APPENDIX B
HYDROLOGY

TABLE OF CONTENTS

1.0 INTRODUCTION.....1
2.0 PROBABLE MAXIMUM PRECIPITATION (PMP).....1
3.0 DESIGN FLOW CALCULATION.....1
4.0 DIVERