was used in the design to maintain stable conditions (i.e. no particle movement).

The MPV method was used to design a stable vegetated top cover with an approximate slope of 2%. Assuming a cover composed of a grass mixture, a 2% average slope, and easily erodible soils an MPV of 4.0 fps was chosen from Table 7-6 in Chow's *Open Channel Hydraulics* (Chow, 1959). PMF unit discharges were used with Manning's equation to determine maximum expected flow depths and velocities. In compliance with recommendations outlined in NUREG-1623, a correction factor was applied to the MPV to accurately represent sheet flow conditions and reduced it to 2.0 fps. A low vegetal retardance factor was chosen to represent a fair stand with average grass lengths of two to six inches on the tailing cell covers. A Manning's n value was subsequently computed using Chow's experimental curves. An iterative approach was taken until a maximum expected PMF velocity was determined. If the expected MPV was less than the permissible MPV of 2.0 fps, the design was considered acceptable.

The Stephenson Method was used to design a rock cover for the tailing cell side slopes. The Stephenson Method is given in Equation (4)

$$D_{50} = \left[\frac{q(\tan(\theta))^{7/6} n_p}{C g^{1/2} \left[(1 - n_p)(SG - 1)\cos(\theta)(\tan(\varphi) - \tan(\theta)) \right]^{5/3}} \right]^{2/3} \quad (4)$$

where D_{50} is the representative particle size in feet, q is maximum unit discharge in cfs/ft, θ is the slope angle in degrees, φ is the material friction angle in degrees, n_p is the cover material porosity, C is the Stephenson coefficient, g is the acceleration of gravity in ft/s^2, and SG is the specific gravity of the cover material.

Drainage Features

The overall erosion cover was designed to minimize concentrating flow in channels that require large sizes of riprap. This was done to minimize costs, future maintenance efforts, and to reduce areas of high volume, high velocity flows. However, runoff will unavoidably be concentrated in the grading intersections between Tailing Cells A and B and Cells B and C. Runoff collected in these areas will be directed to riprap lined channels flowing down the groin area between the tailing cells. The channels are designed to route the PMF away from the tailing cells, eventually discharging into natural drainages at the site. Riprap for the rundown channels was designed using experimental curves developed by Bathurst (1979) published in the *Surface Mining Water Diversion*

Design Manual (1982). It is important to note that the areas receiving concentrated flow are constructed over natural fill embankments and not tailings.

Erosion protection at the toe of the tailing cells was designed using the Abt et al. (1998) method, Equation (5)

$$D_{50} = 10.46 \times S^{0.43} \times (C_f \times q_d)^{0.56} \qquad (5)$$

where D_{50} is the representative particle size in feet, S is the longitudinal slope in feet/foot, C_f is the flow concentration factor, and q_d is the maximum unit discharge in cfs/ft.

All rock material used for the erosion cover will meet the criteria for durability outlined in NUREG-1623, Appendix D.

The tailing cell configuration is generally located on northward sloping terrain with several natural drainages (arroyos) directing flow away from the centerline of the cells toward the northwest and northeast ends of the site. The natural drainage network and overall slope of the site help to direct runoff away from the tailing cells, protecting them from long-term erosion. A riprap-lined diversion berm, designed for the PMF, will be constructed south of Tailing Cell A to redirect runoff from the tailing cell area to natural drainages that will eventually flow offsite. The design of the diversion berm will be consistent with the methods used for the riprap rundown channels.

References

Abt, S.R., Johnson, T.L., Thornton, C.I., and Trabant, S.C., 1998, “Riprap Sizing at the Toe of Embankment Slopes.” J. of Hydr. Engr., ASCE, 1998.

Barfield, B. J., R. C. Warner, and C. T. Hahn, 1981, Applied Hydrology and Sedimentology for Disturbed Areas. Oklahoma Technical Press, Stillwater, Oklahoma, 1981.

Bathurst, J.C., R.M. Li, D.B. Simons, 1979, “Hydraulics of Mountain Rivers.” Civil Engineering Department, Colorado State University, CER78-79JCB-RML-DBS55, 1979.

Chow, V.T., 1959, Open Channel Hydraulics. McGraw-Hill Book Company, Inc., New York, NY, 1959.

Hansen, E., Schwartz, F., Riedel, J., 1984, “Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages.” Hydrometeorological Report No. 49, 1984.

Miller, J.F., R.H. Frederick, R.J. Tracey, 1973, "Precipitation-Frequency Atlas of the Western United States," *NOAA Atlas 2 Volume III--Colorado,* National Oceanic and Atmospheric Administration, National Weather Service, U.S. Department of Commerce, Silver Spring, MD, 1973.

U.S. Nuclear Regulatory Commission (USNRC), 2002, “Design of Erosion Protection for Long-Term Stabilization.” NUREG-1623, 2002.

U.S. Nuclear Regulatory Commission (USNRC), 2003, “Standard Review Plan for the Review of a Reclamation Plan for Mill Tailing Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978.” NUREG-1620, Rev. 1, 2003.

U.S. Dept. of the Interior: Office of Surface Mining, 1982, Surface Mining Water Diversion Design Manual, U.S. Government Printing Office, Washington D.C., 1982.

KLEINFELDER
Bright People. Right Solutions.

CALCULATION LOG AND INSTRUCTIONS

Project No.: 89241 **Project Title:** Piñon Ridge Project

Project Manager: Alan Kuhn **Discipline:** Civil

Calculation Number	Calculation Title	Originator	Checker	Verify Design?	Date of Release/ Revision Date	Revision
89241.7-1	Piñon Ridge Mill Site PMP Determination	Travis Kluthe	Bruce Curtis		11/21/08	0
89241.7-2	Veg. Soil Top Cover Rock Mulch Determination	Travis Kluthe	Bruce Curtis		11/21/08	0
89241.7-3	Side Slope Rock Cover Design	Travis Kluthe	Bruce Curtis		11/21/08	0
89241.7-4	Tailing Cell Toe Erosion Protection	Travis Kluthe	Bruce Curtis		11/21/08	0
89241.7-5	Erosion Cover Riprap Rundown Design	Travis Kluthe	Bruce Curtis		11/21/08	0
89241.7-6	Tailing Diversion Berm	Travis Kluthe	Bruce Curtis		12/1/08	0

Instructions:
1. Enter the project number
2. Enter the title of the project
3. Enter the name of the Project Manager
4. Enter the Engineering discipline responsible for the calculation (i.e. Structural)
5. Enter the calculation number
6. Enter the calculation title (i.e. Settlement and Bearing Capacity of Shallow Foundation System)
7. Enter the name of the calculation Originator
8. Enter the name of the calculation Checker
9. Indicate whether the calculation requires design verification
10. Enter the date and revision on which the Checker signed the calculation.

KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 10/17/08 **Page** 1 **of** 5

Project No.: 89241 **Project Title:** Piñon Ridge Project

Calculation No.: 89241.7-1
Calculation Title: PMP Determination

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ___ Printed Name/Signature/Date	Rev. ___ Printed Name/Signature/Date
Originator:	[signature] 10/17/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 11/21/08		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
U2-AB08WP001	Tailing Cell Closure Design Report	0	AK
DEN8R197	Piñon Ridge Closure Drainage Calcs.	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT PMP Determination BY THR DATE 10/17/08
89241.7-1 REVIEWED BY BAC DATE 11/21/08

Objective: Determine PMP depth and 6-hr distribution for Piñon Ridge Mill Site, and develop intensity-duration curve using maximum 1-hr PMP precipitation depth.

Given:

Typical tailing cell drainage area approximately 60 ac.
Minimum elevation approx. 5465 ft. (Ref. 1, Drawing C2)

Assumptions:

1) Point rainfall for individual tailing cell (i.e. no areal reduction) (Ref. 2, Fig. 4.9)

References

1) Kleinfelder, Piñon Ridge Project: Tailing Cell Cover and Site Grading Closure Plans, Dec. 12, 2008.

2) NOAA, National Weather Service. Hydrometeorological Report No. 49, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages. Silver Spring, Md., 1984.

3) NOAA, Atlas 2, Volume III, Precipitation-Frequency Atlas of the Western United States. Silver Spring, Md., 1973.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT PMP Determination BY TAK DATE 10/17/08
REVIEWED BY BAC DATE 11/21/08

Calculation: Use HMR No. 49 calculation sheet (pg. 4) to determine the maximum 1-hr PMP depth for the 6-hr storm.

1-hr PMP depth = 8.1 in (pg. 4 calc)

Determine Intensity-Duration curve using coefficients from Ref. 3, pg. 15, Table 12.

Duration (min)	Intensity Coefficient		Intensity (in/hr)
5	3.48 (8.1 in)	=	28.2
10	2.70 (8.1 in)	=	21.9
15	2.28 (8.1 in)	=	18.5
30	1.58 (8.1 in)	=	12.8
60	1.00 (8.1 in)	=	8.1

 Piñon Ridge Project
PMP Determination
89241.7-1

BAC 11/21/08

11/21/08
4/5

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Piñon Ridge Mill Site Tailing Cell Area 0.09 mi^2 (km^2)
Latitude 38° 15' N Longitude 108° 46' W Minimum Elevation 5465 ft (m)
Lowest tailing cell elevation

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-mi^2 (2.6-km^2) PMP for drainage [fig. 4.5]. 8.3 in. (mm)

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. 97.5 %

   b. Multiply step 1 by step 2a. 8.1 in. (mm)

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.2

	Duration (hr)									
	1/4	1/2	3/4	1	2	3	4	5	6	
4. Durational variation for 6/1-hr ratio of step 3 [table 4.4].	74	89	95	100	110	115	118	119	120	%
5. 1-mi^2 (2.6-km^2) PMP for indicated durations [step 2b X step 4].	6.0	7.2	7.7	8.1	8.9	9.3	9.6	9.6	9.7	in. (mm)
6. Areal reduction [fig. 4.9].	100%									%
7. Areal reduced PMP [steps 5 X 6].	No Change									in. (mm)
8. Incremental PMP [successive subtraction in step 7].				8.1	0.8	0.6	0.3	0.0	0.1	in. (mm)
	6.0	1.2	0.5	0.4 } 15-min. increments						

9. Time sequence of incremental PMP according to:

   Hourly increments [table 4.7]. 0.1 0.6 8.1 0.8 0.3 0.0 in. (mm)

   Four largest 15-min. increments [table 4.8]. 6.0 1.2 0.5 0.4 in. (mm)

NOAA, HMR No. 49, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages. Silver Springs, Md. 1984.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT PMP Determination BY TAK DATE 10/17/08
89241.7-1 REVIEWED BY BAC DATE 11/21/08

Results:

Intensity - Duration curve for Local Storm PMP at Piñon Ridge Mill site given below.

Duration (min)	5	10	15	30	60
Intensity (in/hr)	28.2	21.9	18.5	12.8	8.1

KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 11/13/08 **Page** 1 **of** 10

Project No.: 89241 **Project Title:** Piñon Ridge Project

Calculation No.: 89241.7-2

Calculation Title: Vegetated Rock Mulch Stability Determination

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date
Originator:	[signature] 11/13/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 11/20/08		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
U2ALBOBWP001	Tailing Cell Closure Design Report	0	AK
DEN8R197	Piñon Ridge Closure Drainage Calcs.	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages
1	Tailing Cell Closure Cover Erosion Design Parameters and Equations	2
2	Tailing Cell Cover and Site Grading Drainage Plans, Drawing C2	1

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Vegetated Rock Mulch Stability BY TMK DATE 11/13/08
89241.7-2 REVIEWED BY BAC DATE 11/20/08

Objective: Using suggested design parameters, check long-term erosion stability of vegetated soil Top Cover.

Given: Slope, S = 2% } (Ref. 1, C2)
Length, L = 345 ft }
C = 0.8 → Runoff Coeff. (Ref. 2)
F = 3.0 → Flow concentration factor (Ref. 3, App. A)
SG = 2.65 → Specific Gravity of material (Ref. 4)
FA = 0.72 Rad. → Friction angle of rock material (Ref. 5, p. 96)
1-hr PMP Depth = 8.1 in (Kleinfelder Calc. No. 89241.7-1)

Assumptions: 1) Use Tc increments of 5, 10, 15, 30, and 60 min. (Ref. 9)
2) Closure cover will maintain sparse, 35%, coverage. (Ref. 6)
3) Runoff will be primarily sheet flow, thus a wide, shallow channel configuration will be used in the calculations. (Ref. 1, C2)
4) Increase Manning's 'n' value based on Velocity - Hydraulic Radius product. (Ref. 7)

Calculations: Refer to Attachment 1, pg. 2 for definition of parameters

1) Use Safety Factor (SF) Method for Rock size calculation. (Ref. 7)

$$SF = \frac{\cos(\theta)\tan(\phi)}{\sin(\theta) + \eta_b \tan(\phi)}$$

* This calculation is performed to verify spreadsheet results in Attachment 1, Table 1, Calc No. 1.

2) Use Maximum Permissible Velocity (MPV) Method for vegetated soil stability check (Ref. 8)

* This calculation is performed to verify spreadsheet results in Attachment 1, Table 3, Calc. No. 3.

ENG-07 REV 05/08

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Vegetated Rock Mulch Stability BY TV DATE 11/13/08
89241.7-2 REVIEWED BY BAC DATE 11/20/08

3) Use ~~Ref. 1~~, Sheet C2 to determine length and slope for Tc calculation and unit peak flow using Rational Method.

$$T_c = 0.0078\left(\frac{345\,ft^{0.77}}{0.02\,ft/ft^{0.385}}\right) = 3.2\,min$$

*Use 5 min. minimum.

L = 345 ft
S = 0.02 ft/ft

A Tc of 3.2 min corresponds to an i of 28.2 in/hr from Kleinfelder Calc. No. 89241.7-7.

$$q = \frac{(3.0)(0.8)(28.2\,in/hr)(345\,ft)}{43{,}560\,ft^2/ac} = 0.5\,cfs/ft$$

(Ref. 3)

F = 3.0
C = 0.8
i = 28.2 in/hr
L = 345 ft

Determine flow depth using Manning's equation for a wide channel.

$$d = \left[\frac{nq}{1.49\sqrt{S}}\right]^{3/5}$$

(Ref. 8)

Increased for sheet flow conditions.
n = 0.045 (Ref. 8)
q = 0.5 cfs/ft
S = 0.02 ft/ft

$$d = \left[\frac{(0.045)(0.5\,cfs/ft)}{1.49\sqrt{0.02}}\right]^{3/5} = 0.3\,ft$$

Determine tractive force:

(Ref. 7)

$$\tau = \gamma d S$$

$$\tau = (62.4\,lb/ft^3)(0.3\,ft)(0.02\,ft/ft) = 0.37\,lb/ft^2$$

γ = 62.4 lb/ft³
d = 0.3 ft
S = 0.02 ft/ft

Calculate critical tractive force, τ_c, assuming D50 of 1.1 in.

$$\tau_c = 0.047\gamma(SG-1)D_{50} = (0.047)(62.4\,lb/ft^3)(2.65-1)(1.1\,in/12) = 0.40\,lb/ft^2$$

(Ref. 7)

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Vegetated Rock Mulch Stability BY TAK DATE 11/13/08
89241.7-2 REVIEWED BY BAC DATE 11/20/08

Calculate stability parameter, η_b; (Ref. 7)

$$\eta_b = \frac{\tau}{\tau_c} = \frac{0.37\,lb/ft^2}{0.40\,lb/ft^2} = 0.93$$

Calculate Safety Factor (SF) assuming angular rock with an angle of repose of 41° (Ref. 5)

$$SF = \frac{\cos(\theta)\tan(\phi)}{\sin(\theta) + \eta_b \tan(\phi)}$$

$\theta = 0.02$ rad.
$\phi = 0.72$ rad
$\eta_b = 0.93$

$$SF = \frac{\cos(0.02)\tan(0.72)}{\sin(0.02) + 0.93\tan(0.72)} = 1.1$$

SF = 1.1 > 1.0, therefore design is acceptable

4) Use $q = 0.5$ cfs/ft, $S = 0.02$ ft/ft, and $d = 0.3$ ft in MPV method to determine long-term stability of vegetated soil cover alone.

Determine PMF velocity for wide channel

$$V = \frac{q}{d} = \frac{0.5\,cfs/ft}{0.3\,ft} = 1.7\,ft/s$$

Select MPV from Ref. 8, assuming a 2% slope and easily erodible soils.

MPV = 4.0 ft/s

Adjust MPV to account for higher average velocities in shallow flow (Ref. 3)

d = 0.3 ft ∴ Reduction Factor = 0.5 (Ref. 3)

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Vegetated Rock Mulch Stability 89241.7-2 BY TAK DATE 11/13/08
REVIEWED BY BAC DATE 11/20/08

$MPV_{RF} = 0.5 MPV = (4.0 ft/s)(0.5) = 2.0 ft/s$

Actual velocity (1.7 ft/s) < MPV_{RF} (2.0 ft/s), therefore design is stable and acceptable.

Results:

See Attachment 1, Table 1 for Results.

References:

1) Kleinfelder, Piñon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans, Dec. 12, 2008.
2) Chow, V.T., Maidment, D., Mays, L. Applied Hydrology, McGraw-Hill. 1988
3) U.S. Nuclear Regulatory Commission, NUREG-1623: Design of Erosion Protection for Long-Term Stabilization, August 2002.
4) Kleinfelder Calculation No. 89241.7. September 2008, Piñon Ridge Closure Cover Geotechnical and Hydrologic Properties. Rev. 0, Energy Fuels Resource Corporation Piñon Ridge Uranium Mill Project.
5) Bureau of Reclamation, Design of Small Dams, Water Resources Technical Publication, 1960.
6) Kleinfelder Memorandum, Review of Soil and Vegetation Parameters for Piñon Ridge Closure Cap, Energy Fuels Resource Corporation Piñon Ridge Uranium Mill Project, September 24, 2008.
7) Barfield, et al., Applied Hydrology and Sedimentology for Disturbed Areas, 1981.
8) Chow, V.T., Open Channel Hydraulics, McGraw Hill, 1959.
9) NOAA Atlas 2, Vol. III, Precipitation Frequency Atlas for Western United States. Silver Spring, Md. 1973.

Piñon Ridge Project
Vegetated Rock Mulch Stability

 89241.7-2

6/10
1/13/08

~~The runoff coefficient is also dependent on the character and condition of the soil. The infiltration rate decreases as rainfall continues, and is also influenced by the antecedent moisture condition of the soil. Other factors influencing the runoff coefficient are rainfall intensity, proximity of the water table, degree of soil compaction, porosity of the subsoil, vegetation, ground slope, and depression storage. A reasonable coefficient must be chosen to represent the integrated effects of all these factors. Suggested coefficients for various surface types as used in Austin, Texas are given in Table 15.1.1.~~

TABLE 15.1.1
Runoff coefficients for use in the rational method

Character of surface	Return Period (years) 2	5	10	25	50	100	500
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

PMP

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

Chow, V.T., Maidment, D., Mays, L., Applied Hydrology, 1988

Piñon Ridge Project
Vegetated Rock Mulch Stability
89241.7-2

7/10
11/13/08

Step 6. Solve for stable slope, using the Horton/NRC equation. If the computed slope is different from that assumed, return to Step 2 with new values of slope and/or slope length.

2.2.2 Vegetated Soil Cover

Step 1. Maximum permissible velocities (MPVs) should be estimated using data developed by the U.S. Soil Conservation Service (SCS, 1984); or by Nelson et al., 1986). Based on these data, maximum MPVs should generally range from about 2½ to 3½ ft per second for any vegetation other than dense grasses. These velocities need to be further reduced, as discussed in Step 6.

Step 2. Determine slope and slope length.

Step 3. Determine flow concentration (F). See Step 3 in Section 2.2.1, above for additional information.

Step 4. Estimate Manning's "n" value using procedures recommended by Chow (1959, Table 7.6) for very low vegetal retardance (Fig. 7.14).

Step 5. Determine rainfall intensity and runoff rate using procedures discussed in Step 5 in Section 2.2.1.

Step 6. Determine the flow depth (y) by solving the Manning Equation for normal depth on a one-foot-wide strip. This equation can be solved directly in this case using the following derivation:

$$y^{5/3} = Qn / (1.486\ S^{1/2}). \quad \text{(A-3)}$$

Step 7. Determine the permissible velocity for the slope, based on the computed depth of flow. Chow has developed correction factors that may be applied to determine the permissible velocity. The permissible velocity is multiplied by the following correction factors, depending on the depth of flow.

Depth of Flow (ft)	Correction Factor
3.0 or greater	1.0
1.9	0.9
1.0	0.8
0.65	0.7
0.4	0.6
0.25 or less	0.5

Step 8. ~~For the assumed one-foot-wide strip, determine the actual flow velocity (V_a) by dividing the discharge by the flow depth:~~

Design of Erosion Protection for Long-Term Stabilization: NUREG-1623, NRC, 2002.

Piñon Ridge Project
Vegetated Rock Mulch Stability
89241.7-2

8/10
11/13/08

Table 5-1.—Average engineering properties of compacted soils. From the Western United States. Last updated October 6, 1982.

GP appropriate for soil/rock matrix cover

USCS soil type	Specific gravity: No. 4 minus	Specific gravity: No. 4 plus	Compaction, Laboratory: Maximum unit weight, lb/ft³	Compaction, Laboratory: Optimum moisture content, %	Compaction, Index unit weight: Max., lb/ft³	Compaction, Index unit weight: Min., lb/ft³	Shear strength, Avg. placement: Unit weight, lb/ft³	Shear strength, Avg. placement: Moisture content, %	Shear strength, Effective stress: c′ lb/in²	Shear strength, Effective stress: ϕ′, degrees	Values listed
	2.69	2.58	124.2	11.4	133.6	108.8	—	—	—	—	Average of all values
	0.02	0.08	3.2	1.2	10.4	10.2	—	—	—	—	Standard deviation
GW	2.65	2.39	119.1	9.9	113.0	88.5	—	—	—	—	Minimum value
	2.75	2.67	127.5	13.3	145.6	132.9	—	—	—	—	Maximum value
	16	9	5		16				0		Total number of tests
	2.68	2.57	121.7	11.2	137.2	112.5	127.5	6.5	5.9	41.4	Average of all values
	0.03	0.07	5.9	2.2	6.3	8.3	7.2	1.2	—	2.5	Standard deviation
GP	2.61	2.42	104.9	9.1	118.3	85.9	117.4	5.3	5.9	38.0	Minimum value
	2.76	2.65	127.7	17.7	148.8	123.7	133.9	8.0	5.9	43.7	Maximum value
	35	12	15		34				3		Total number of tests
	2.73	2.43	113.3	15.8	132.0	108.0	126.9	10.3	13.4	34.0	Average of all values
	0.07	0.18	11.5	5.8	3.1	0.2	0.9	1.2	3.7	2.6	Standard deviation
GM	2.65	2.19	87.0	5.8	128.9	107.8	125.0	9.1	9.7	31.4	Minimum value
	2.92	2.92	133.0	29.5	135.1	108.1	126.9	11.5	17.0	36.5	Maximum value
	34	17	36		2				2		Total number of tests
	2.73	2.57	116.6	13.9	—	—	111.1	15.9	10.2	27.5	Average of all values
	0.08	0.21	7.8	3.8	—	—	10.4	1.6	1.5	7.2	Standard deviation
GC	2.67	2.38	96.0	6.0	—	—	96.8	11.2	5.0	17.7	Minimum value
	3.11	2.94	129.0	23.6	—	—	120.9	22.2	16.0	35.0	Maximum value
	34	6	37		0				3		Total number of tests
	2.67	2.57	126.1	9.1	125.0	99.5	—	—	—	—	Average of all values
	0.03	0.03	6.0	1.7	6.0	7.1	—	—	—	—	Standard deviation
SW	2.61	2.51	118.1	7.4	116.7	87.4	—	—	—	—	Minimum value
	2.72	2.59	135.0	11.2	137.8	109.8	—	—	—	—	Maximum value
	13	2	1		12				0		Total number of tests
	2.65	2.62	115.6	10.8	115.1	93.4	103.4	5.4	5.5	37.4	Average of all values
	0.03	0.10	9.7	2.0	7.2	8.8	14.6	—	3.0	2.0	Standard deviation
SP	2.60	2.52	106.5	7.8	105.9	78.2	88.8	5.4	2.5	35.4	Minimum value
	2.77	2.75	134.8	13.4	137.3	122.4	118.1	5.4	8.4	39.4	Maximum value
	36	3	7		39				2		Total number of tests
	2.68	2.18	116.6	12.5	110.1	84.9	112.0	12.7	6.6	33.6	Average of all values
	0.06	0.11	8.9	3.4	8.7	7.9	11.1	5.4	5.6	5.7	Standard deviation
SM	2.51	2.24	92.9	6.8	88.5	61.6	91.1	1.6	0.2	23.3	Minimum value
	3.11	2.63	132.6	25.5	122.9	97.1	132.5	25.0	21.2	45.0	Maximum value
	149	9	123		21				17		Total number of tests
	2.69	2.17	118.9	12.4	—	—	115.6	14.2	5.0	33.9	Average of all values
	0.04	0.18	5.9	2.3	—	—	14.1	5.7	2.5	2.9	Standard deviation
SC	2.56	2.17	104.3	6.7	—	—	91.1	7.5	0.7	28.4	Minimum value
	2.81	2.59	131.7	18.2	—	—	131.8	22.7	8.5	38.3	Maximum value
	88	4	73		0				10		Total number of tests
	2.69	—	103.3	19.7	—	—	98.9	22.1	3.6	34.0	Average of all values
	0.09	—	10.4	5.7	—	—	11.5	6.9	4.3	3.1	Standard deviation
ML	2.52	—	81.6	10.6	—	—	80.7	11.1	0.1	25.2	Minimum value
	3.10	—	126.0	34.6	—	—	119.3	40.3	11.9	37.7	Maximum value
	65	0	39		0				14		Total number of tests
	2.71	2.59	109.3	16.7	—	—	106.5	17.7	10.3	25.1	Average of all values
	0.05	0.13	5.5	2.9	—	—	7.8	5.1	7.6	7.0	Standard deviation
CL	2.56	2.42	90.0	6.4	—	—	85.6	11.6	0.9	8.0	Minimum value
	2.87	2.75	121.4	29.2	—	—	118.7	35.0	23.8	33.8	Maximum value
	270	3	221		0				31		Total number of tests
	2.79	—	85.1	33.6	—	—	—	—	—	—	Average of all values
	0.25	—	2.3	1.6	—	—	—	—	—	—	Standard deviation
MH	2.47	—	82.9	31.5	—	—	—	—	—	—	Minimum value
	3.50	—	89.0	35.5	—	—	—	—	—	—	Maximum value
	10	0	5		0				0		Total number of tests

Piñon Ridge Project
Vegetated Rock Mulch Stability
89241.7-2

9/10
11/13/08

establishment, the grass will grow and the channel will be stabilized under a condition of low degree of retardance. The channel will not reach its maximum capacity until the grass cover is fully developed and well established. Therefore, it is suggested that the hydraulic design of a grassed channel consist of two stages. The first stage (*A*) is to design the channel for stability, that is, to determine the channel dimensions under the condition of a *lower* degree of retardance. The second stage

TABLE 7-6. PERMISSIBLE VELOCITIES FOR CHANNELS LINED WITH GRASS*

Cover	Slope range, %	Permissible velocity, fps	
		Erosion-resistant soils	Easily eroded soils
Bermuda grass	0–5	8	6
	5–10	7	5
	>10	6	4
Buffalo grass, Kentucky bluegrass, smooth brome, blue grama	0–5	7	5
	5–10	6	4
	>10	5	3
Grass mixture	0–5	5	4
	5–10	4	3
	Do not use on slopes steeper than 10%		
Lespedeza sericea, weeping love grass, ischaemum (yellow bluestem), kudzu, alfalfa, crabgrass	0–5	3.5	2.5
	Do not use on slopes steeper than 5%, except for side slopes in a combination channel		
Annuals—used on mild slopes or as temporary protection until permanent covers are established, common lespedeza, Sudan grass	0–5	3.5	2.5
	Use on slopes steeper than 5% is not recommended		

REMARKS. The values apply to average, uniform stands of each type of cover. Use velocities exceeding 5 fps only where good covers and proper maintenance can be obtained.

* U.S. Soil Conservation Service [41].

(*B*) is to review the design for maximum capacity, that is, to determine the increase in depth of flow necessary to maintain a maximum capacity under the condition of a *higher* degree of retardance. For instance, if common lespedeza is selected as the grass for lining, the common lespedeza of low vegetal retardance (green, average length 4.5 in.) is used for the first stage in design. Then, in the second stage, the common lespedeza of moderate vegetal retardance (green, uncut, average length 11 in.) should be used. Finally, a proper freeboard is added to the computed

Open Channel Hydraulics, Chow, 1959

Pixon Ridge Project
Vegetated Rock Mulch Stability
89241.7-2

10/10
11/13/08

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

Chow, V.T., Open Channel Hydraulics, McGraw Hill, 1959.

Attachment 1
11/13/2008
Piñon Ridge Project
Tailing Cell Closure Cover Erosion Design Parameters and Equations

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Table 1 Vegetated Soil Top Cover Rock Mulch (Safety Factor Method)

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	SG	SA	FA	τ	τ_c	η_b	SF_b	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	--	(rad)	(rad)	(psf)	(psf)	--	--	(in)
1	Rock Mulch (All Soil Top Cover Areas)	345	1	0.02	0.045	3.2	28.2	0.8	3.0	0.5	0.3	2.65	0.02	0.72	0.37	0.40	0.93	1.1	1.0

Table 2 Side Slope Toe Protection Rock Cover (Abt et al. Method)

Calc. No.	Drainage Section	Length	Width	Slope	Tc	i	C	F	q	D_{50}
		(ft)	(ft)	(ft/ft)	(min)	(in/hr)			(cfs/ft)	(in)
2.0	Side Slope Toe Protection (Tailing Cell C)	713	1	0.10	3.9	28.2	0.8	3.0	1.1	7.6
2.1	Side Slope Toe Protection (Tailing Cell B)	609	1	0.10	3.8	28.2	0.8	3.0	0.9	6.8
2.2	Side Slope Toe Protection (Tailing Cell A)	559	1	0.10	3.5	28.2	0.8	3.0	0.9	6.8

Table 3 Vegetated Soil Top Cover (Maximum Permissible Velocity Method)

Calc. No.	Drainage Section	Length	Slope	Tc	C	i	F	q	d	V	n	MPV	MPV_{RF}
		(ft)	(ft/ft)	(min)	--	(in/hr)	--	(cfs/ft)	(ft)	(fps)	--	(fps)	(fps)
3	Vegetated Soil Slope (All Soil Top Cover Areas)	345	0.02	3.2	0.8	28.2	3.0	0.5	0.3	1.7	0.045	4.0	2.0

Flow Reduction Factor

d	RF
(ft)	
0.00	0.5
0.25	0.5
0.40	0.6
0.65	0.7
1.00	0.8

Table 4 Side Slope Rock Cover (Stephenson Method)

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	V	C_s	n_p	SG	SA	FA	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	(fps)	--	--	--	(rad)	(rad)	(in)
4	Rock Cover A1	103	1	0.10	0.05	3.8	28.2	0.8	3.0	0.7	0.2	3.3	0.22	0.39	2.65	0.10	0.72	1.6
5	Rock Cover A2	203	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
6	Rock Cover A3	60	1	0.10	0.05	3.6	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
7	Rock Cover A4	214	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
8	Rock Cover B1	117	1	0.10	0.05	3.9	28.2	0.8	3.0	0.7	0.2	3.2	0.22	0.39	2.65	0.10	0.72	1.6
9	Rock Cover B2	217	1	0.10	0.05	4.4	28.2	0.8	3.0	0.8	0.2	3.7	0.22	0.39	2.65	0.10	0.72	1.8
10	Rock Cover B3	31	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
11	Rock Cover B4	264	1	0.10	0.05	4.6	28.2	0.8	3.0	0.9	0.3	3.6	0.22	0.39	2.65	0.10	0.72	1.9
12	Rock Cover C1	356	1	0.10	0.05	4.9	28.2	0.8	3.0	1.1	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
13	Rock Cover C2	350	1	0.10	0.05	4.9	28.2	0.8	3.0	1.0	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
14	Rock Cover C3	32	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
15	Rock Cover C4	368	1	0.10	0.05	5.0	28.2	0.8	3.0	1.1	0.3	4.0	0.22	0.39	2.65	0.10	0.72	2.2

Table 5 Intersection Channel Riprap (Mining Water Diversion Manual Experimental Curves)

Calc. No.	Drainage Section	Length	Area	Slope	Tc	i	C	F	Q
		(ft)	(ac)	(ft/ft)	(min)	(in/hr)	--	--	(cfs)
16	Cell A and B Intersection Rundown	1478	29.46	0.01	11.1	21.9	0.8	1.0	258
17	Cell B and C Intersection Rundown	1560	30.29	0.01	11.6	21.9	0.8	1.0	265

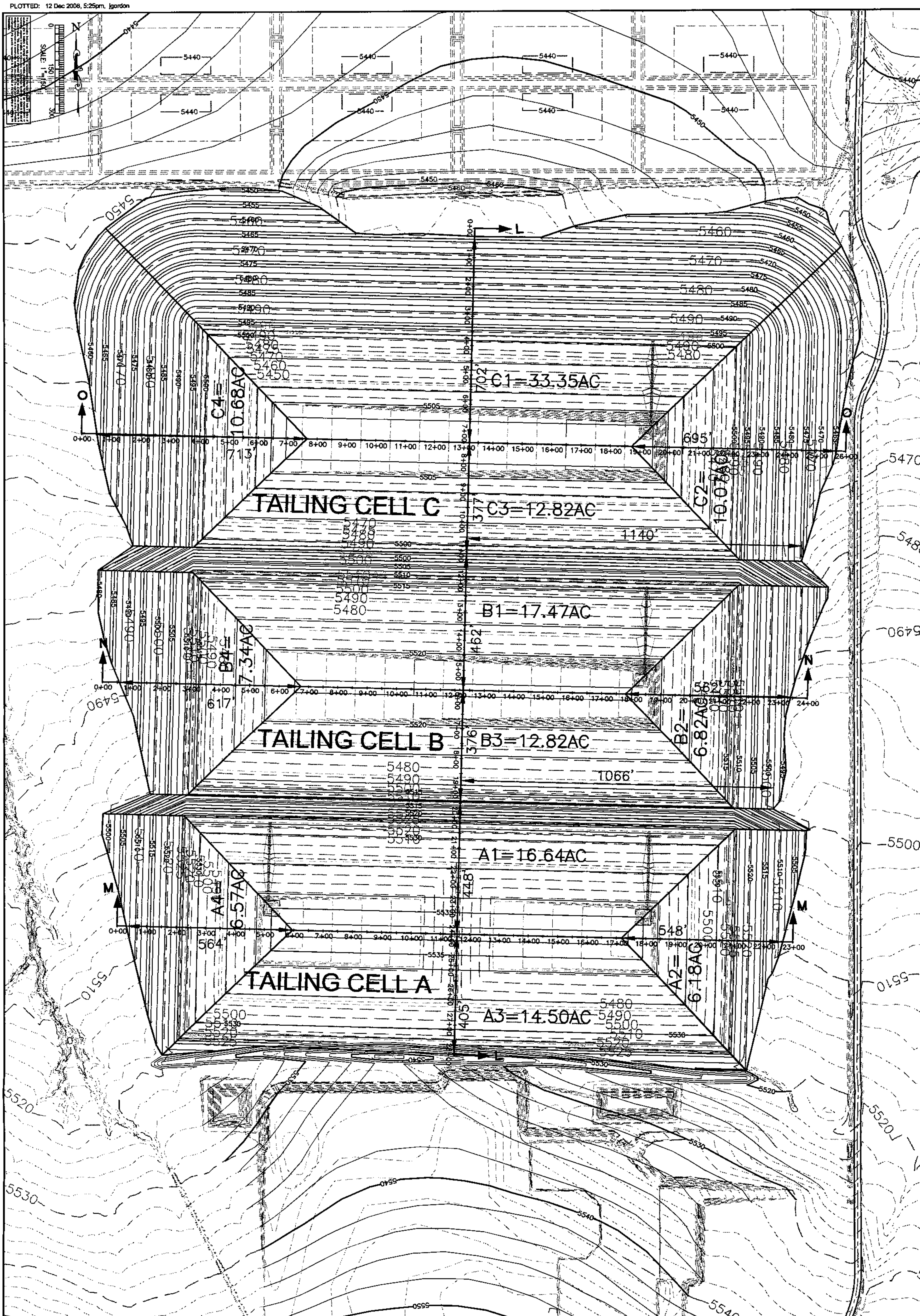
Drainage Sections correspond to Drawing C2 in "Kleinfelder, Pinon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans. December 12th, 2008."
Safety Factor Method used on slopes less than 10%
Stephenson Method used on slopes 10% and greater
Abt et al. Method used for embankment toe riprap sizing

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Symbol/Term	Definition
Length, L	Length of longest flow path in catchments
Width, W	Unit width of flow control section
Slope, S	Slope of local flow path
S_{EFF}	Effective Slope
n	Manning's roughness
Tc	Time of concentration
i	Rainfall intensity
C	Runoff coefficient
F	Flow concentration factor
q	Unit flow rate
Q	Flow rate
d	Flow depth
V	Flow velocity
SG	Specific gravity of rock material
SA	Slope angle
FA	Friction angle of rock material
C_s	Stephenson factor
n_p	Cover material porosity
τ	Actual tractive force
τ_c	Critical tractive force
η_b	Stability parameter
SF_b	Safety factor
D_{50}	Particle size such that 50% of material by weight is smaller
RF	Reduction Factor
MPV	Maximum Permissible Velocity
MPV_{RF}	Reduced Maximum Permissible Velocity
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
HMR	Hydrometeorological Report

Attachment 2
12/12/08
Piñon Ridge Project
Tailing Cells Closure Grading Plan, Drawing C2

PLOTTED: 12 Dec 2008, 5:25pm, jgordon



TAILING CELLS CLOSURE GRADING PLAN

PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

Energy Fuels Resources
44 Union Blvd., Suite 600
Lakewood, CO 80228
PH. 303.974.2140

PRELIMINARY NOT FOR CONSTRUCTION

KLEINFELDER
Bright People. Right Solutions.
611 Corporate Circle, Ste. C
Golden, Colorado 80401
PH. 303.237.6601 FAX. 303.237.6602
www.kleinfelder.com

PROJ. NO.	89241
ACAD FILE:	12027_Closure Sheets.dwg
DESIGNED BY:	JAG
DRAWN BY:	JAG
CHECKED BY:	TAK
DATE:	12/12/08
SCALE:	NO SCALE

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
0 0.5 1.0 1.5 2.0

DRAWING
C2
1 of 7 sheets

KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 11/13/08 Page 1 of 7

Project No.: 89241 Project Title: Piñon Ridge Project

Calculation No.: 89241.7-3

Calculation Title: Side Slope Rock Cover Design

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ___ Printed Name/Signature/Date	Rev. ___ Printed Name/Signature/Date
Originator:	[signature] 11/13/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 11/21/08		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
U2ALB08WP001	Tailing Cell Closure Design Report	0	AK
DEN8R197	Piñon Ridge Closure Drainage Calcs.	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages
1	Tailing Cell Closure Cover Erosion Design Parameters and Equations	2
2	Tailing Cell Cover and Site Grading Drainage Plans, Drawing C2	1

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241.
SUBJECT Side Slope Rock Cover BY TAK DATE 11/13/08
89241.7-3 REVIEWED BY BAC DATE 11/20/08

Objective: Determine d_{50} of rock size necessary to protect tailing cell outslopes from PMF events.

Given: Slope = 10H:1V
Length = 713 ft (Ref. 1, C2)

$C = 0.8$ → Runoff Coefficient (Ref. 4)
$F = 3.0$ → Flow Concentration Factor (Ref. 5)
$C_s = 0.22$ → Stephenson Factor (Ref. 6)

$SG = 2.65$ → Specific Gravity of Rock Material (Ref. 2)
$FA = 0.72$ Rad → Friction Angle of Rock Material (Ref. 7)
1-hr PMP = 8.1 in → (Kleinfelder Calc No. 89241.7-2)

Assumptions:

1) $n_p = 0.39$ → Rock Cover Porosity (Ref. 2)
2) Use T_c increments of 5, 10, 15, 30, and 60 min. (Ref. 8)

Calculations: * Refer to Attachment 1, pg. 2 for definition of parameters.
Use Calc. No. 15, Attachment 1, to verify spreadsheet calculations.

Use Kirpich equation to determine T_c, lengths and areas taken from Ref. 1, C2.

$$T_c = 0.0078\left(\frac{713\,ft^{0.77}}{0.10\,ft/ft^{0.385}}\right) = 3.0\,min \qquad L = 713\,ft \quad S = 0.10\,ft/ft$$
(Ref. 3)

Total T_c includes runoff from 2% veg. soil slope;
(Calc No. 89241.7-2)

Use 5 min T_c.

A T_c of 5.0 min corresponds to an i of 28.2 in/hr from Kleinfelder Calc. No. 89241.7-2.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Side Slope Rock Cover BY TK DATE 11/13/08
89241.7-3 REVIEWED BY BAC DATE 11/20/08

Determine unit peak flow using Rational Method:

$q = FCiA$

$$q = \frac{(3.0)(0.8)(28.2 in/hr)(713 ft)}{43{,}560} = 1.1 \, cfs/ft$$

$F = 3.0$
$C = 0.8$
$i = 28.2 \, in/hr$
$L = 713 \, ft$

Total q includes runoff from Veg. soil slope:
(Calc. No 89241.7-2)

Determine D_{50} of rock cover using Stephenson Equation:

$$D_{50} = \left[\frac{q(\tan(\theta))^{7/6} n_p^{1/6}}{C_g^{1/2}\left[(1-n_p)(SG-1)\cos(\theta)(\tan(\phi)-\tan(\theta))\right]^{5/3}}\right]^{2/3}$$

(Ref. 6)

$q = 1.1 \, cfs/ft$
$\theta = 0.10$ rad
$\phi = 0.72$ rad
$n_p = 0.35$
$SG = 2.65$
$g = 32.2 \, ft/s^2$
$C_g = 0.22$
$D_{50} \Rightarrow$ Particle size in ft

$$D_{50} = \left[\frac{(1.1 cfs/ft)(\tan(0.10))^{7/6}(0.35)^{1/6}}{(0.22)(32.2 ft/s^2)^{1/2}\left[(1-0.39)(2.65-1)\cos(0.10)(\tan(0.72)-\tan(0.10))\right]^{5/3}}\right]^{2/3} = 0.18 \, ft$$

$D_{50} = 0.18 \, ft \, (12 \, in/ft) = 2.2 \, in.$

Results:

See Attachment 1, Table 4, for complete Results.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Side Slope Rock Cover BY TAK DATE 11/13/08
89241.7-3 REVIEWED BY BAC DATE 11/21/08

References:

1) Kleinfelder, Piñon Ridge Project; Tailing Cell Cover and Site Grading Drainage Plans, Dec. 12, 2008.

2) Kleinfelder Calculation No. 89241.7. September 2008, Piñon Ridge Closure Cover Geotechnical and Hydrologic Properties. Rev. 0, Energy Fuels Resource Corporation Piñon Ridge Uranium Mill Project.

3) Barfield, et al. Applied Hydrology and Sedimentology for Disturbed Areas. 1981.

4) Chow, V.T., Maidment, D., Mays, L. Applied Hydrology. McGraw-Hill, 1988.

5) U.S. Nuclear Regulatory Commission, NUREG-1623: Design of Erosion Protection for Long-Term Stabilization, August 2002.

6) Tailings and Mine Waste 1998: Proceedings of 5th International Conference. Colorado State University. 1998.

7) U.S. Bureau of Reclamation, Design of Small Dams, Water Resources Publication. 1960.

8) NOAA Atlas 2, Vol. III, Precipitation Frequency Atlas for Western United States. Silver Spring, Md. 1973.

~~soil.~~ The infiltration rate decreases as rainfall continues, and is also influenced by the antecedent moisture condition of the soil. Other factors influencing the runoff coefficient are rainfall intensity, proximity of the water table, degree of soil compaction, porosity of the subsoil, vegetation, ground slope, and depression storage. A reasonable coefficient must be chosen to represent the integrated effects of all these factors. Suggested coefficients for various surface types as used in Austin, Texas are given in Table 15.1.1.

Piñon Ridge Project
Side Slope Rock Cover
8941.7-3

5|7
11/13/08

TABLE 15.1.1
Runoff coefficients for use in the rational method

	Return Period (years)						
Character of surface	**2**	**5**	**10**	**25**	**50**	**100**	**500**
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

Chow, V.T., Maidment, D. Mays, L., Applied Hydrology, McGraw-Hill. 1988.

Piñon Ridge Project
Side Slope Rock Cover
892417-3

6/7
11/13/08

4.2 Pile side slope rock armor sizing using Stephenson's Method

For the steeper embankment slopes, the Stephenson Method (Stephenson, 1979) developed for flow over and through rockfill on steep slope was applied. The stone size is computed from the following equation:

$$D_{50} = \left[\frac{q(\tan\theta)^{7/6} n_p^{1/6}}{Cg^{1/2}[(1-n_p)(G_s-1)\cos\theta(\tan\phi-\tan\theta)]^{5/3}} \right]^{2/3} \tag{7}$$

where q is the flow rate per unit width determined from the rational method, n_p is the rock fill porosity, C is an empirical coefficient ranging from 0.22 for gravel and pebbles to 0.27 for

crushed granite, g is the acceleration of gravity, G_s is the relative rock density, θ is the angle of slope from horizontal, and ϕ is the angle of repose of rock.

4.3 Pile side slope rock armor stability in response to PMF flows in the Colorado River

In addition to overland flow conditions, the rock armor on the eastern side slope of the tailings pile was evaluated for stability against the shear forces resulting from several flood events in the Colorado River ranging from 48,900 to 300,000 (NRC PMF value) cubic feet per second (cfs). Shear stress equations developed by the USACE (1971) were followed to compute the boundary stresses given the anticipated velocities from the various flood events. Velocities used to obtain the average boundary shear stresses were obtained from HEC-2 analyses on the Colorado River performed by Mussetter Engineering, Inc. (MEI, 1994). Depth of flow for the 300,000 cubic feet per second event was estimated at approximately 30% of the way up the reclaimed tailings pile embankment. The USACE shear stress equations are discussed in more detail below.

5 TAILINGS PILE COLLECTION DITCHES AND DRAINAGE CHANNELS

As shown on Figure 1, three collection ditches were designed to collect water from the top of

Tailings and Mine Waste 1998: Proceedings of 5th International Conf. CSU, 1998.

Piñon Ridge Project
Side Slope Rock Cover
89241.7-3

7/7
11/13/08

Table 5-1.—Average engineering properties of compacted soils. From the Western United States. Last updated October 6, 1982.

GP appropriate for soil/rock matrix cover.

USCS soil type	Specific gravity		Compaction				Shear strength				Values listed
			Laboratory		Index unit weight		Avg. placement		Effective stress		
	No. 4 minus	No. 4 plus	Maximum unit weight, lb/ft³	Optimum moisture content, %	Max., lb/ft³	Min., lb/ft³	Unit weight, lb/ft³	Moisture content, %	c′ lb/in²	φ′, degrees	
	2.69	2.58	124.2	11.4	133.6	108.8	—	—	—	—	Average of all values
	0.02	0.08	3.2	1.2	10.4	10.2	—	—	—	—	Standard deviation
GW	2.65	2.39	119.1	9.9	113.0	88.5	—	—	—	—	Minimum value
	2.75	2.67	127.5	13.3	145.6	132.9	—	—	—	—	Maximum value
	16	9	5		16				0		Total number of tests
	2.68	2.57	121.7	11.2	137.2	112.5	127.5	6.5	5.9	41.4	Average of all values
	0.03	0.07	5.9	2.2	6.3	8.3	7.2	1.2	—	2.5	Standard deviation
GP	2.61	2.42	104.9	9.1	118.3	85.9	117.4	5.3	5.9	38.0	Minimum value
	2.76	2.65	127.7	17.7	148.8	123.7	133.9	8.0	5.9	43.7	Maximum value
	35	12	15		34				3		Total number of tests
	2.73	2.43	113.3	15.8	132.0	108.0	125.9	10.3	13.4	34.0	Average of all values
	0.07	0.18	11.5	5.8	3.1	0.2	0.9	1.2	3.7	2.6	Standard deviation
GM	2.65	2.19	87.0	5.8	128.9	107.8	125.0	9.1	9.7	31.4	Minimum value
	2.92	2.92	133.0	29.5	135.1	108.1	126.9	11.5	17.0	36.5	Maximum value
	34	17	36		2				2		Total number of tests
	2.73	2.57	116.6	13.9	—	—	111.1	15.9	10.2	27.5	Average of all values
	0.08	0.21	7.8	3.8	—	—	10.4	1.6	1.5	7.2	Standard deviation
GC	2.67	2.38	96.0	6.0	—	—	96.8	11.2	5.0	17.7	Minimum value
	3.11	2.94	129.0	23.6	—	—	120.9	22.2	16.0	35.0	Maximum value
	34	6	37		0				3		Total number of tests
	2.67	2.57	126.1	9.1	125.0	99.5	—	—	—	—	Average of all values
	0.03	0.03	6.0	1.7	6.0	7.1	—	—	—	—	Standard deviation
SW	2.61	2.51	118.1	7.4	116.7	87.4	—	—	—	—	Minimum value
	2.72	2.59	135.0	11.2	137.8	109.8	—	—	—	—	Maximum value
	13	2	1		12				0		Total number of tests
	2.65	2.62	115.6	10.8	115.1	93.4	103.4	5.4	5.5	37.4	Average of all values
	0.03	0.10	9.7	2.0	7.2	8.8	14.6	—	3.0	2.0	Standard deviation
SP	2.60	2.52	106.5	7.8	105.9	78.2	88.8	5.4	2.5	35.4	Minimum value
	2.77	2.75	134.8	13.4	137.3	122.4	118.1	5.4	8.4	39.4	Maximum value
	36	3	7		39				2		Total number of tests
	2.68	2.18	116.6	12.5	110.1	84.9	112.0	12.7	6.6	33.6	Average of all values
	0.06	0.11	8.9	3.4	8.7	7.9	11.1	5.4	5.6	5.7	Standard deviation
SM	2.51	2.24	92.9	6.8	88.5	61.6	91.1	1.6	0.2	23.3	Minimum value
	3.11	2.63	132.6	25.5	122.9	97.1	132.5	25.0	21.2	45.0	Maximum value
	149	9	123		21				17		Total number of tests
	2.69	2.17	118.9	12.4	—	—	115.6	14.2	5.0	33.9	Average of all values
	0.04	0.18	5.9	2.3	—	—	14.1	5.7	2.5	2.9	Standard deviation
SC	2.56	2.17	104.3	6.7	—	—	91.1	7.5	0.7	28.4	Minimum value
	2.81	2.59	131.7	18.2	—	—	131.8	22.7	8.5	38.3	Maximum value
	88	4	73		0				10		Total number of tests
	2.69	—	103.3	19.7	—	—	98.9	22.1	3.6	34.0	Average of all values
	0.09	—	10.4	5.7	—	—	11.5	8.9	4.3	3.1	Standard deviation
ML	2.52	—	81.6	10.6	—	—	80.7	11.1	0.1	25.2	Minimum value
	3.10	—	126.0	34.6	—	—	119.3	40.3	11.9	37.7	Maximum value
	65	0	39		0				14		Total number of tests
	2.71	2.59	109.3	16.7	—	—	106.5	17.7	10.3	25.1	Average of all values
	0.05	0.13	5.5	2.9	—	—	7.8	5.1	7.6	7.0	Standard deviation
CL	2.56	2.42	90.0	6.4	—	—	85.6	11.6	0.9	8.0	Minimum value
	2.87	2.75	121.4	29.2	—	—	118.7	35.0	23.8	33.8	Maximum value
	270	3	221		0				31		Total number of tests
	2.79	—	85.1	33.6	—	—	—	—	—	—	Average of all values
	0.25	—	2.3	1.6	—	—	—	—	—	—	Standard deviation
MH	2.47	—	82.9	31.5	—	—	—	—	—	—	Minimum value
	3.50	—	89.0	35.5	—	—	—	—	—	—	Maximum value
	10	0	5		0				0		Total number of tests

U.S. Bureau of Reclamation, Design of Small Dams, Water Resources Technical Publication, 1960.

Attachment 1
11/13/2008
Piñon Ridge Project
Tailing Cell Closure Cover Erosion Design Parameters and Equations

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Table 1 **Vegetated Soil Top Cover Rock Mulch (Safety Factor Method)**

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	SG	SA	FA	τ	τ_c	η_b	SF_b	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	--	(rad)	(rad)	(psf)	(psf)	--	--	(in)
1	Rock Mulch (All Soil Top Cover Areas)	345	1	0.02	0.045	3.2	28.2	0.8	3.0	0.5	0.3	2.65	0.02	0.72	0.37	0.40	0.93	1.1	1.0

Table 2 **Side Slope Toe Protection Rock Cover (Abt et al. Method)**

Calc. No.	Drainage Section	Length	Width	Slope	Tc	i	C	F	q	D_{50}
		(ft)	(ft)	(ft/ft)	(min)	(in/hr)			(cfs/ft)	(in)
2.0	Side Slope Toe Protection (Tailing Cell C)	713	1	0.10	3.9	28.2	0.8	3.0	1.1	7.6
2.1	Side Slope Toe Protection (Tailing Cell B)	609	1	0.10	3.8	28.2	0.8	3.0	0.9	6.8
2.2	Side Slope Toe Protection (Tailing Cell A)	559	1	0.10	3.5	28.2	0.8	3.0	0.9	6.8

Table 3 **Vegetated Soil Top Cover (Maximum Permissible Velocity Method)**

Calc. No.	Drainage Section	Length	Slope	Tc	C	i	F	q	d	V	n	MPV	MPV_{RF}
		(ft)	(ft/ft)	(min)	--	(in/hr)	--	(cfs/ft)	(ft)	(fps)	--	(fps)	(fps)
3	Vegetated Soil Slope (All Soil Top Cover Areas)	345	0.02	3.2	0.8	28.2	3.0	0.5	0.3	1.7	0.045	4.0	2.0

Flow Reduction Factor

d	RF
(ft)	
0.00	0.5
0.25	0.5
0.40	0.6
0.65	0.7
1.00	0.8

Table 4 **Side Slope Rock Cover (Stephenson Method)**

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	V	C_s	n_p	SG	SA	FA	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	(fps)	--	--	--	(rad)	(rad)	(in)
4	Rock Cover A1	103	1	0.10	0.05	3.8	28.2	0.8	3.0	0.7	0.2	3.3	0.22	0.39	2.65	0.10	0.72	1.6
5	Rock Cover A2	203	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
6	Rock Cover A3	60	1	0.10	0.05	3.6	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
7	Rock Cover A4	214	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
8	Rock Cover B1	117	1	0.10	0.05	3.9	28.2	0.8	3.0	0.7	0.2	3.2	0.22	0.39	2.65	0.10	0.72	1.6
9	Rock Cover B2	217	1	0.10	0.05	4.4	28.2	0.8	3.0	0.8	0.2	3.7	0.22	0.39	2.65	0.10	0.72	1.8
10	Rock Cover B3	31	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
11	Rock Cover B4	264	1	0.10	0.05	4.6	28.2	0.8	3.0	0.9	0.3	3.6	0.22	0.39	2.65	0.10	0.72	1.9
12	Rock Cover C1	356	1	0.10	0.05	4.9	28.2	0.8	3.0	1.1	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
13	Rock Cover C2	350	1	0.10	0.05	4.9	28.2	0.8	3.0	1.0	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
14	Rock Cover C3	32	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
15	Rock Cover C4	368	1	0.10	0.05	5.0	28.2	0.8	3.0	1.1	0.3	4.0	0.22	0.39	2.65	0.10	0.72	2.2

Table 5 **Intersection Channel Riprap (Mining Water Diversion Manual Experimental Curves)**

Calc. No.	Drainage Section	Length	Area	Slope	Tc	i	C	F	Q
		(ft)	(ac)	(ft/ft)	(min)	(in/hr)	--	--	(cfs)
16	Cell A and B Intersection Rundown	1478	29.46	0.01	11.1	21.9	0.8	1.0	258
17	Cell B and C Intersection Rundown	1560	30.29	0.01	11.6	21.9	0.8	1.0	265

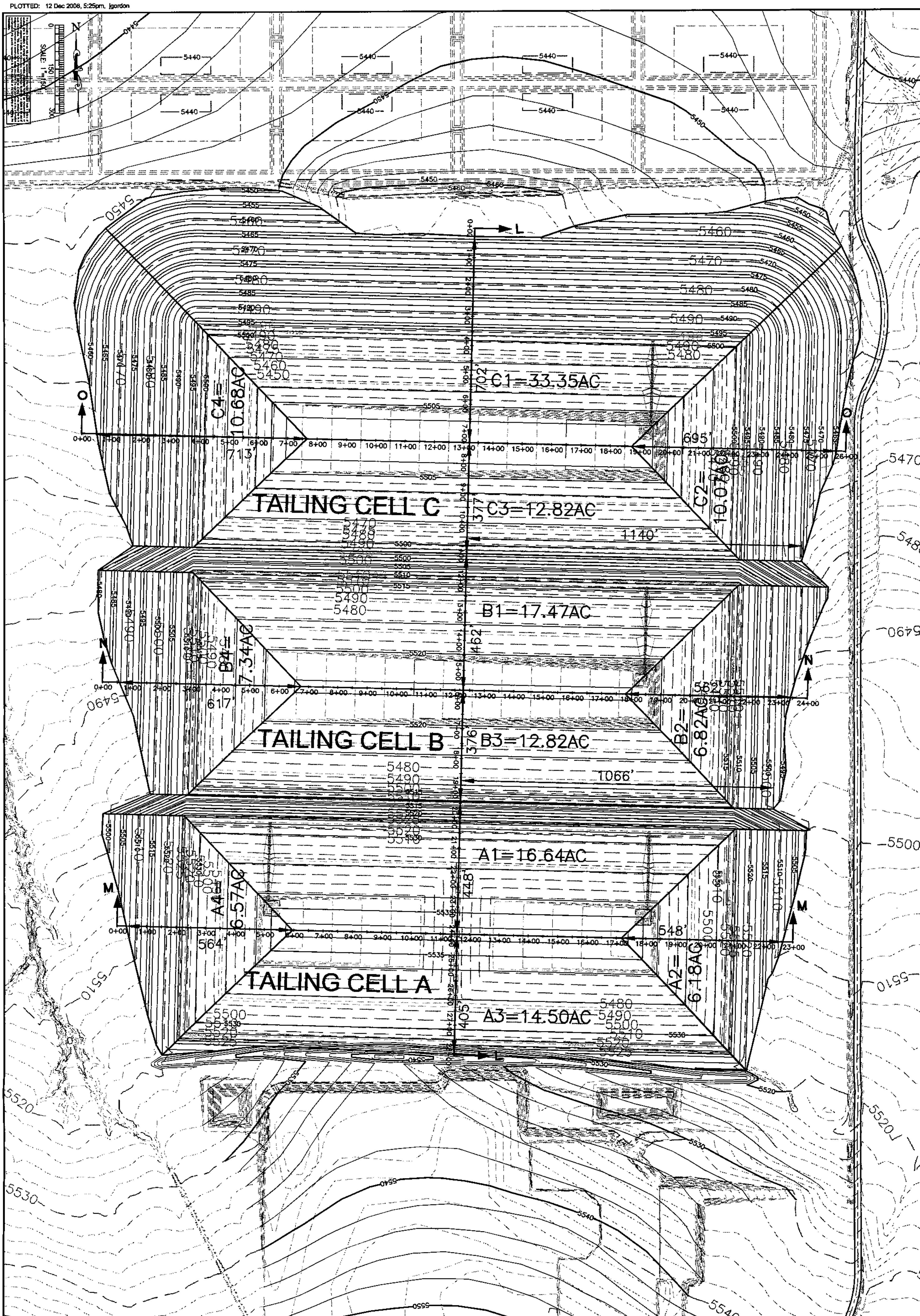
Drainage Sections correspond to Drawing C2 in "Kleinfelder, Pinon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans. December 12th, 2008."
Safety Factor Method used on slopes less than 10%
Stephenson Method used on slopes 10% and greater
Abt et al. Method used for embankment toe riprap sizing

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Symbol/Term	Definition
Length, L	Length of longest flow path in catchments
Width, W	Unit width of flow control section
Slope, S	Slope of local flow path
S_{EFF}	Effective Slope
n	Manning's roughness
Tc	Time of concentration
i	Rainfall intensity
C	Runoff coefficient
F	Flow concentration factor
q	Unit flow rate
Q	Flow rate
d	Flow depth
V	Flow velocity
SG	Specific gravity of rock material
SA	Slope angle
FA	Friction angle of rock material
C_s	Stephenson factor
n_p	Cover material porosity
τ	Actual tractive force
τ_c	Critical tractive force
η_b	Stability parameter
SF_b	Safety factor
D_{50}	Particle size such that 50% of material by weight is smaller
RF	Reduction Factor
MPV	Maximum Permissible Velocity
MPV_{RF}	Reduced Maximum Permissible Velocity
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
HMR	Hydrometeorological Report

Attachment 2
12/12/08
Piñon Ridge Project
Tailing Cells Closure Grading Plan, Drawing C2

PLOTTED: 12 Dec 2008, 5:25pm, jgordon



TAILING CELLS
CLOSURE GRADING PLAN

PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

Energy Fuels Resources
44 Union Blvd., Suite 600
Lakewood, CO 80228
PH. 303.974.2140

PRELIMINARY
NOT FOR
CONSTRUCTION

KLEINFELDER
Bright People. Right Solutions.
611 Corporate Circle, Ste. C
Golden, Colorado 80401
PH. 303.237.6601 FAX. 303.237.6602
www.kleinfelder.com

PROJ. NO. 89241
ACAD FILE: 12027_Closure Sheets.dwg

DESIGNED BY: JAG
DRAWN BY: JAG
CHECKED BY: TAK
DATE: 12/12/08
SCALE: NO SCALE

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
0 0.5 1.0 1.5 2.0

DRAWING
C2
1 of 7 sheets

KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 11/13/08 **Page** 1 **of** 5

Project No.: 89241 **Project Title:** Piñon Ridge Project

Calculation No.: 89241.7-4

Calculation Title: Tailing Cell Toe Erosion Protection

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date
Originator:	[signature] 11/13/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 11/21/08		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
U2ALB08WP001	Tailing Cell Closure Design Report	0	AK
DEN 8R197	Piñon Ridge Closure Drainage Calcs.	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages
1	Tailing Cell Closure Cover Erosion Design	2
	Parameters and Equations.	
2	Tailing Cell Cover and Site Grading Drainage	
	Plans, Drawing C2	1

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Toe Erosion Protection BY TAK DATE 11/13/08
89241.7-4 REVIEWED BY BAC DATE 11/20/08

Objective: Determine rock size required for long-term protection of tailing cell toes under PMF conditions.

Given: $S_1 = 0.02$ ft/ft
$S_2 = 0.10$ ft/ft
$L_1 = 345$ ft
$L_2 = 368$ ft } (Ref. 1)
1-hr PMP = 8.1 in (Kleinfelder Calc. No. 89241.7-2)

Assumptions:

1) C = 0.8 → Runoff Coefficient (Ref. 2)
F = 3.0 → Flow Concentration Factor (Ref. 3)
2) Use Time of Concentration, Tc, Increments of 5, 10, 15, 30, and 60 min. (Ref 6)

* See Attachment 1, pg. 2 for definition of parameters.

Calculations: Performed to verify spreadsheet calculations in Attachment 1, Table 2, Calc. No. 2.0.

Use Abt et. al Method (Ref. 3)

Determine effective slope using equation (Ref. 4)

Use subbasin C4, (Ref. 1) as most extreme runoff condition.
$L_1 = 345$ ft $S_1 = 0.02$ ft/ft
$L_2 = 368$ ft $S_2 = 0.10$ ft/ft

$$S_{eff} = \left[\frac{(345\,ft)(0.02\,ft/ft)^{0.24} + (368\,ft)(0.10\,ft/ft)^{0.24}}{345\,ft + 368\,ft}\right]^{4.17} = 0.05\,ft/ft$$

Determine Tc using Kirpich Method:

$$T_c = 0.0078\left(\frac{713\,ft^{0.77}}{0.05\,ft/ft^{.385}}\right) = 3.9\,min$$

$L = 713$ ft
$S = 0.05$ ft/ft

(Ref. 5)

Use Tc of 5 min, smallest value in I-D curve.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Toe Erosion Protection BY TAK DATE 11/13/08
89241.7-4 REVIEWED BY BAC DATE 11/20/08

A Tc of 5.0 min corresponds ~~to~~ an i of 28.2 in/hr from Kleinfelder Calc. No. 89241.7-1.

Use Rational Method to determine unit peak flow:

$$q = \frac{(3.0)(0.8)(28.2\,in/hr)(713\,ft)}{43{,}560} = 1.1\ cfs/ft$$

$C = 0.8$
$F : 3.0$
$i = 28.2\ in/hr$
$L = 713\ ft$

(Ref. 3)

Use Abt et al. equation to determine rock size necessary to resist PMF at toe of tailing cells.

$$D_{50} = 10.46(0.10\,ft/ft)^{0.43}(3.0 * 1.1\,cfs/ft)^{0.56} = 7.6\ in$$

$S = 0.10\ ft/ft$
$C_f = 3.0$
$q = 1.1\ cfs/ft$

(Ref. 3)

Results:

$D_{50} = 7.6$ in → Use $D_{50} = 9.0$ in for standard size

According to NUREG-1623 "Design of Erosion Protection for Long-Term Stabilization" the rock should be placed at a thickness of about 3-D_{50}s. (Ref. 3)

Thickness = 3(~~7.2~~ 9.0 in) = ~~21.6~~ 27.0 in, say ~~22~~ 30 in min. thickness. TAK 11/14/08

Also, the toe protection should extend outward from the toe a minimum of 15 D_{50}s.

Extension = 15(~~7.2~~ 9.0 in) = ~~108~~ 135 in, say ~~10~~ 12 ft min. for these conditions. TAK 11/14/08

Smaller rock sizes may be acceptable under areas with less runoff.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Toe Erosion Protection BY TAK DATE 11/13/08
REVIEWED BY BAC DATE 11/21/08

See Attachment 1, Table 2, for complete results.

References:

1) Kleinfelder, Piñon Ridge Project; Tailing Cell Cover and Site Grading Drainage Plans, Dec. 12, 2008.
2) Chow, V.T., Maidment, D., Mays, L. Applied Hydrology. McGraw-Hill, 1988.
3) U.S. Nuclear Regulatory Commission, NUREG-1623: Design of Erosion Protection for Long-Term Stabilization, August 2002.
4) Urban Drainage and Flood Control District, Drainage Criteria Manual (V.1), pg. RO-24. 2001.
5) Barfield et. al, Applied Hydrology and Sedimentology for Disturbed Areas
6) NOAA, Atlas 2, Vol. III, Precipitation-Frequency Atlas of the Western United States. Silver Spring, Md. 1973.

Piñon Ridge Project
Toe Erosion Protection

11/13/08
89241.7-4

5/5

6 RIPRAP SIZING AT TOE OF EMBANKMENT SLOPES

Rock toes, or toe basins, are often placed at the base of sloped embankments to: stabilize and/or anchor rock placed on the side slope; serve as a toe drainage channel, serve as an impact basin and provide for energy dissipation from tributary flow; provide erosion protection at the toe; transition flow from the side slope to adjacent properties; and/or provide gully intrusion protection to the embankment. Therefore, proper rock sizing is an imperative element of the design process to meet the project stability requirements.

6.1 Technical Basis

Rock sizing procedures have been developed by the U.S. Bureau of Reclamation (USBR) for stilling basins founded, based on the work of Berry (1948) and as presented by the Department of the Interior (DOI, 1978). The procedure estimates the median stone size as a function of localized bottom velocity (V_b) at the location where the flow transitions onto a stone-filled basin. If the bottom velocity cannot be determined, the local average velocity may be substituted where the local average velocity can be determined using the U.S. Army Corps of Engineers procedures (ACE, 1994). Campbell (1966) presented a velocity-based riprap design procedure for stone placed in stilling basins. Both the USBR and Campbell rock sizing procedures were developed to dissipate energy and provide a stable toe as flow transitioned onto a rock basin or apron. These procedures are difficult to apply for relatively small rock requirements (less than 0.3 m) and yield conservative rock sizes.

To better understand the phenomena and mechanisms affecting the design of riprap to prevent erosion by overtopping flow as it transitions from the side slope to the embankment toe and/or apron, the U.S. Nuclear Regulatory Commission staff sponsored technical assistance efforts. As a result of these efforts, an alternative method of sizing the median stone size (D_{50}) for riprap placed at the toe of the slope was developed.

Abt et al. (1998) empirically derived an equation to compute the median stone size for riprap used to prevent erosion from flow transitioning off an embankment side slope onto the toe region. The relationship is expressed in English units as

$$D_{50} = 10.46 * S^{0.43} * (C_f * q_d)^{0.56} \qquad \text{(D-18)}$$

where: D_{50} = the median stone diameter in inches,

S = the embankment side slope in decimal form,

C_f = the flow concentration factor,

q_d = the design unit discharge in cubic ft per second.

Design of Erosion Protection for Long-Term Stabilization: NUREG-1623, NRC, 2002

Attachment 1
11/13/2008
Piñon Ridge Project
Tailing Cell Closure Cover Erosion Design Parameters and Equations

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Table 1 **Vegetated Soil Top Cover Rock Mulch (Safety Factor Method)**

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	SG	SA	FA	τ	τ_c	η_b	SF_b	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	--	(rad)	(rad)	(psf)	(psf)	--	--	(in)
1	Rock Mulch (All Soil Top Cover Areas)	345	1	0.02	0.045	3.2	28.2	0.8	3.0	0.5	0.3	2.65	0.02	0.72	0.37	0.40	0.93	1.1	1.0

Table 2 **Side Slope Toe Protection Rock Cover (Abt et al. Method)**

Calc. No.	Drainage Section	Length	Width	Slope	Tc	i	C	F	q	D_{50}
		(ft)	(ft)	(ft/ft)	(min)	(in/hr)			(cfs/ft)	(in)
2.0	Side Slope Toe Protection (Tailing Cell C)	713	1	0.10	3.9	28.2	0.8	3.0	1.1	7.6
2.1	Side Slope Toe Protection (Tailing Cell B)	609	1	0.10	3.8	28.2	0.8	3.0	0.9	6.8
2.2	Side Slope Toe Protection (Tailing Cell A)	559	1	0.10	3.5	28.2	0.8	3.0	0.9	6.8

Table 3 **Vegetated Soil Top Cover (Maximum Permissible Velocity Method)**

Calc. No.	Drainage Section	Length	Slope	Tc	C	i	F	q	d	V	n	MPV	MPV_{RF}
		(ft)	(ft/ft)	(min)	--	(in/hr)	--	(cfs/ft)	(ft)	(fps)	--	(fps)	(fps)
3	Vegetated Soil Slope (All Soil Top Cover Areas)	345	0.02	3.2	0.8	28.2	3.0	0.5	0.3	1.7	0.045	4.0	2.0

Flow Reduction Factor

d	RF
(ft)	
0.00	0.5
0.25	0.5
0.40	0.6
0.65	0.7
1.00	0.8

Table 4 **Side Slope Rock Cover (Stephenson Method)**

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	V	C_s	n_p	SG	SA	FA	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	(fps)	--	--	--	(rad)	(rad)	(in)
4	Rock Cover A1	103	1	0.10	0.05	3.8	28.2	0.8	3.0	0.7	0.2	3.3	0.22	0.39	2.65	0.10	0.72	1.6
5	Rock Cover A2	203	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
6	Rock Cover A3	60	1	0.10	0.05	3.6	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
7	Rock Cover A4	214	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
8	Rock Cover B1	117	1	0.10	0.05	3.9	28.2	0.8	3.0	0.7	0.2	3.2	0.22	0.39	2.65	0.10	0.72	1.6
9	Rock Cover B2	217	1	0.10	0.05	4.4	28.2	0.8	3.0	0.8	0.2	3.7	0.22	0.39	2.65	0.10	0.72	1.8
10	Rock Cover B3	31	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
11	Rock Cover B4	264	1	0.10	0.05	4.6	28.2	0.8	3.0	0.9	0.3	3.6	0.22	0.39	2.65	0.10	0.72	1.9
12	Rock Cover C1	356	1	0.10	0.05	4.9	28.2	0.8	3.0	1.1	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
13	Rock Cover C2	350	1	0.10	0.05	4.9	28.2	0.8	3.0	1.0	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
14	Rock Cover C3	32	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
15	Rock Cover C4	368	1	0.10	0.05	5.0	28.2	0.8	3.0	1.1	0.3	4.0	0.22	0.39	2.65	0.10	0.72	2.2

Table 5 **Intersection Channel Riprap (Mining Water Diversion Manual Experimental Curves)**

Calc. No.	Drainage Section	Length	Area	Slope	Tc	i	C	F	Q
		(ft)	(ac)	(ft/ft)	(min)	(in/hr)	--	--	(cfs)
16	Cell A and B Intersection Rundown	1478	29.46	0.01	11.1	21.9	0.8	1.0	258
17	Cell B and C Intersection Rundown	1560	30.29	0.01	11.6	21.9	0.8	1.0	265

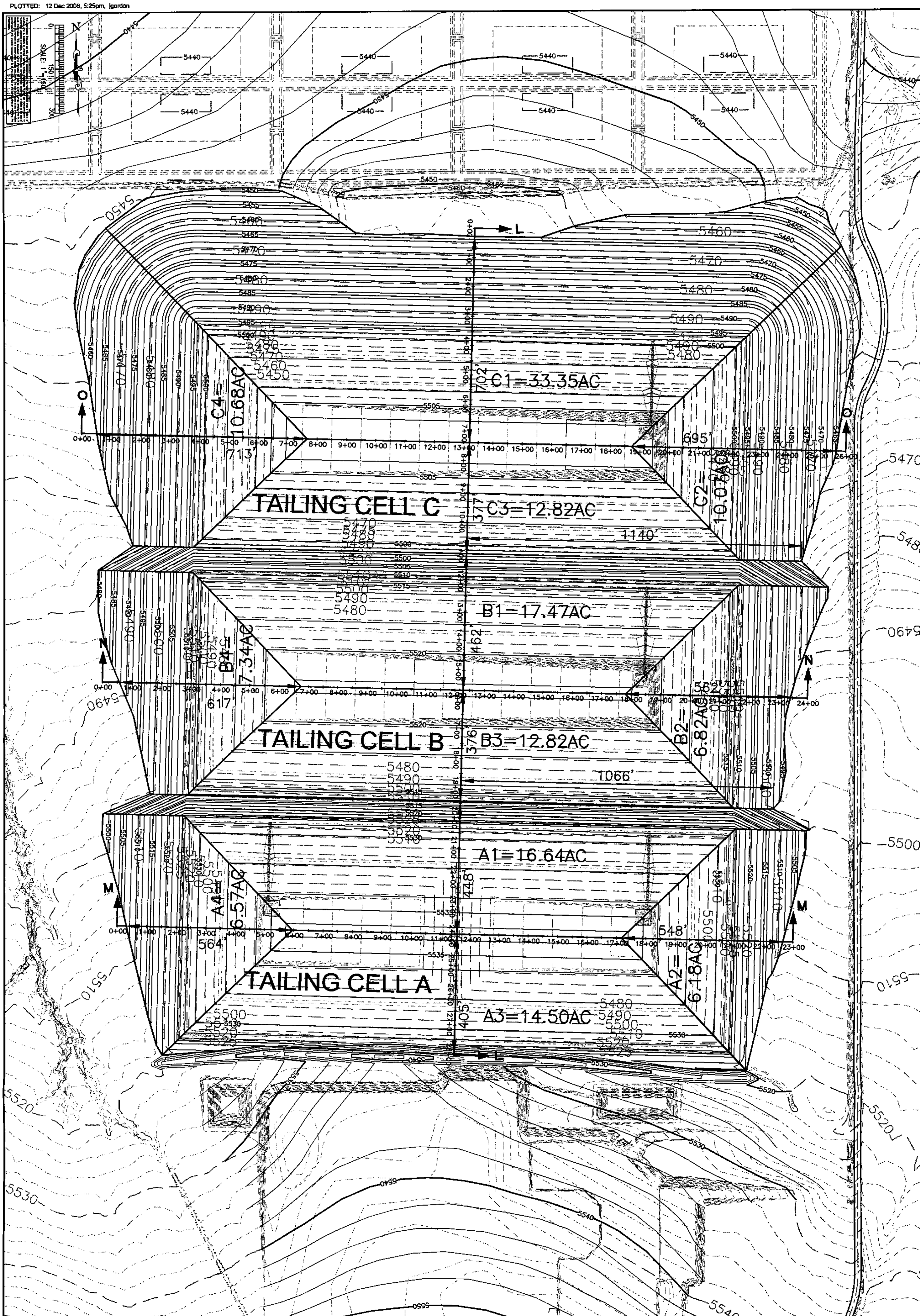
Drainage Sections correspond to Drawing C2 in "Kleinfelder, Pinon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans. December 12th, 2008."
Safety Factor Method used on slopes less than 10%
Stephenson Method used on slopes 10% and greater
Abt et al. Method used for embankment toe riprap sizing

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Symbol/Term	Definition
Length, L	Length of longest flow path in catchments
Width, W	Unit width of flow control section
Slope, S	Slope of local flow path
S_{EFF}	Effective Slope
n	Manning's roughness
Tc	Time of concentration
i	Rainfall intensity
C	Runoff coefficient
F	Flow concentration factor
q	Unit flow rate
Q	Flow rate
d	Flow depth
V	Flow velocity
SG	Specific gravity of rock material
SA	Slope angle
FA	Friction angle of rock material
C_s	Stephenson factor
n_p	Cover material porosity
τ	Actual tractive force
τ_c	Critical tractive force
η_b	Stability parameter
SF_b	Safety factor
D_{50}	Particle size such that 50% of material by weight is smaller
RF	Reduction Factor
MPV	Maximum Permissible Velocity
MPV_{RF}	Reduced Maximum Permissible Velocity
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
HMR	Hydrometeorological Report

Attachment 2
12/12/08
Piñon Ridge Project
Tailing Cells Closure Grading Plan, Drawing C2

PLOTTED: 12 Dec 2008, 5:25pm, jgordon



TAILING CELLS CLOSURE GRADING PLAN PIÑON RIDGE PROJECT MONTROSE COUNTY, COLORADO	Energy Fuels Resources 44 Union Blvd., Suite 600 Lakewood, CO 80228 PH. 303.974.2140	PRELIMINARY NOT FOR CONSTRUCTION	KLEINFELDER Bright People. Right Solutions. 611 Corporate Circle, Ste. C Golden, Colorado 80401 PH. 303.237.6601 FAX. 303.237.6602 www.kleinfelder.com	PROJ. NO. 89241 ACAD FILE: 12027_Closure Sheets.dwg

DESIGNED BY: JAG
DRAWN BY: JAG
CHECKED BY: TAK
DATE: 12/12/08
SCALE: NO SCALE
ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 0.5 1.0 1.5 2.0

DRAWING C2

1 of 7 sheets

KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 11/14/08 **Page** 1 **of** 9

Project No.: 89241 **Project Title:** Piñon Ridge Project

Calculation No.: 89241.7-5

Calculation Title: Erosion Cover Riprap Rundown Design

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date
Originator:	[signature] 11/14/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 1/19/09		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
UZALB08WP001	Tailing Cell Closure Design Report	0	AK
DEN8R197	Piñon Ridge Closure Drainage Calcs.	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages
1	Tailing Cell Closure Cover Erosion Design Parameters and Equations	2
2	Tailing Cell Cover and Site Grading Drainage Plans, Drawing C2	1
3	HEC-RAS Output	8

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Riprap Rundown Design BY TAK DATE 11/14/08
89241.7-5 REVIEWED BY BAC DATE 11/20/08

Objective: Determine channel dimensions and riprap size for PMF resistant erosion cover rundowns.

Givens 1-hr PMP = 7.6 in. (Kleinfelder calc. No. 89241.7-1)
Side Slope = 10H:1V = 10% (Ref. 1, C2)
Average Watercourse Length = 1520 ft (Ref. 1, C2)
Average Drainage Area = 30 ac. (Ref. 1, C2)
C = 0.8 → Runoff coefficient (Ref. 2)
F = 1.0 → Flow Concentration Factor (Ref. 3)
* Refer to Attachment 1, pg. 2 for definition of parameters

Assumptions: 1) Select highest peak flow from drainages between A1 - B3 and B1 - C3 and apply to both areas for riprap design. (Shown in Attachment 2, Ref. 1, C2)
2) Use effective slope equation for Tc Calculations.
3) Use Tc Increments of 5, 10, 15, 30, and 60 min. (Ref. 5)
TAK 10/17/08 4) 1-hr PMP depth recalculated to be 8.1 in. resulting in <10% change in calculated peak flow values. (Kleinfelder Calc. No 89241.7-1)

Calculations: (Use calc. No. 17 as check, Att. A)

Determine watercourse slope using Effective Slope equation, (Ref. 4)

$L_1 = 345\text{ ft}$ $S_1 = 0.02$
$L_2 = 930\text{ ft}$ $S_2 = 0.005$ (Ref. 1, C2)
$L_3 = 285\text{ ft}$ $S_3 = 0.10$

$$S_{EFF} = \left[\frac{(345\text{ft})(0.02)^{0.24} + (930\text{ft})(0.005)^{0.24} + (285\text{ft})(0.10)^{0.24}}{345\text{ft} + 930\text{ft} + 285\text{ft}}\right]^{4.17} = 0.014\text{ ft/ft}$$

Use S_{EFF} in Kirpich Equation to determine time of concentration, T_c.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Riprap Rundown Design BY TK DATE 11/14/08
89241.7-5 REVIEWED BY BAC DATE 11/20/08

$$T_c = 0.0078\left(\frac{L^{0.77}}{S^{0.385}}\right)$$

L = 1560 ft
S = 0.014 ft/ft

(Ref. 5)

$$T_c = 0.0078\left(\frac{1560\text{ ft}^{0.77}}{(0.014\text{ ft/ft})^{0.385}}\right) = 11.6\text{ min}$$ ✓

Use Tc of 10 min (Ref. 5)

A Tc of 10.0 min corresponds to an i = 21.9 in/hr in Kleinfelder calc. No. 89241.7-1.

Use Rational Method to determine peak flow:

$Q = FCiA$

(Ref. 2)

F = 1.0
C = 0.8
i = 21.9 in/hr
A = 30.29 ac / 2 = 15.15 ac for single rundown channel.

$Q = (1.0)(0.8)(21.9\text{ in/hr})(15.15\text{ ac}) = 265\text{ cfs}$

Use a peak flow of 265 cfs and a channel slope of 0.10 ft/ft in experimental curves developed for steep slope erosion protection. (Ref. 6)

Results:

For results of Tc and Peak flows see Attachment 1, Table 5.

Channel with 2H:1V side slopes, 20 ft base width, and 2 ft deep, giving 1 ft of freeboard.

TK 1/7/09

Use D_{50} = 18 in, standard size riprap, minimum 3 ft thickness placement.

Piñon Ridge Project
Riprap Rundown Design
11/14/08

The runoff coefficient is also dependent on the character and condition of the soil. The infiltration rate decreases as rainfall continues, and is also influenced by the antecedent moisture condition of the soil. Other factors influencing the runoff coefficient are rainfall intensity, proximity of the water table, degree of soil compaction, porosity of the subsoil, vegetation, ground slope, and depression storage. A reasonable coefficient must be chosen to represent the integrated effects of all these factors. Suggested coefficients for various surface types as used in Austin, Texas are given in Table 15.1.1.

4/9

TABLE 15.1.1
Runoff coefficients for use in the rational method

Character of surface	Return Period (years) 2	5	10	25	50	100	500
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

Chow, V.T., Maidment, D., Mays, L., Applied Hydrology. McGraw-Hill, 1988

Piñon Ridge Project
Riprap Rundown Design

BAC 1/19/09

5/9
11/14/08

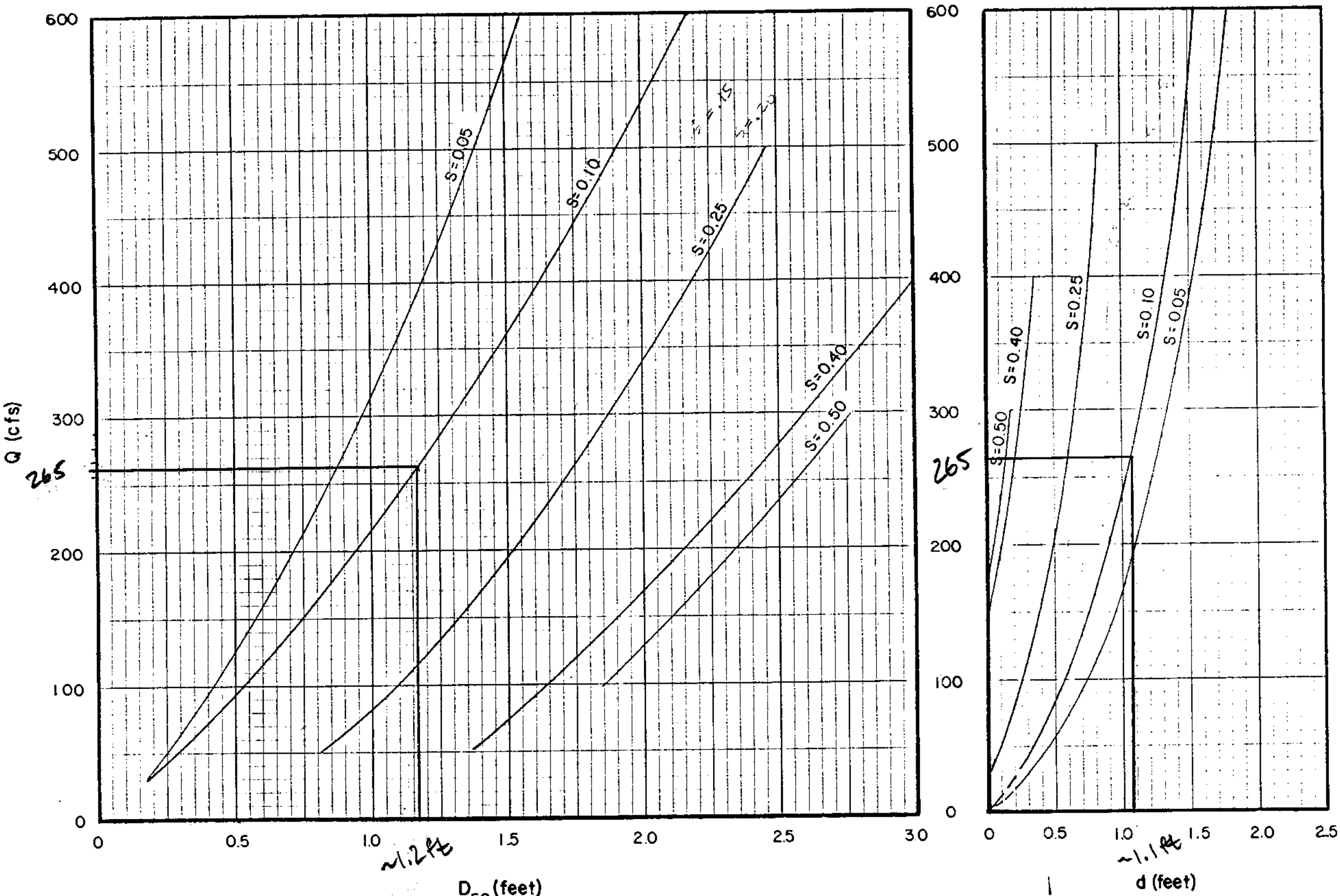


Figure 5.7. Steep slope riprap design, trapezoidal channels, 2:1 sideslopes, 20 ft base width.

Surface Mining Water Diversion Design Manual, Office of Surface Mining, DOI, 1982

Piñon Ridge Project
Riprap Rundown Design

6/9
11/14/08

Where the flow-line slope varies along the channel, calculate a weighted basin slope for use with CUHP. Do this by first segmenting the major drainageway into reaches having similar longitudinal slopes. Then calculate the weighted slope using the Equation RO-9.

$$S = \left[\frac{L_1 S_1^{\ 0.24} + L_2 S_2^{\ 0.24} + ... + L_n S_n^{\ 0.24}}{L_1 + L_2 + L_3 ... L_n} \right]^{4.17} \qquad \text{(RO-9)}$$

In which:

S = weighted basin waterway slopes in ft/ft

$S_1, S_2, ... S_n$ = slopes of individual reaches in ft/ft (after adjustments using Figure RO-10)

$L_1, L_2, ... L_n$ = lengths of corresponding reaches

6. Time of Concentration—As an option for small urbanized areas (e.g., less than 90 acres), the CUHP user must enter time of concentration in minutes. For catchments between 90 acres and 160 acres, the user may enter the time of concentration to determine the difference between flow calculated using CUHP parameters and the flow using input time of concentration. The procedure for estimating time of concentration is given in Section 2.4.

7. Pervious Retention—Maximum depression storage on pervious surfaces in inches. (See Section 3.2.2 for more details.)

8. Impervious Retention—Maximum depression storage on impervious surfaces in inches. (See Section 3.2.2 for more details.)

9. Infiltration Rate—Initial infiltration rate for pervious surfaces in the catchment in inches per hour. If this entry is used by itself, it will be used as a constant infiltration rate throughout the storm. (See Section 4.2.3 for more details.)

10. Decay—Exponential decay coefficient in Horton's equation in "per second" units.

11. Final Infiltration—Final infiltration rate in Horton's equation in inches per hour.

The program computes the coefficients C_t and C_p; however, values for these parameters can be specified by the user as an option. The unit hydrograph is developed by the computer using the algorithm in the 1984 version of the *Manual*.

The shaping of the unit hydrograph also relies on proportioning the widths at 50% and 75% of the unit hydrograph peak. The proportioning is based on 0.35 of the width at 50% of peak being ahead of the "time to peak" and 0.45 of the width at 75% of peak being ahead of the "time to peak." These proportioning factors were selected after observing a number of unit hydrographs derived from the

Urban Drainage and Flood Control District, Drainage Criteria Manual, 2001

KLEINFELDER
Bright People. Right Solutions.

PROJECT Pinon Ridge Project PROJECT NO. 89241
SUBJECT Riprap Rundown Design BY TAK DATE 1/7/09
Continued, 89241.7-5 REVIEWED BY BAC DATE 1/19/09

Objective: Determine channel dimensions and transition between V-ditch and outslope rundowns in Tailing Cell groin areas.

Givens: PMF Design Flow of 265 cfs (Kleinfelder Calc. No. 89241.7-5)
10H:1V outslopes (Ref. 7, C2)
B/C transition has trap. channel with 20 ft base width and 12% and 18% side slopes. (Ref. 7, C2)

Assumptions:

1) Use design flow of 285 cfs for entire channel.
2) Riprap of $d_{50} = 18''$ for outslopes (Ref. 6 Curves suggestion)
3) Rock cover for intersection channel of $d_{50} = 2.5''$ (Suggested standard size from Attachment 1, Table 4)

Calculations:

Use Strickler formula (Barfield et. al, 1982) to determine Manning's roughness values.

$n = 0.0395\, d_{50}^{1/6}$ d_{50} in ft.

for 18", 2.5 ft riprap $n = 0.0395(2.5)^{1/6} = 0.046$

for 2.5", 0.2 ft rock $n = 0.0395(0.2)^{1/6} = 0.030$

Results: →

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Riprap Rundown Design BY TAR DATE 1/7/09
REVIEWED BY BAC DATE 1/19/09

Use existing channel, with 0.5% slopes, geometry for intersection channel with rock cover, d_{50} = 2.5". Transition to rundown channel using trap. channel with 20 ft base width 2H:1V rt. side slope and 5.65H:1V (existing) left side slope. Channel depth of 3.0 ft. Maintain channel dimensions down entire side slope. Line rundown with riprap, d_{50} = 18", minimum thickness of 3 ft. Extend channel 25ft past toe of embankment at 1% slope.

See HEC-RAS output for hydraulic analysis. (Ref. 8)

* HEC-RAS uses design flow of 285cfs, 20cfs greater than calculated design flow of 265cfs. HEC-RAS analysis was not updated because Ref. 6 Charts show adequate protection and similar depth of flow for both discharges.

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Project PROJECT NO. 89241
SUBJECT Riprap Rundown Design BY TAK DATE 11/14/08
89241.7-5 REVIEWED BY BAC DATE 11/21/08

References

1) Kleinfelder, Piñon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans. Dec. 12, 2008.
2) Chow, V.T., Maidment, D., Mays, L., Applied Hydrology. McGraw-Hill. 1988
3) U.S. Nuclear Regulatory Commission, NUREG-1623: Design of Erosion Protection for Long-Term Stabilization, August 2002.
4) Urban Drainage and Flood Control District. Drainage Criteria Manual (V.1). Denver, Co. 2001.
5) NOAA Atlas 2, Vol. III, Precipitation Frequency Atlas for Western United States. Silver Spring, Md. 1973.
6) Office of Surface Mining, U.S. Dept. of Interior. Surface Mining Water Diversion Design Manual. September, 1982.
7) Barfield, et.al. Applied Hydrology and Sedimentology for Disturbed Areas. 1981.
8) U.S. Army Corps of Engineers, Hydrologic Engineering Center River Analysis System (V.4.0), March 2008.

Attachment 1
11/13/2008
Piñon Ridge Project
Tailing Cell Closure Cover Erosion Design Parameters and Equations

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Table 1 Vegetated Soil Top Cover Rock Mulch (Safety Factor Method)

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	SG	SA	FA	τ	τ_c	η_b	SF_b	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	--	(rad)	(rad)	(psf)	(psf)	--	--	(in)
1	Rock Mulch (All Soil Top Cover Areas)	345	1	0.02	0.045	3.2	28.2	0.8	3.0	0.5	0.3	2.65	0.02	0.72	0.37	0.40	0.93	1.1	1.0

Table 2 Side Slope Toe Protection Rock Cover (Abt et al. Method)

Calc. No.	Drainage Section	Length	Width	Slope	Tc	i	C	F	q	D_{50}
		(ft)	(ft)	(ft/ft)	(min)	(in/hr)			(cfs/ft)	(in)
2.0	Side Slope Toe Protection (Tailing Cell C)	713	1	0.10	3.9	28.2	0.8	3.0	1.1	7.6
2.1	Side Slope Toe Protection (Tailing Cell B)	609	1	0.10	3.8	28.2	0.8	3.0	0.9	6.8
2.2	Side Slope Toe Protection (Tailing Cell A)	559	1	0.10	3.5	28.2	0.8	3.0	0.9	6.8

Table 3 Vegetated Soil Top Cover (Maximum Permissible Velocity Method)

Calc. No.	Drainage Section	Length	Slope	Tc	C	i	F	q	d	V	n	MPV	MPV_{RF}
		(ft)	(ft/ft)	(min)	--	(in/hr)	--	(cfs/ft)	(ft)	(fps)	--	(fps)	(fps)
3	Vegetated Soil Slope (All Soil Top Cover Areas)	345	0.02	3.2	0.8	28.2	3.0	0.5	0.3	1.7	0.045	4.0	2.0

Flow Reduction Factor

d	RF
(ft)	
0.00	0.5
0.25	0.5
0.40	0.6
0.65	0.7
1.00	0.8

Table 4 Side Slope Rock Cover (Stephenson Method)

Calc. No.	Drainage Section	Length	Width	Slope	n	Tc	i	C	F	q	d	V	C_s	n_p	SG	SA	FA	D_{50}
		(ft)	(ft)	(ft/ft)	--	(min)	(in/hr)	--	--	(cfs/ft)	(ft)	(fps)	--	--	--	(rad)	(rad)	(in)
4	Rock Cover A1	103	1	0.10	0.05	3.8	28.2	0.8	3.0	0.7	0.2	3.3	0.22	0.39	2.65	0.10	0.72	1.6
5	Rock Cover A2	203	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
6	Rock Cover A3	60	1	0.10	0.05	3.6	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
7	Rock Cover A4	214	1	0.10	0.05	4.3	28.2	0.8	3.0	0.8	0.2	3.6	0.22	0.39	2.65	0.10	0.72	1.8
8	Rock Cover B1	117	1	0.10	0.05	3.9	28.2	0.8	3.0	0.7	0.2	3.2	0.22	0.39	2.65	0.10	0.72	1.6
9	Rock Cover B2	217	1	0.10	0.05	4.4	28.2	0.8	3.0	0.8	0.2	3.7	0.22	0.39	2.65	0.10	0.72	1.8
10	Rock Cover B3	31	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
11	Rock Cover B4	264	1	0.10	0.05	4.6	28.2	0.8	3.0	0.9	0.3	3.6	0.22	0.39	2.65	0.10	0.72	1.9
12	Rock Cover C1	356	1	0.10	0.05	4.9	28.2	0.8	3.0	1.1	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
13	Rock Cover C2	350	1	0.10	0.05	4.9	28.2	0.8	3.0	1.0	0.3	3.9	0.22	0.39	2.65	0.10	0.72	2.1
14	Rock Cover C3	32	1	0.10	0.05	3.4	28.2	0.8	3.0	0.6	0.2	3.1	0.22	0.39	2.65	0.10	0.72	1.4
15	Rock Cover C4	368	1	0.10	0.05	5.0	28.2	0.8	3.0	1.1	0.3	4.0	0.22	0.39	2.65	0.10	0.72	2.2

Table 5 Intersection Channel Riprap (Mining Water Diversion Manual Experimental Curves)

Calc. No.	Drainage Section	Length	Area	Slope	Tc	i	C	F	Q
		(ft)	(ac)	(ft/ft)	(min)	(in/hr)	--	--	(cfs)
16	Cell A and B Intersection Rundown	1478	29.46	0.01	11.1	21.9	0.8	1.0	258
17	Cell B and C Intersection Rundown	1560	30.29	0.01	11.6	21.9	0.8	1.0	265

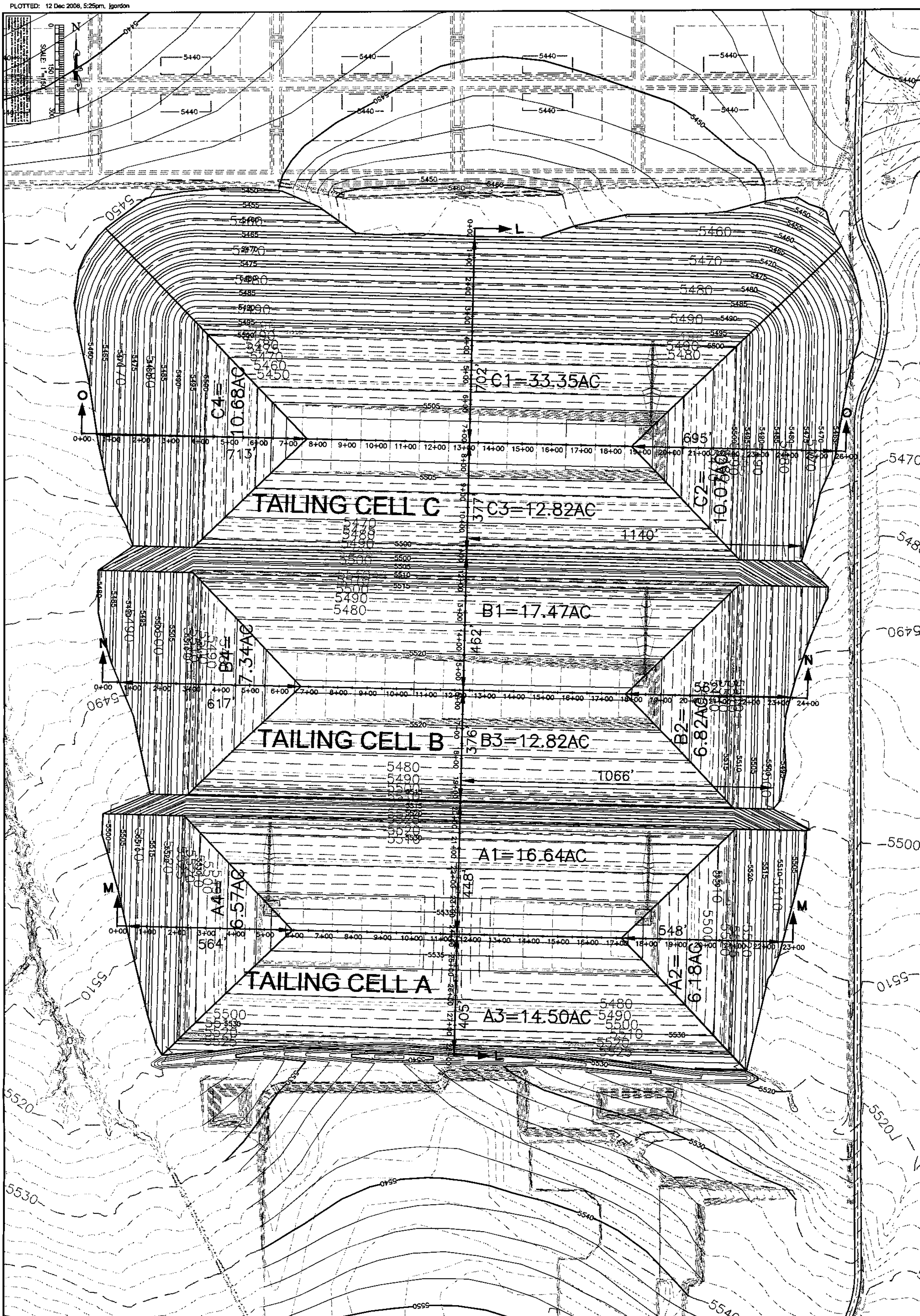
Drainage Sections correspond to Drawing C2 in "Kleinfelder, Pinon Ridge Project: Tailing Cell Cover and Site Grading Drainage Plans. December 12th, 2008."
Safety Factor Method used on slopes less than 10%
Stephenson Method used on slopes 10% and greater
Abt et al. Method used for embankment toe riprap sizing

Tailing Cell Closure Cover Erosion Design Parameters and Equations
Piñon Ridge Project
Montrose County, Colorado
Attachment 1

Symbol/Term	Definition
Length, L	Length of longest flow path in catchments
Width, W	Unit width of flow control section
Slope, S	Slope of local flow path
S_{EFF}	Effective Slope
n	Manning's roughness
Tc	Time of concentration
i	Rainfall intensity
C	Runoff coefficient
F	Flow concentration factor
q	Unit flow rate
Q	Flow rate
d	Flow depth
V	Flow velocity
SG	Specific gravity of rock material
SA	Slope angle
FA	Friction angle of rock material
C_s	Stephenson factor
n_p	Cover material porosity
τ	Actual tractive force
τ_c	Critical tractive force
η_b	Stability parameter
SF_b	Safety factor
D_{50}	Particle size such that 50% of material by weight is smaller
RF	Reduction Factor
MPV	Maximum Permissible Velocity
MPV_{RF}	Reduced Maximum Permissible Velocity
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
HMR	Hydrometeorological Report

Attachment 2
12/12/08
Piñon Ridge Project
Tailing Cells Closure Grading Plan, Drawing C2

PLOTTED: 12 Dec 2008, 5:25pm, jgordon



TAILING CELLS
CLOSURE GRADING PLAN

PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

Energy Fuels Resources
44 Union Blvd., Suite 600
Lakewood, CO 80228
PH. 303.974.2140

PRELIMINARY
NOT FOR
CONSTRUCTION

KLEINFELDER
Bright People. Right Solutions.
611 Corporate Circle, Ste. C
Golden, Colorado 80401
PH. 303.237.6601 FAX. 303.237.6602
www.kleinfelder.com

PROJ. NO.	89241
ACAD FILE:	12027_Closure Sheets.dwg
DESIGNED BY:	JAG
DRAWN BY:	JAG
CHECKED BY:	TAK
DATE:	12/12/08
SCALE:	NO SCALE

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS
0 0.5 1.0 1.5 2.0

DRAWING
C2

1 of 7 sheets

Attachment 3
1/7/09
Piñon Ridge Project
Riprap Rundown Channel HEC-RAS Output

Piñon Ridge Project
Riprap Rundown Design
Attachment 3

1/8

1/7/04

HEC-RAS Plan:

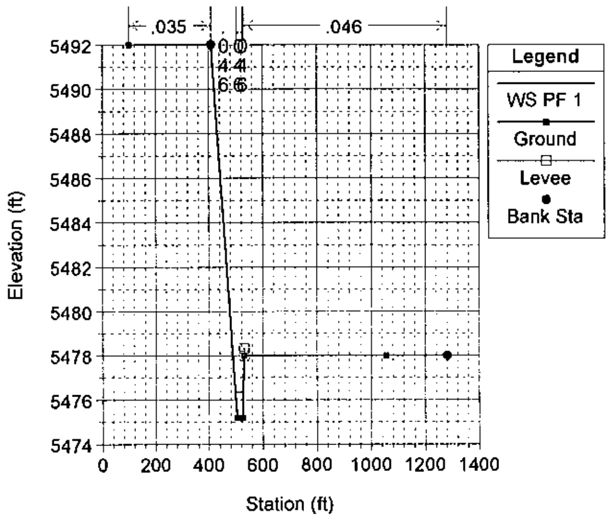
Reach	River Sta	Profile	Q Total	Vel Chnl	Hydr Depth	Length Chnl	Froude # Chl
			(cfs)	(ft/s)	(ft)	(ft)	
Reach #1	106	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.928*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.857*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.785*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.714*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.642*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.571*	PF 1	285	4.3	1.39	46.86	0.64
Reach #1	105.5*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.428*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.357*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.285*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.214*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.142*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105.071*	PF 1	285	4.3	1.39	46.86	0.65
Reach #1	105	PF 1	285	4.3	1.38	48.90	0.65
Reach #1	104.5*	PF 1	285	4.3	1.39	48.90	0.65
Reach #1	104	PF 1	285	4.3	1.38	33.40	0.65
Reach #1	103.666*	PF 1	285	4.4	1.38	33.40	0.65
Reach #1	103.333*	PF 1	285	4.5	1.36	33.40	0.68
Reach #1	103	PF 1	285	6.0	1.14	25.32	0.99
Reach #1	102.5*	PF 1	285	10.9	0.92	25.32	2.01
Reach #1	102	PF 1	285	8.5	1.11	38.76	1.43
Reach #1	101	PF 1	285	10.9	0.93	39.84	1.99
Reach #1	100.75*	PF 1	285	9.5	1.02	39.84	1.67
Reach #1	100.5*	PF 1	285	10.2	0.97	39.84	1.83
Reach #1	100.25*	PF 1	285	9.9	0.99	39.84	1.75
Reach #1	100	PF 1	285	10.1	0.98	1.00	1.79
Reach #1	99	PF 1	285	15.4	0.79	20.03	3.06
Reach #1	98.3	PF 1	285	4.9	1.97	19.48	0.62
Reach #1	98.2	PF 1	285	5.0	1.96	10.13	0.62
Reach #1	98.1	PF 1	285	4.9	1.97	10.48	0.62
Reach #1	98	PF 1	285	4.9	1.97	123.29	0.62
Reach #1	97	PF 1	285	4.9	1.96	205.12	0.62
Reach #1	96	PF 1	285	4.9	1.97	185.89	0.62
Reach #1	95	PF 1	285	4.9	1.96		0.62

Transition to Subcritical

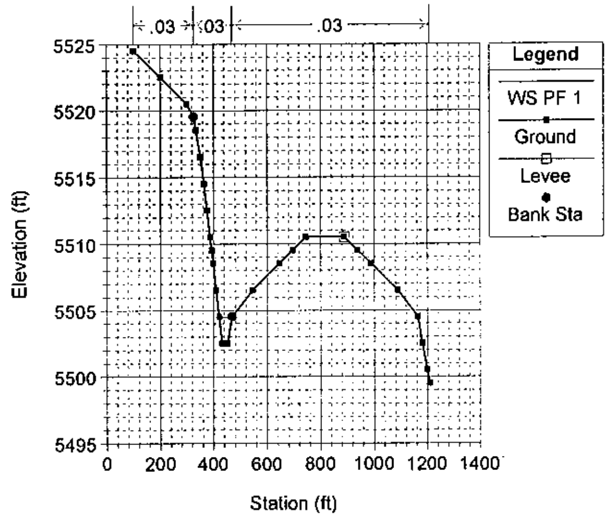
Use 25 ft for runout channel

Piñon Ridge Project
Riprap Rundown Design
Attachment 3 2/8
1/7/09

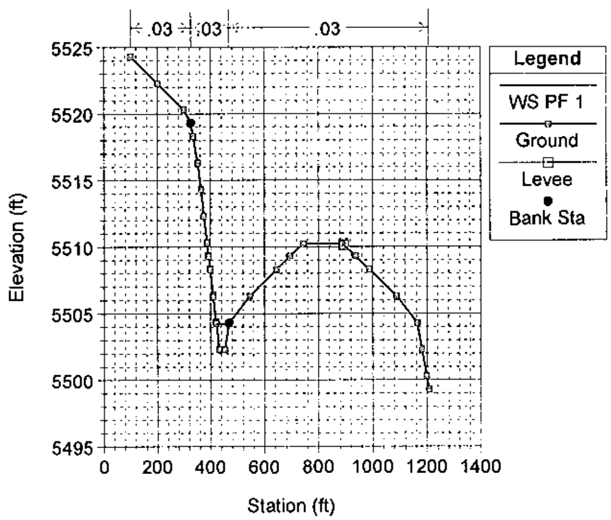
HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 100 Tailing Cell Cover Riprap Rundown Channel Profile



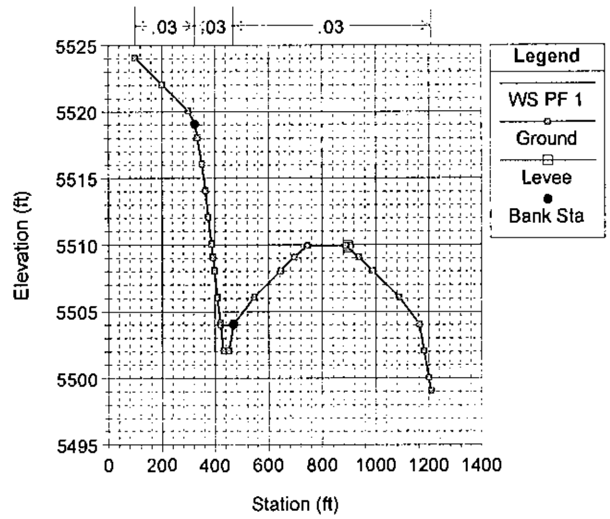
HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 106 Tailing Cell Cover Riprap Rundown Channel Profile



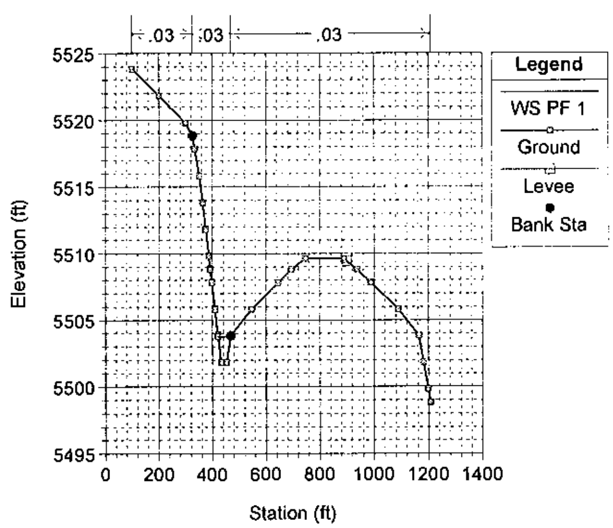
HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 105.928' Tailing Cell Cover Riprap Rundown Channel Profile



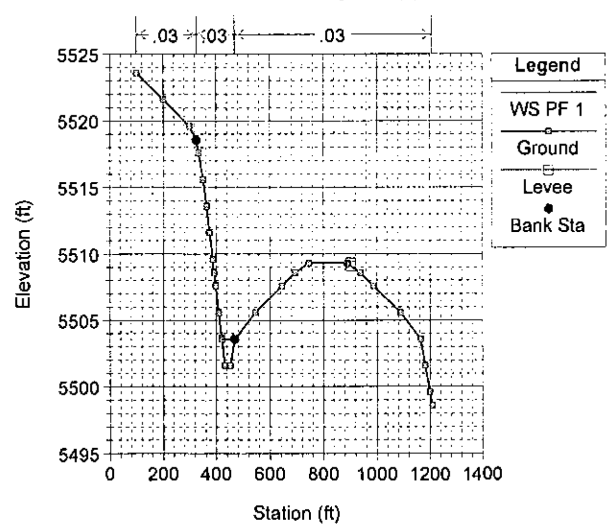
HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 105.857' Tailing Cell Cover Riprap Rundown Channel Profile



HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 105.785' Tailing Cell Cover Riprap Rundown Channel Profile

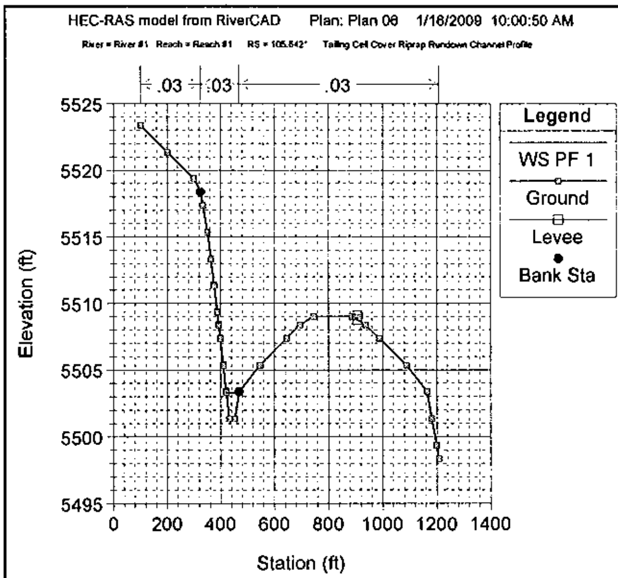


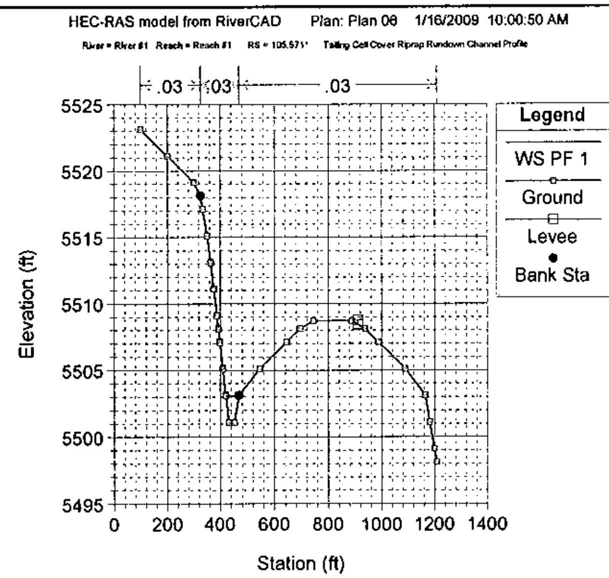
HEC-RAS model from RiverCAD Plan: Plan 06 1/16/2009 10:00:50 AM
River = River #1 Reach = Reach #1 RS = 105.714' Tailing Cell Cover Riprap Rundown Channel Profile

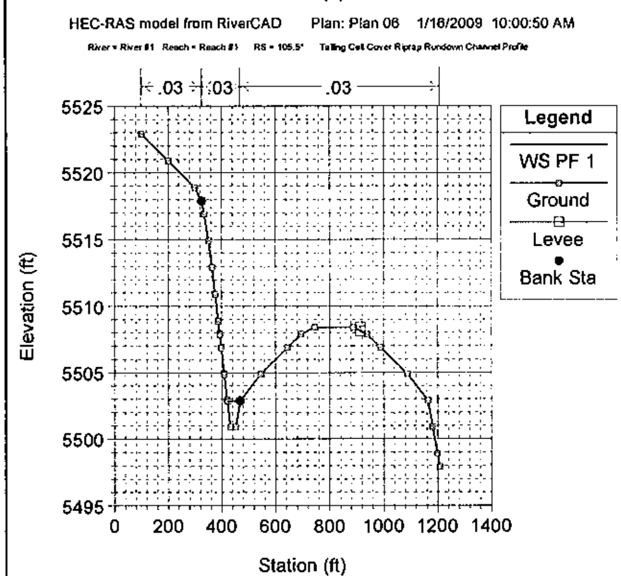


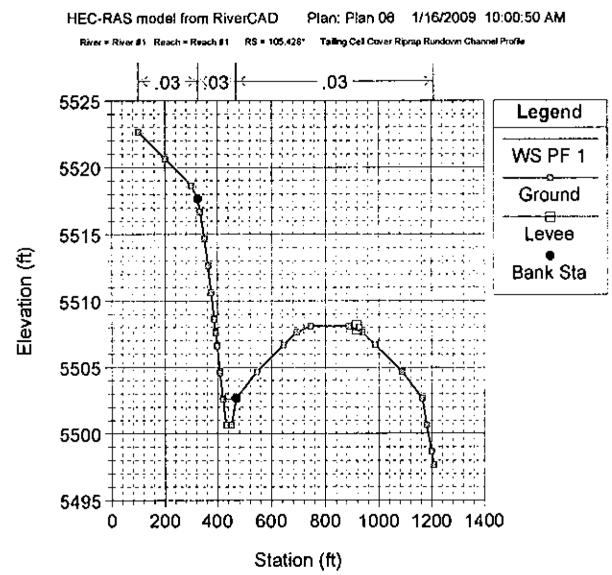
Piñon Ridge Project
Riprap Rundown Design
Attachment 3

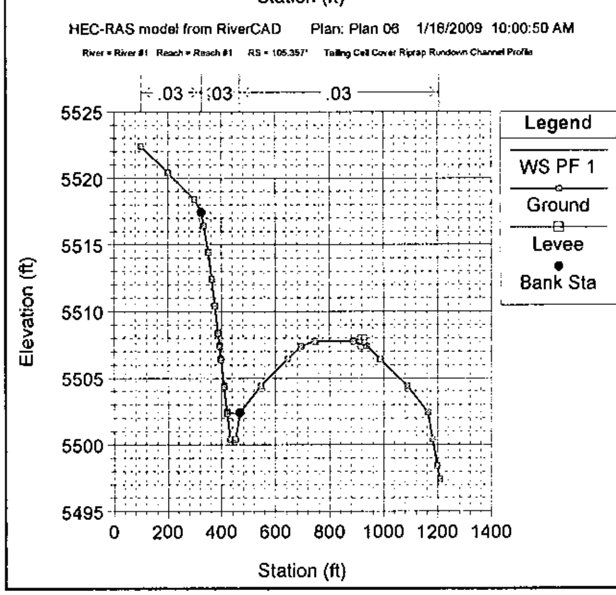
3/8
1/7/09

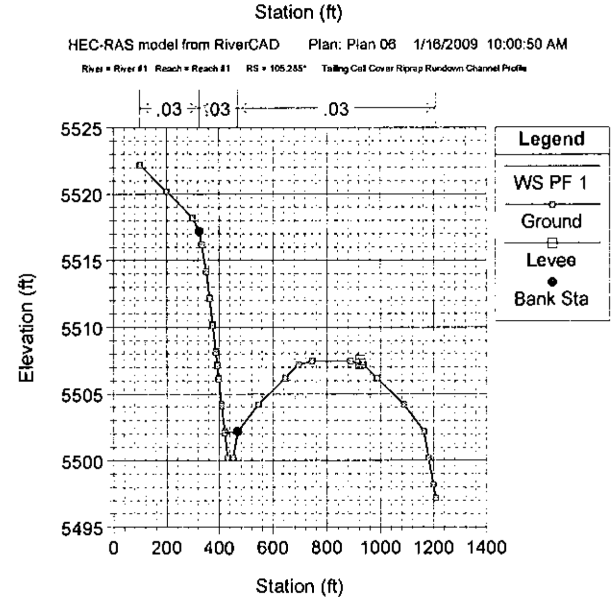








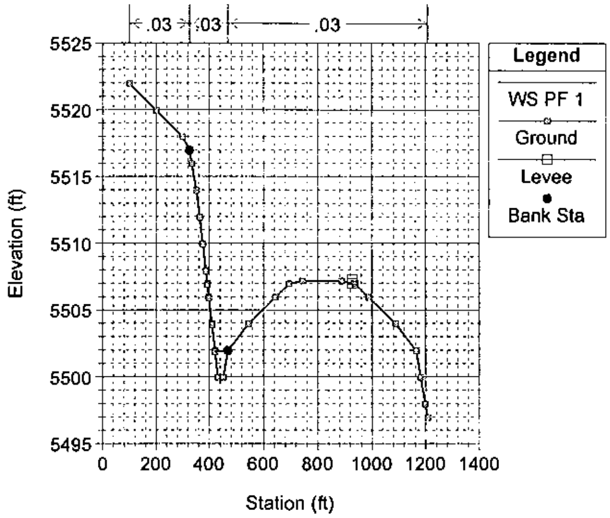




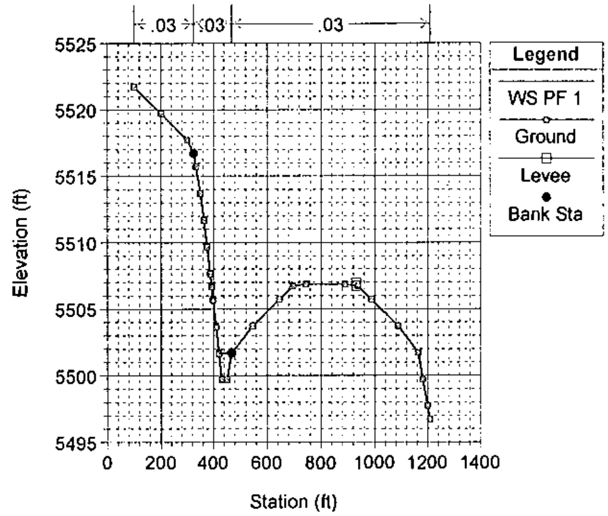
Piñon Ridge Project
Riprap Rundown Design
Attachment 3

4/8
1/7/09

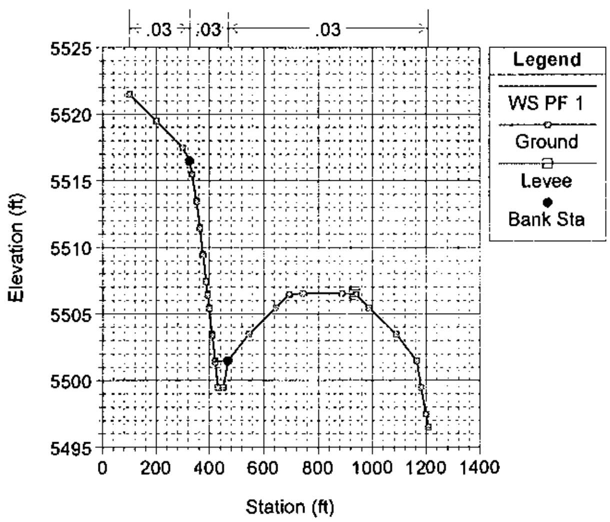
HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 105.214*   Tailing Cell Cover Riprap Rundown Channel Profile



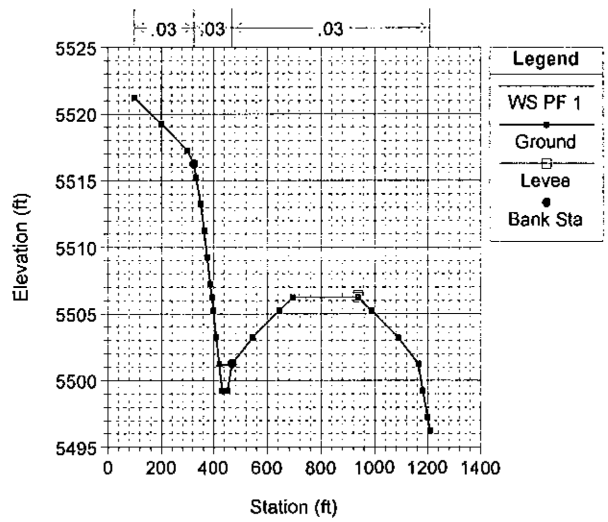
HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 105.142*   Tailing Cell Cover Riprap Rundown Channel Profile



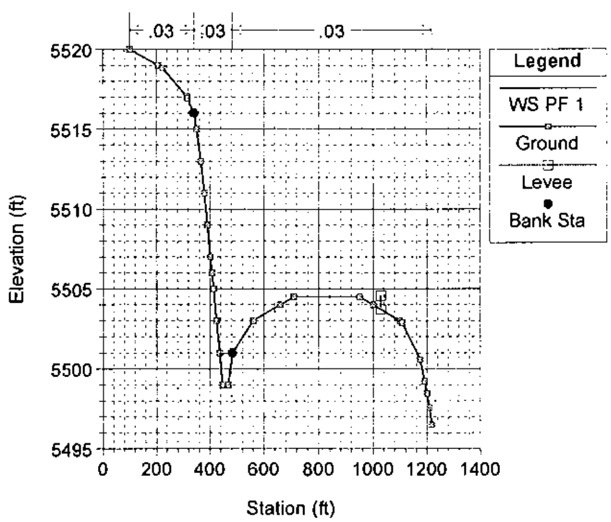
HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 105.071*   Tailing Cell Cover Riprap Rundown Channel Profile



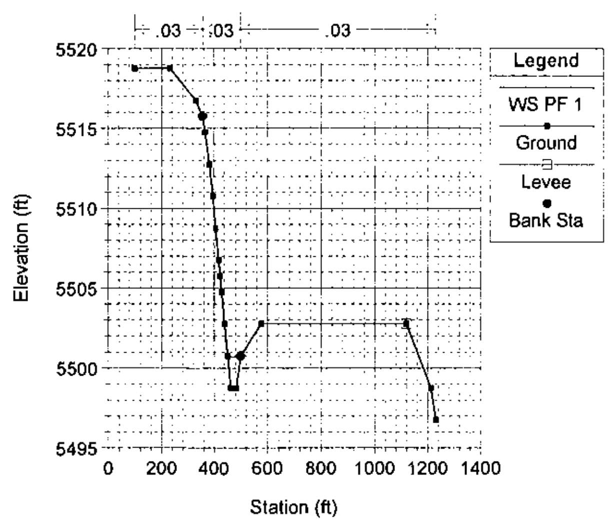
HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 105   Tailing Cell Cover Riprap Rundown Channel Profile



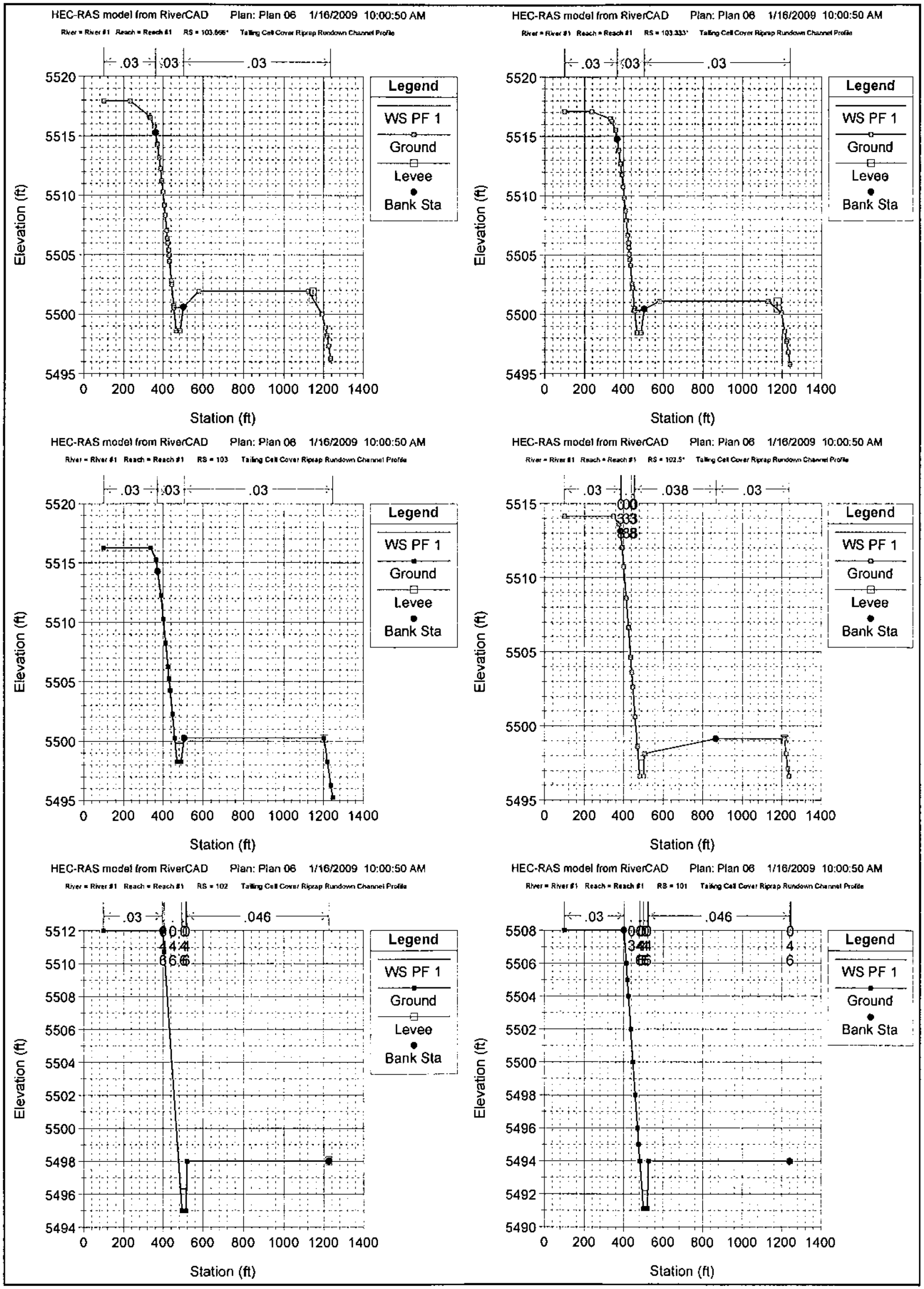
HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 104.5*   Tailing Cell Cover Riprap Rundown Channel Profile



HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
River = River #1   Reach = Reach #1   RS = 104   Tailing Cell Cover Riprap Rundown Channel Profile

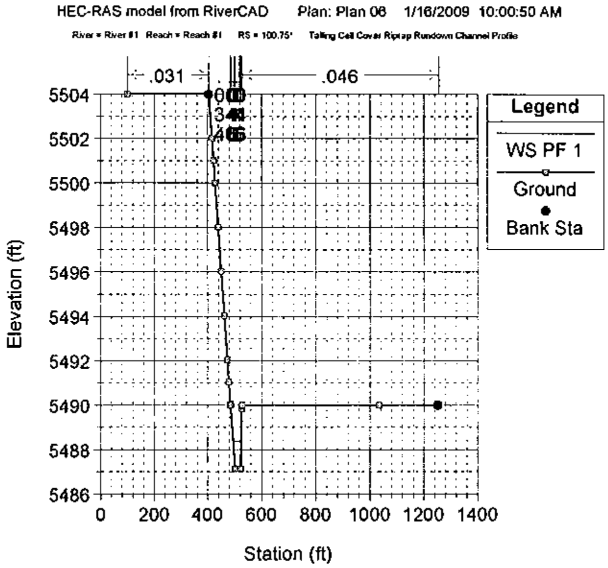


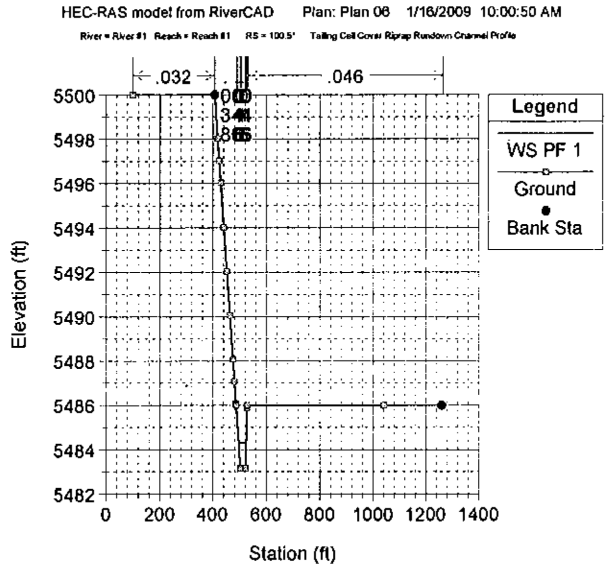
Piñon Ridge Project
Riprap Rundown Design
Attachment 3
5/8
1/7/09

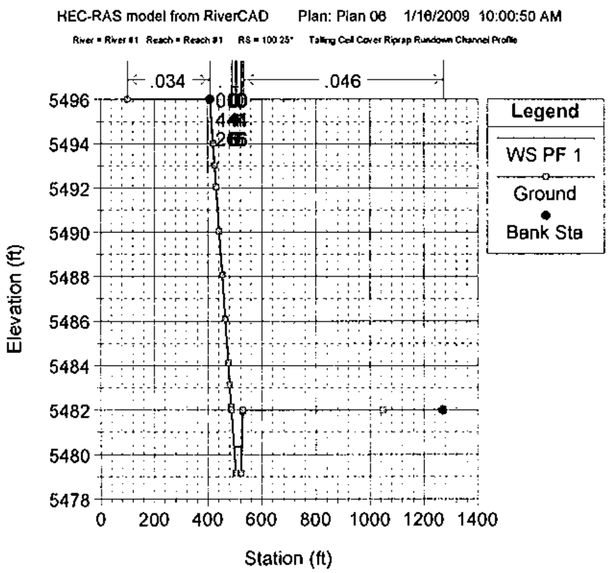


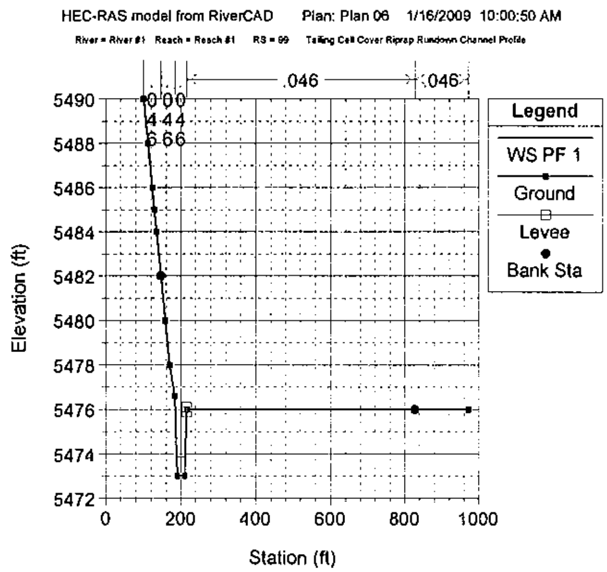
Piñon Ridge Project
Riprap Rundown Design
Attachment 3

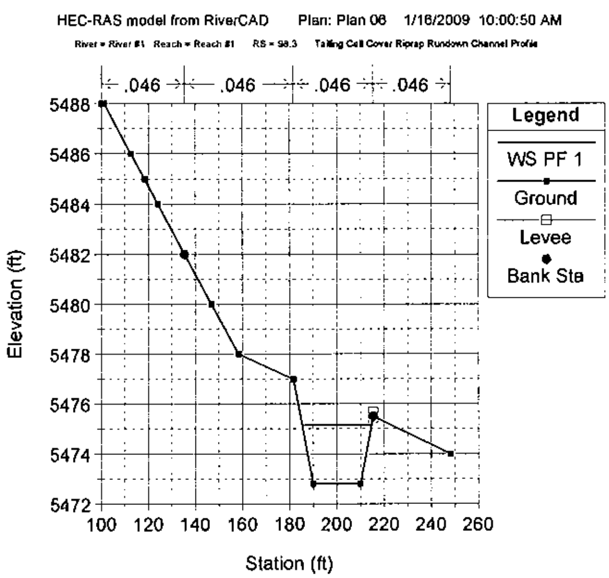
6/8
1/7/09

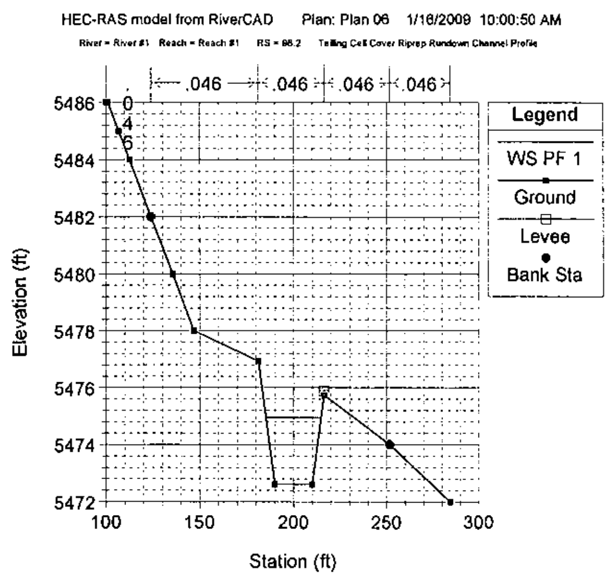






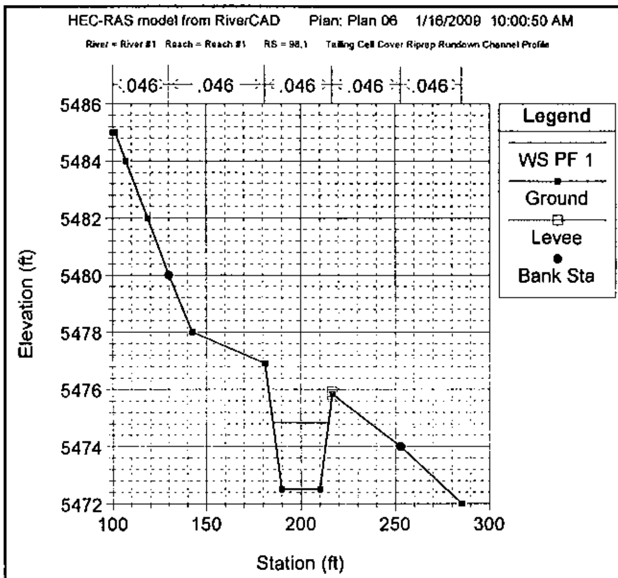


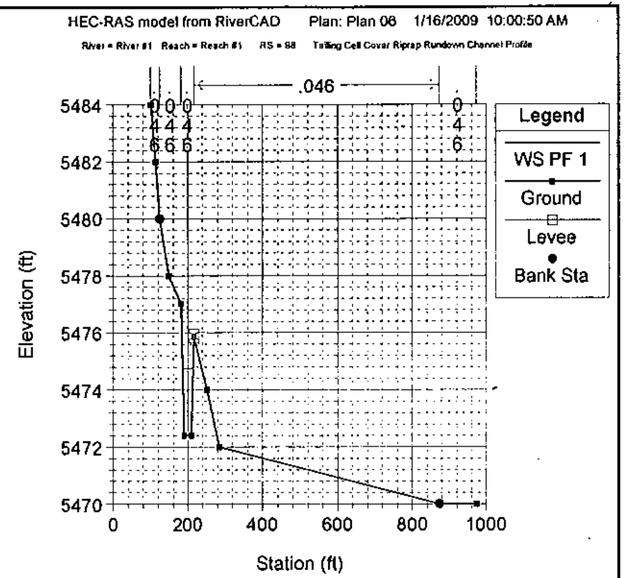


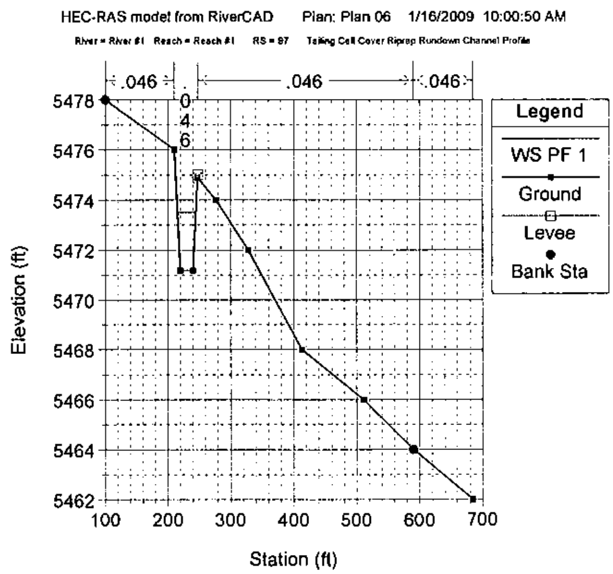


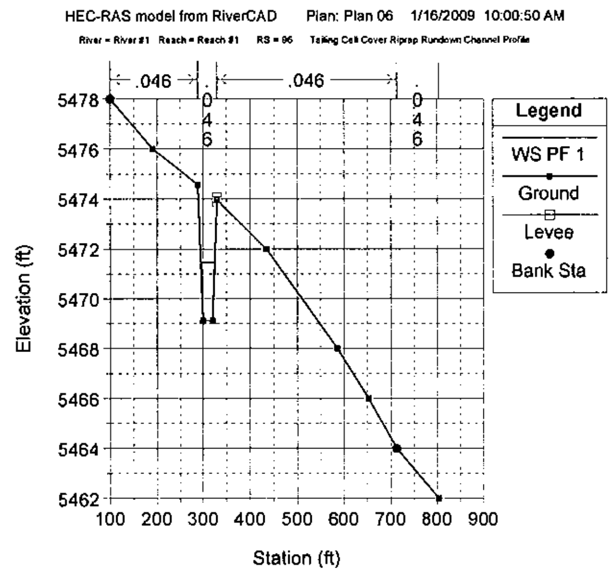
Piñon Ridge Project
Riprap Rundown Design
Attachment 3

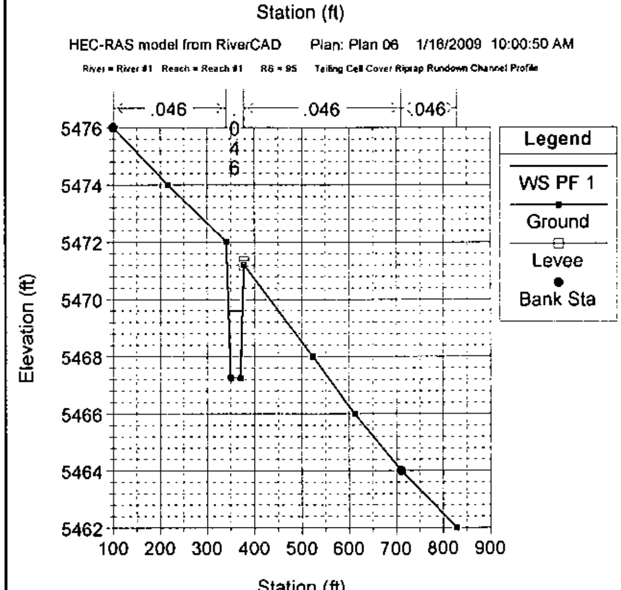
7/8
1/7/09







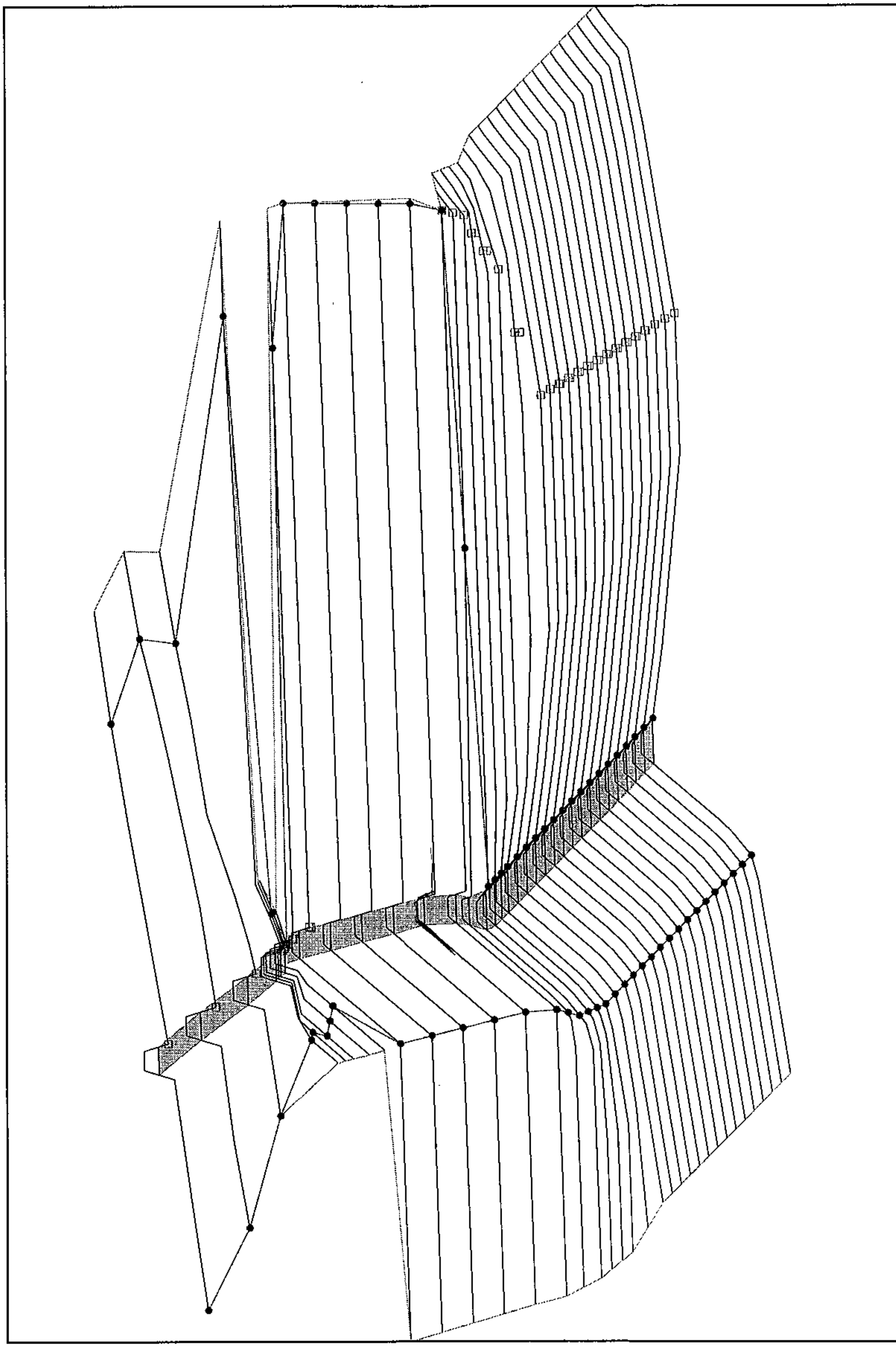




Piñon Ridge Project
Riprap Rundown Design
Attachment 3

8/8
1/7/09

HEC-RAS model from RiverCAD   Plan: Plan 06   1/16/2009 10:00:50 AM
Tailing Cell Cover Riprap Rundown Channel Profile



KLEINFELDER
Bright People. Right Solutions.

CALCULATION COVER SHEET

Date: 12/1/08 **Page** 1 **of** 9

Project No.: 89241 **Project Title:** Piñon Ridge Project

Calculation No.: 89241.7-6

Calculation Title: Tailings Diversion Berm

Design Verification Required: ☐ Yes ☑ No

Calculation Type: ☐ Scoping ☐ Preliminary ☑ Final ☐ Voided
☐ Superseded by Calculation No.: ______

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

	Rev. 0 Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date	Rev. ____ Printed Name/Signature/Date
Originator:	[signature] 12/1/08 Travis Kluthe		
Checked By:	Bruce Curtis [signature] 12/8/08		
Approved By:			
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. No.	Responsible Project Manager Initials
UZALB08WP001	Tailing Cell Closure Design Report	0	AK

RECORD OF REVISION

Rev.	Reason for Revision
0	Original Issue

ATTACHMENTS

Attachment No.	Title	Total Pages
1	HEC-1 Model Output	3

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Tailing Diversion Berm BY TAK DATE 12/1/08
89241.7-6 REVIEWED BY BAC DATE 12/8/08

Objective: Determine size of berm necessary to protect tailing cells from PMF.

Given: Drainage Area = 492 ac
Slope = 827 ft/mi
Length of Watercourse = 1.51 mi
Distance to Basin Centroid = 0.69 mi
(Attached figures)
Manning's Kn = 0.07 (Ref. 1)
Use HMR-49 6-hr Local Storm PMP as design event. (Kleinfelder Calc. No. 89241.7-1)

Assumptions:

1) Design flow is half of PMF peak flow because berm will direct approximately the same amount of runoff East and West.
2) Roughly 5% ground cover is impervious (e.g. rock outcrops). based on personnel experience.

Calculations:

Use Curve Number Method and HMR-49 6-hr rainfall distribution with synthetic unit hydrograph to build HEC-1 rainfall-runoff model.

Soil information gathered from NRCS Web Soil Survey site, 2008. Vegetation types determined by personnel survey.

Soil ID	Area (ac.)	Hydrologic Soil Group	Veg Type	(Ref. 3) CN
18	36.8	B	Sag.	51
87	216.2	D	Pin.	80
45	24.5	D	Pin.	80
88	48.0	D	Pin.	80
23	79.8	C	Pin.	73
75	26.2	D	Pin.	80
56	55.2	B	Sag.	63
104	5.3	D	Sag.	70

KLEINFELDER
Bright People. Right Solutions.

PROJECT Piñon Ridge Mill Design PROJECT NO. 89241
SUBJECT Tailing Diversion Berm BY TAK DATE 12/1/08
89241.7-6 REVIEWED BY BAC DATE 12/9/08

$$CN = \frac{(51 \cdot 36.8ac)+(80 \cdot 314.9ac)+(73 \cdot 79.8ac)+(63 \cdot 55.2ac)+(70 \cdot 5.3ac)}{492ac} = 74.7 \approx 75$$

CN = 75, assume 5% impervious from rock outcrops. (personnel survey)

See Att. 1 for HEC-1 rainfall-runoff model results. (Ref. 2)

Peak Flow from HEC-1 is 2756 cfs, ≈ 2760 cfs

Design Flow = 2760cfs/2 = 1380 cfs

A spreadsheet program uses Manning's equation to develop a rating curve for the berm under normal flow conditions.

Results:

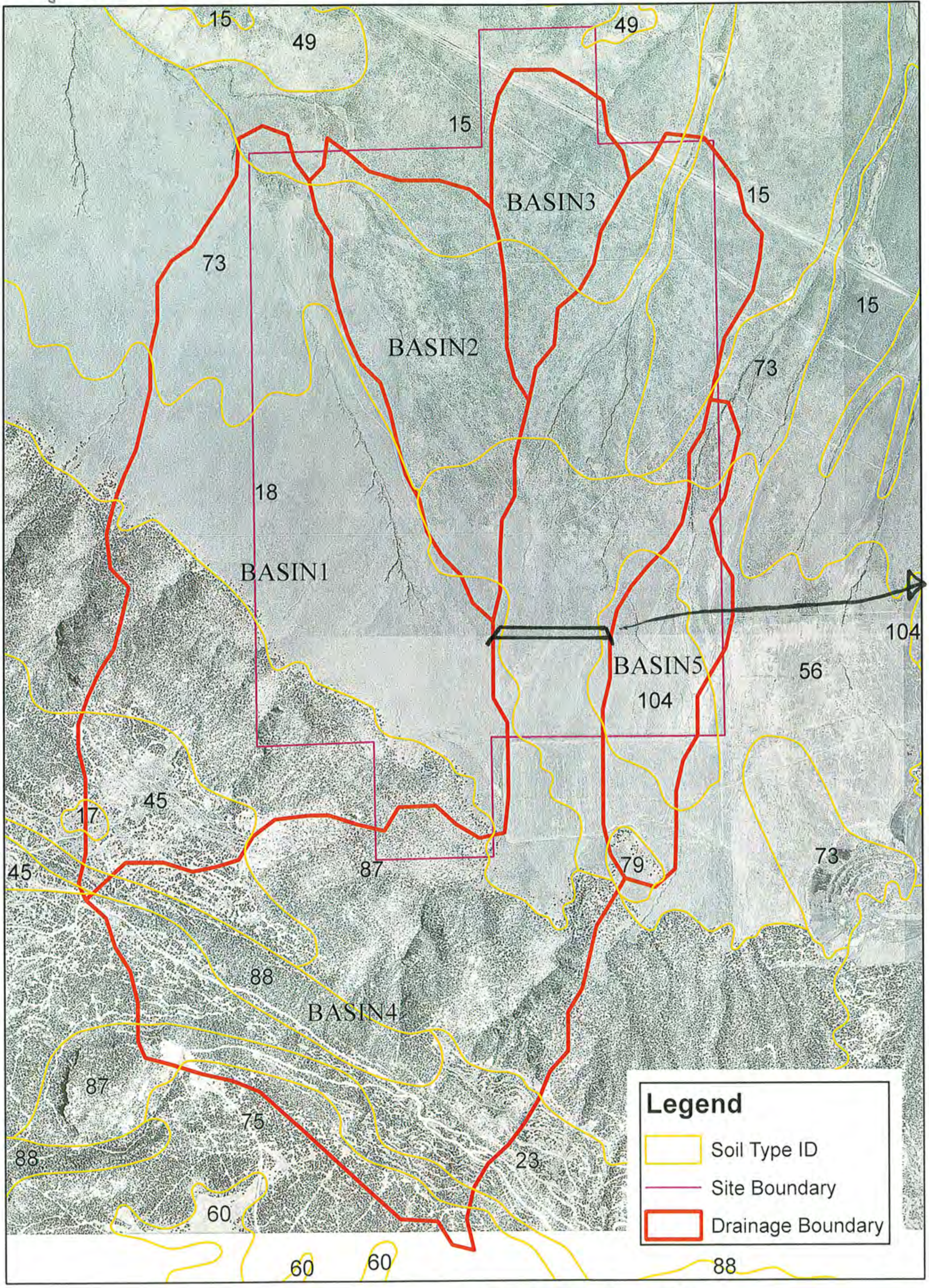
A diversion berm 6ft high with a 3H:1V side slope lined with d_{50} = 9" riprap will be required to divert the PMF runoff to natural drainages. The berm should be constructed near the Southern toe of Tailing Cell A.

References:

1) Bureau of Reclamation. Flood Hydrology Manual. Water Resources Technical Publication. Denver, 1989.
2) U.S. Army Corps of Engineers. Hydrologic Engineering Center's Flood Hydrograph Package. June 1998.
3) Soil Conservation Service (SCS). Technical Report 55. Urban Hydrology for Small Watersheds. June, 1986.

Piñon Ridge Project
Tailings Diversion Berm

4/9
12/1/08



Approximate location of diversion berm

1 inch equals 1,500 feet

0 750 1,500 3,000 Feet

Pinon Ridge Basins Map
Drainage Alternative 2

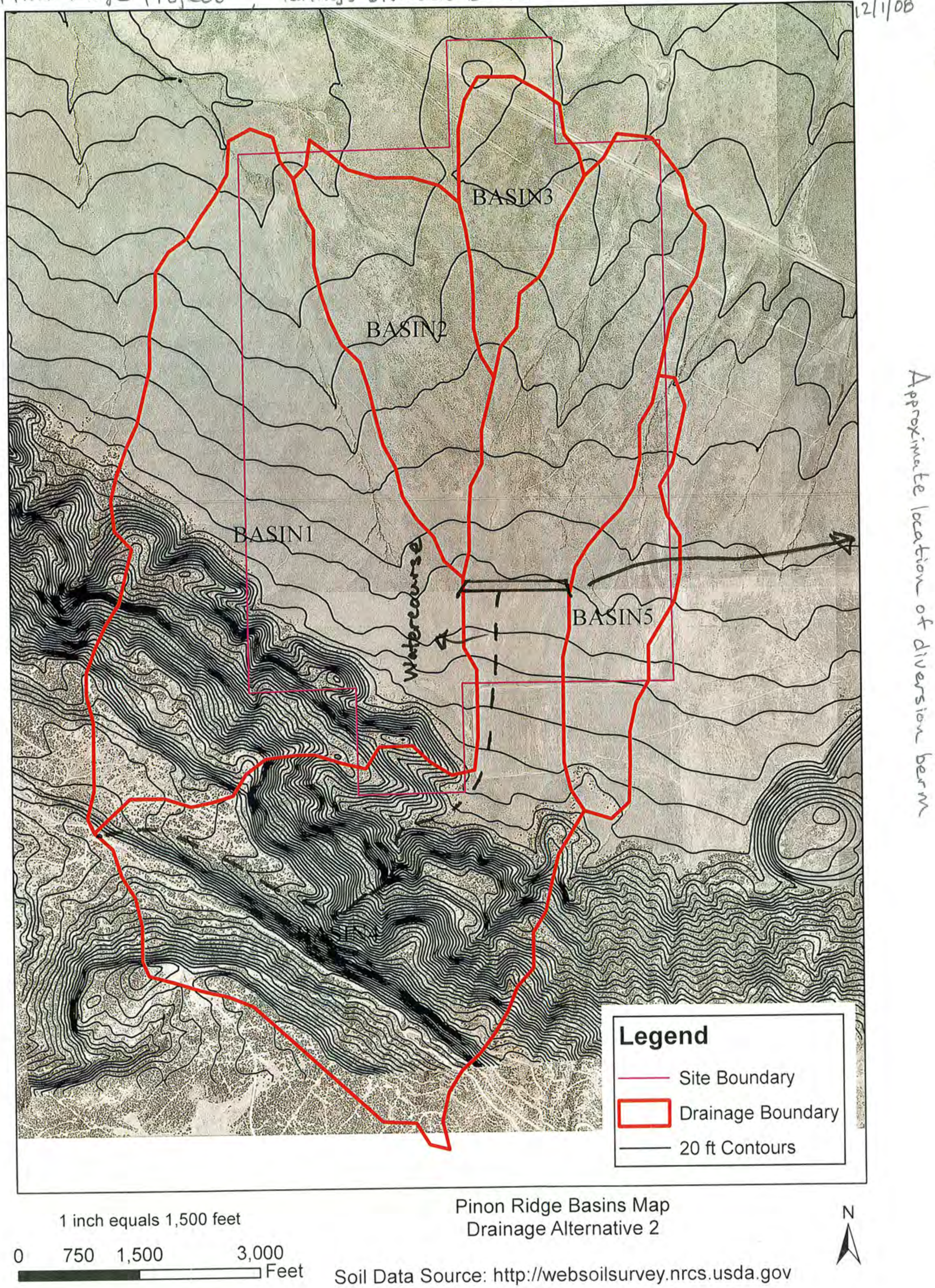
N

Soil Data Source: http://websoilsurvey.nrcs.usda.gov

Piñon Ridge Project, Tailings Diversion Berm

5/9

12/1/08



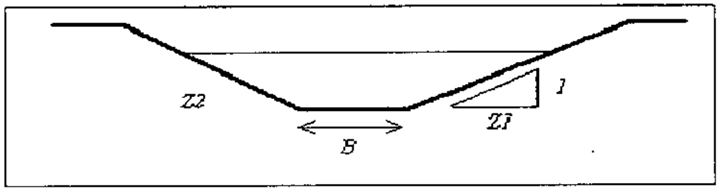
Pinon Ridge Basins Map
Drainage Alternative 2

Soil Data Source: http://websoilsurvey.nrcs.usda.gov

Piñon Ridge Project
Tailings Diversion Berm

6/9
12/1/08

RATING CURVE FOR TRAPEZOIDAL CHANNEL

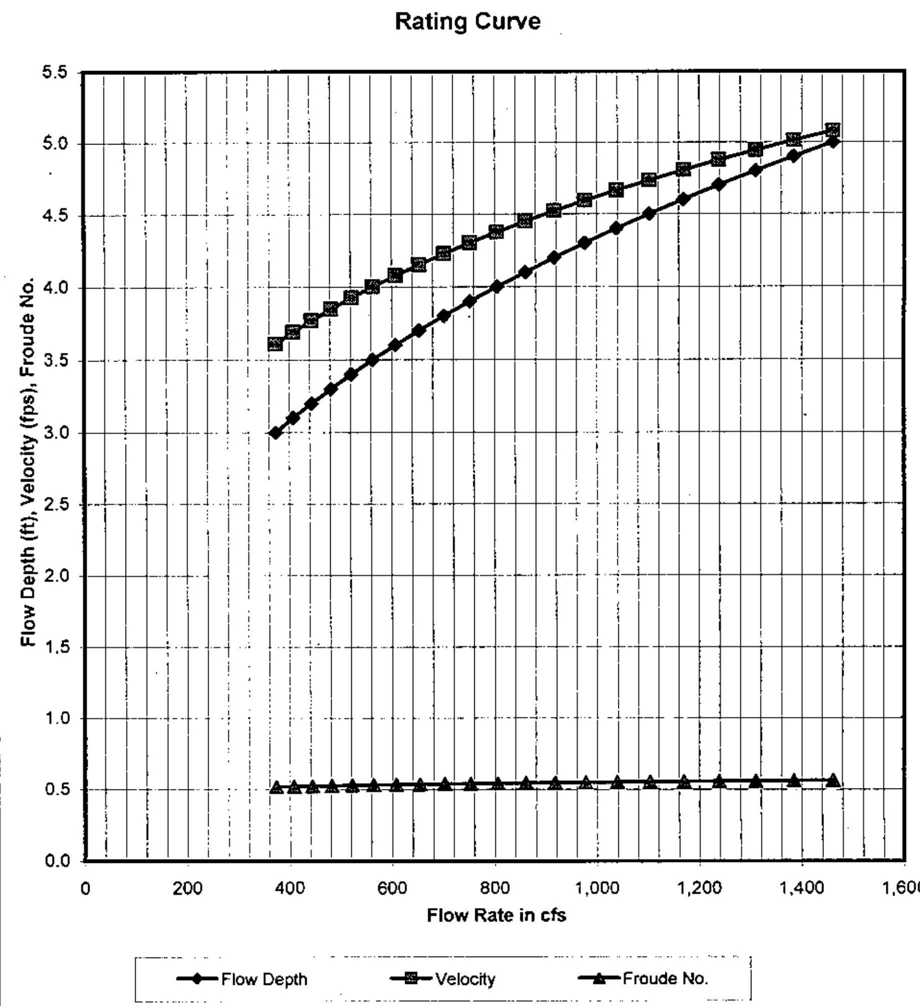


Bottom Width	B =	0.00	feet
Left Side Slope	Z1 =	20.00	ft/ft
Right Side Slope	Z2 =	3.00	ft/ft
Manning's n	n =	0.038	
Longitudinal Slope	S =	0.0050	ft/ft

Flow Depth Y (ft)	Flow Area A (sq ft)	Wetted Perimeter P (ft)	Hydraulic Radius R (ft)	Flow Velocity V (fps)	Flow rate Q (cfs)	Froude Number Fr
3.00	103.50	69.56	1.49	3.6	373.5	0.52
3.10	110.52	71.88	1.54	3.7	407.7	0.52
3.20	117.76	74.20	1.59	3.8	443.7	0.52
3.30	125.24	76.52	1.64	3.8	481.7	0.53
3.40	132.94	78.84	1.69	3.9	521.7	0.53
3.50	140.88	81.16	1.74	4.0	563.7	0.53
3.60	149.04	83.47	1.79	4.1	607.7	0.54
3.70	157.44	85.79	1.84	4.2	653.8	0.54
3.80	166.06	88.11	1.88	4.2	702.1	0.54
3.90	174.92	90.43	1.93	4.3	752.5	0.54
4.00	184.00	92.75	1.98	4.4	805.1	0.55
4.10	193.32	95.07	2.03	4.4	860.0	0.55
4.20	202.86	97.39	2.08	4.5	917.2	0.55
4.30	212.64	99.71	2.13	4.6	976.6	0.55
4.40	222.64	102.02	2.18	4.7	1,038.5	0.55
4.50	232.88	104.34	2.23	4.7	1,102.7	0.56
4.60	243.34	106.66	2.28	4.8	1,169.3	0.56
4.70	254.04	108.98	2.33	4.9	1,238.4	0.56
4.80	264.96	111.30	2.38	4.9	1,310.0	0.56
4.90	276.12	113.62	2.43	5.0	1,384.2	0.56
5.00	287.50	115.94	2.48	5.1	1,460.9	0.57

PMF

RATING CURVE FOR TRAPEZOIDAL CHANNEL



Use 1ft freeboard for 6ft high diversion berm.

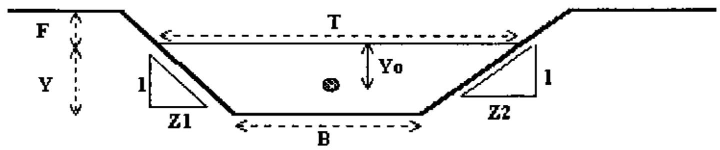
Piñon Ridge Project
Tailings Diversion Berm

12/1/08

Design of Riprap Channel Cross Section

Project: ______________________

Channel ID: ______________________



Design Information (Input)			
Channel Invert Slope	So =	0.0100	ft/ft
Bottom Width	B =	0.0	ft
Left Side Slope	Z1 =	20.0	ft/ft
Right Side Slope	Z2 =	3.0	ft/ft
Specific Gravity of Rock	Ss =	2.65	
Radius of Channel Centerline	Ccr =	10,000.0	ft
Design Disharge	**Q =**	**1,380.0**	**cfs**
Flow Condition (Calculated)			
Riprap Type (Straight Channel)	**Type =**	**L**	
Intermediate Rock Diameter (Straight Channel)	**D50 =**	**9**	**inches**
Calculated Manning's n (Straight Channel)	**n =**	**0.0377**	
Riprap Type (Outside Bend of Curved Channel)	**Type =**	**L**	
Intermediate Rock Dia. (O.B. of Curved Channel)	**D50 =**	**9**	**inches**
Calculated Manning's N (Curved Channel)	**n =**	**0.0377**	
Water Depth	Y =	4.29	ft
Top Width of Flow	T =	98.7	ft
Flow Area	A =	211.6	sq ft
Wetted Perimeter	P =	99.5	ft
Hydraulic Radius (A/P)	R =	2.1	ft
Average Flow Velocity (Q/A)	V =	6.5	fps
Hydraulic Depth (A/T)	D =	2.1	ft
Froude Number (max. = 0.8)	Fr =	0.79	
Channel Radius / Top Width	Ccr/T =	101.35	
Riprap Design Velocity Factor For Curved Channel	Kv =	1.00	
Riprap Sizing Velocity For Curved Channel	V_{Kv} =	6.6	fps
Riprap Sizing Paramenter for Straight Channel	**K =**	**2.15**	
Riprap Sizing Paramenter for Outside Bend of Curve	**K_{curve} =**	**2.15**	
Superelevation (dh)	dh =	0.00	ft
Discharge (Check)	**Q =**	**1,385.6**	**cfs**

Check on Rock Size for Riprap

Range of K, K_{curve}	Riprap	D50
< 3.3	VL	6 inch
≥ 3.3 to < 4.0	L	9 inch
≥ 4.0 to < 4.6	M	12 inch
≥ 4.6 to < 5.6	H	18 inch
≥ 5.6 to 6.4	VH	24 inch

Piñon Ridge Project
Tailings Diversion Berm

8/9
12/1/08

Table 2-2d Runoff curve numbers for arid and semiarid rangelands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition [2]	A [3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

Soil Conservation Service (SCS), Technical Report 55, Urban Hydrology for Small Watersheds. June, 1986.

Piñon Ridge Project
Tailings Diversion Berm

9/9
12/1/08

ROCKY MOUNTAIN (THUNDERSTORM) UNIT HYDROGRAPH 02-Dec-08

Pinon Ridge Uranium Mill Site Diversion Alternative 2

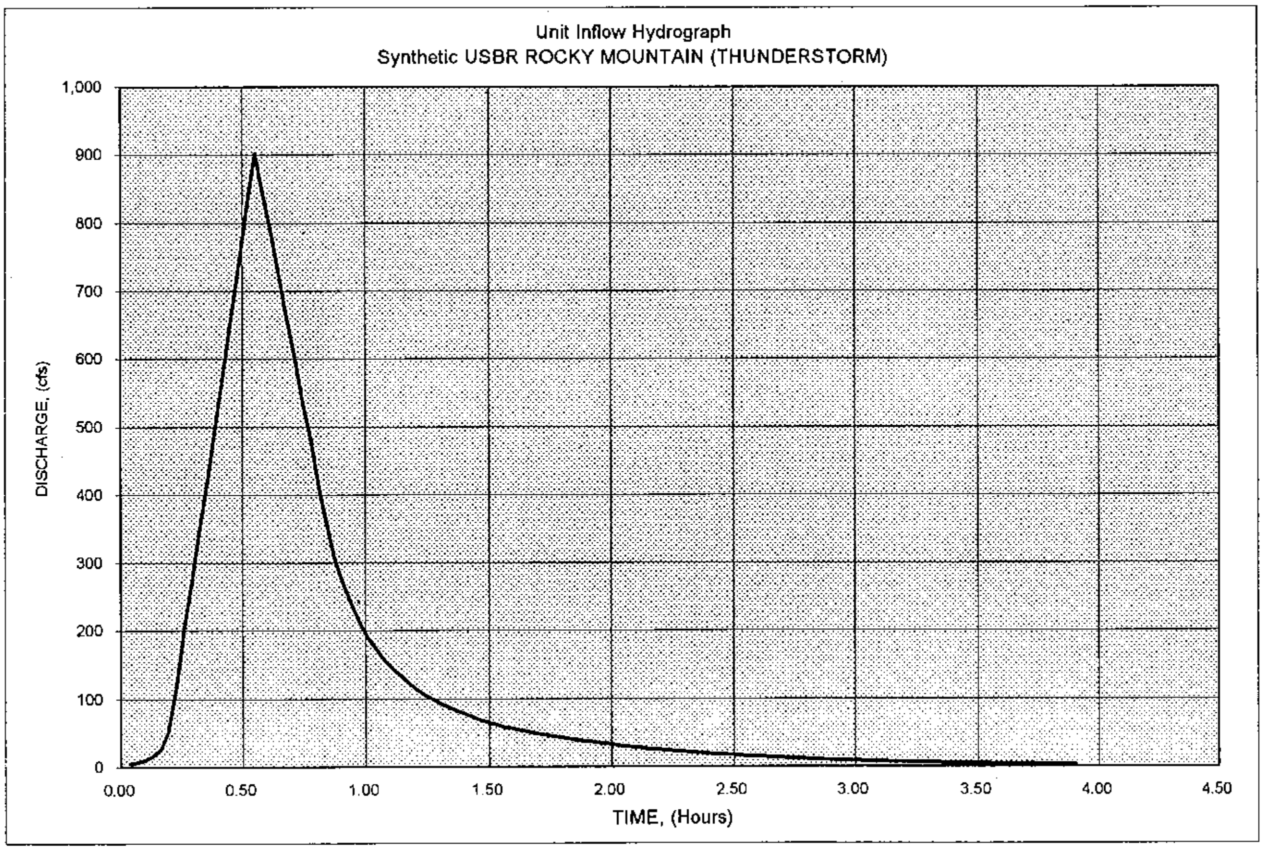
Drainage Area =	0.77	sq. miles	Lg+D/2 =	0.65	Hours
Basin Slope =	827.00	ft./mile	Basin Factor =	0.04	
L =	1.51	mi., Length of Watercourse	V' =	20.71	cfs/Day
Lca =	0.69	mi., Distance to Centroid	Qs =	31.8	* q, cfs
Kn =	0.070	-, Ave. Weighted Manning's n			

PARAMETERS:

Calculated: Lag Time, Lg = 0.61 Hours — Unit Duration, D = 6.64 minutes; Calculated Timestep = 1.95 minutes

Data to be used in Analysis Unit Duration, D = 5 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360

Selected Timestep = 5 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 5 **minute interval**

UI	9	30	177	366	565	771	848	692	532	373
UI	262	196	154	125	103	88	75	65	57	51
UI	46	41	36	33	29	26	23	21	19	17
UI	15	13	12	10	9	9	8	7	6	5
UI	5	5	4	4	3	3	2			
UI										
UI										
UI										
UI										
UI										
UI										
UI										

UI Records used in HEC-1 model analysis. (Attachment 1)

USBR calculated unitgraph peak = 903 Interpolated Peak = 848

Attachment 1
12/1/08
Piñon Ridge Project
Tailings Diversion Berm HEC-1 Output

Piñon Ridge Project
Tailings Diversion Berm
Attachment 1

1/3
12/1/08

```
1****************************************                ****************************************
 *                                      *                *                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                *  U.S. ARMY CORPS OF ENGINEERS        *
 *             JUN   1998               *                *  HYDROLOGIC ENGINEERING CENTER       *
 *           VERSION 4.1                *                *        609 SECOND STREET             *
 *                                      *                *     DAVIS, CALIFORNIA 95616          *
 * RUN DATE   02FEB09  TIME  14:16:48   *                *         (916) 756-1104               *
 *                                      *                *                                      *
 ****************************************                ****************************************


                          X       X  XXXXXXX   XXXXX          X
                          X       X  X        X     X        XX
                          X       X  X        X               X
                          XXXXXXX    XXXX     X       XXXXX   X
                          X       X  X        X               X
                          X       X  X        X     X         X
                          X       X  XXXXXXX   XXXXX         XXX


         THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

         THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
         THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
         NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
         DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
         KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM
```

```
1                                           HEC-1 INPUT                                              PAGE  1

        LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 *** FREE ***
          1         ID   ENERGY FUELS - PINON RIDGE PROJECT
          2         ID   PROJECT NO. 89241
          3         ID   TAILINGS CLOSURE DIVERSION BERM DESIGN HYDROLOGY
          4         ID   6-HR HMR 49 LOCAL STORM
          5         ID   ROCKY MOUNTAIN LOCAL STORM UNIT GRAPH  KN=0.07
          6         IT       5       0       0     100
          7         IO       5       1
                    *

          8         KK   DVBRM
          9         KM   DRAINAGE ALTERNATIVE 2
         10         BA    0.77
         11         IN      60
         12         PB       0
         13         PC     0.1     0.7     8.8     9.6     9.9     9.9
         14         LS       0      75       5
         15         UI       9      30     177     366     565     771     848     692     532     373
         16         UI     262     196     154     125     103      88      75      65      57      51
         17         UI      46      41      36      33      29      26      23      21      19      17
         18         UI      15      13      12      10       9       9       8       7       6       5
         19         UI       5       5       4       4       3       3       2
         20         KO       1
                    *
         21         ZZ
```



```
1****************************************                ****************************************
 *                                      *                *                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                *  U.S. ARMY CORPS OF ENGINEERS        *
 *             JUN   1998               *                *  HYDROLOGIC ENGINEERING CENTER       *
 *           VERSION 4.1                *                *        609 SECOND STREET             *
 *                                      *                *     DAVIS, CALIFORNIA 95616          *
 * RUN DATE   02FEB09  TIME  14:16:48   *                *         (916) 756-1104               *
 *                                      *                *                                      *
 ****************************************                ****************************************
```



```
                    ENERGY FUELS - PINON RIDGE PROJECT
                    PROJECT NO. 89241
                    TAILINGS CLOSURE DIVERSION BERM DESIGN HYDROLODY
                    6-HR HMR 49 LOCAL STORM
```

Piñon Ridge Project
Tailings Diversion Berm
Attachment 1

2/3
12/1/08

```
                    ROCKY MOUNTAIN LOCAL STORM UNIT GRAPH  KN=0.07

  7 IO        OUTPUT CONTROL VARIABLES
                    IPRNT          5  PRINT CONTROL
                    IPLOT          1  PLOT CONTROL
                    QSCAL         0.  HYDROGRAPH PLOT SCALE

    IT        HYDROGRAPH TIME DATA
                     NMIN          5  MINUTES IN COMPUTATION INTERVAL
                    IDATE     1    0  STARTING DATE
                    ITIME       0000  STARTING TIME
                       NQ        100  NUMBER OF HYDROGRAPH ORDINATES
                   NDDATE     1    0  ENDING DATE
                   NDTIME       0815  ENDING TIME
                    ICENT         19  CENTURY MARK

             COMPUTATION INTERVAL      .08 HOURS
                  TOTAL TIME BASE     8.25 HOURS

      ENGLISH UNITS
           DRAINAGE AREA         SQUARE MILES
           PRECIPITATION DEPTH   INCHES
           LENGTH, ELEVATION     FEET
           FLOW                  CUBIC FEET PER SECOND
           STORAGE VOLUME        ACRE-FEET
           SURFACE AREA          ACRES
           TEMPERATURE           DEGREES FAHRENHEIT

*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***

        **************
        *            *
  8 KK  *    DVBRM   *
        *            *
        **************

 20 KO        OUTPUT CONTROL VARIABLES
                    IPRNT          1  PRINT CONTROL
                    IPLOT          1  PLOT CONTROL
                    QSCAL         0.  HYDROGRAPH PLOT SCALE

           SUBBASIN RUNOFF DATA

 10 BA        SUBBASIN CHARACTERISTICS
                    TAREA        .77  SUBBASIN AREA

              PRECIPITATION DATA

 12 PB              STORM       9.80  BASIN TOTAL PRECIPITATION

 13 PI          INCREMENTAL PRECIPITATION PATTERN
                    .05       .05       .05       .05       .05       .05       .05       .05       .05       .05
                    .05       .05       .68       .68       .67       .67       .68       .68       .67       .68
                    .68       .67       .68       .67       .07       .07       .07       .07       .07       .07
                    .07       .07       .07       .07       .07       .07       .02       .03       .02       .02
                    .03       .02       .02       .03       .02       .02       .03       .02

 14 LS        SCS LOSS RATE
                   STRTL         .67  INITIAL ABSTRACTION
                  CRVNBR       75.00  CURVE NUMBER
                   RTIMP        5.00  PERCENT IMPERVIOUS AREA

 15 UI        INPUT UNITGRAPH,  47 ORDINATES,  VOLUME = 1.00
                  9.0      30.0     177.0     366.0     565.0     771.0     848.0     692.0     532.0     373.0
                262.0     196.0     154.0     125.0     103.0      88.0      75.0      65.0      57.0      51.0
                 46.0      41.0      36.0      33.0      29.0      26.0      23.0      21.0      19.0      17.0
                 15.0      13.0      12.0      10.0       9.0       9.0       8.0       7.0       6.0       5.0
                  5.0       5.0       4.0       4.0       3.0       3.0       2.0
                                                             ***

***********************************************************************************************************************************

                                              HYDROGRAPH AT STATION     DVBRM

***********************************************************************************************************************************
                                                             *
     DA MON HRMN  ORD     RAIN    LOSS  EXCESS     COMP Q    *     DA MON HRMN  ORD     RAIN    LOSS  EXCESS     COMP Q
```

Piñon Ridge Project
Tailing Diversion Berm
Attachment 1

3/3
12/1/08

1	0000	1	.00	.00	.00	0.	*	1	0410	51	.00	.00	.00	244.
1	0005	2	.05	.05	.00	0.	*	1	0415	52	.00	.00	.00	228.
1	0010	3	.05	.05	.00	0.	*	1	0420	53	.00	.00	.00	210.
1	0015	4	.05	.05	.00	1.	*	1	0425	54	.00	.00	.00	187.
1	0020	5	.05	.05	.00	1.	*	1	0430	55	.00	.00	.00	161.
1	0025	6	.05	.05	.00	3.	*	1	0435	56	.00	.00	.00	134.
1	0030	7	.05	.05	.00	5.	*	1	0440	57	.00	.00	.00	112.
1	0035	8	.05	.05	.00	7.	*	1	0445	58	.00	.00	.00	94.
1	0040	9	.05	.05	.00	9.	*	1	0450	59	.00	.00	.00	81.
1	0045	10	.05	.05	.00	10.	*	1	0455	60	.00	.00	.00	71.
1	0050	11	.05	.05	.00	11.	*	1	0500	61	.00	.00	.00	61.
1	0055	12	.05	.05	.00	12.	*	1	0505	62	.00	.00	.00	53.
1	0100	13	.05	.05	.00	12.	*	1	0510	63	.00	.00	.00	46.
1	0105	14	.68	.55	.12	14.	*	1	0515	64	.00	.00	.00	40.
1	0110	15	.68	.39	.28	19.	*	1	0520	65	.00	.00	.00	35.
1	0115	16	.67	.29	.38	46.	*	1	0525	66	.00	.00	.00	30.
1	0120	17	.67	.23	.45	122.	*	1	0530	67	.00	.00	.00	25.
1	0125	18	.68	.18	.50	270.	*	1	0535	68	.00	.00	.00	21.
1	0130	19	.68	.15	.53	503.	*	1	0540	69	.00	.00	.00	17.
1	0135	20	.67	.12	.55	819.	*	1	0545	70	.00	.00	.00	14.
1	0140	21	.68	.10	.57	1177.	*	1	0550	71	.00	.00	.00	11.
1	0145	22	.68	.09	.59	1531.	*	1	0555	72	.00	.00	.00	9.
1	0150	23	.67	.08	.60	1853.	*	1	0600	73	.00	.00	.00	8.
1	0155	24	.68	.07	.61	2132.	*	1	0605	74	.00	.00	.00	7.
1	0200	25	.67	.06	.62	2368.	*	1	0610	75	.00	.00	.00	6.
1	0205	26	.07	.01	.06	2561.	*	1	0615	76	.00	.00	.00	5.
1	0210	27	.07	.01	.06	2712.	*	1	0620	77	.00	.00	.00	5.
1	0215	28	.07	.01	.06	2756.	*	1	0625	78	.00	.00	.00	4.
1	0220	29	.07	.01	.06	2672.	*	1	0630	79	.00	.00	.00	3.
1	0225	30	.07	.01	.06	2457.	*	1	0635	80	.00	.00	.00	3.
1	0230	31	.07	.01	.06	2111.	*	1	0640	81	.00	.00	.00	2.
1	0235	32	.07	.01	.06	1706.	*	1	0645	82	.00	.00	.00	2.
1	0240	33	.07	.00	.06	1376.	*	1	0650	83	.00	.00	.00	2.
1	0245	34	.07	.00	.06	1126.	*	1	0655	84	.00	.00	.00	1.
1	0250	35	.07	.00	.06	958.	*	1	0700	85	.00	.00	.00	1.
1	0255	36	.07	.00	.06	846.	*	1	0705	86	.00	.00	.00	1.
1	0300	37	.07	.00	.06	766.	*	1	0710	87	.00	.00	.00	1.
1	0305	38	.02	.00	.02	707.	*	1	0715	88	.00	.00	.00	1.
1	0310	39	.03	.00	.02	659.	*	1	0720	89	.00	.00	.00	1.
1	0315	40	.02	.00	.02	615.	*	1	0725	90	.00	.00	.00	0.
1	0320	41	.02	.00	.02	571.	*	1	0730	91	.00	.00	.00	0.
1	0325	42	.03	.00	.02	524.	*	1	0735	92	.00	.00	.00	0.
1	0330	43	.02	.00	.02	472.	*	1	0740	93	.00	.00	.00	0.
1	0335	44	.02	.00	.02	421.	*	1	0745	94	.00	.00	.00	0.
1	0340	45	.03	.00	.02	378.	*	1	0750	95	.00	.00	.00	0.
1	0345	46	.02	.00	.02	342.	*	1	0755	96	.00	.00	.00	0.
1	0350	47	.02	.00	.02	314.	*	1	0800	97	.00	.00	.00	0.
1	0355	48	.03	.00	.02	292.	*	1	0805	98	.00	.00	.00	0.
1	0400	49	.02	.00	.02	273.	*	1	0810	99	.00	.00	.00	0.
1	0405	50	.00	.00	.00	258.	*	1	0815	100	.00	.00	.00	0.

```
*****************************************************************************************************

   TOTAL RAINFALL =    9.80, TOTAL LOSS =    2.95, TOTAL EXCESS =    6.85

 PEAK FLOW     TIME                              MAXIMUM AVERAGE FLOW
                                     6-HR        24-HR       72-HR       8.25-HR
+   (CFS)      (HR)
                         (CFS)
+   2756.      2.25                  565.        411.        411.        411.
                       (INCHES)      6.828       6.832       6.832       6.832
                        (AC-FT)      280.        281.        281.        281.

                    CUMULATIVE AREA =     .77 SQ MI

1
                                          RUNOFF SUMMARY
                                   FLOW IN CUBIC FEET PER SECOND
                                TIME IN HOURS,  AREA IN SQUARE MILES

                                      PEAK    TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD     BASIN    MAXIMUM    TIME OF
         OPERATION        STATION     FLOW     PEAK                                            AREA     STAGE    MAX STAGE
+                                                        6-HOUR      24-HOUR      72-HOUR

         HYDROGRAPH AT
+                          DVBRM     2756.     2.25        565.        411.         411.        .77


*** NORMAL END OF HEC-1 ***
```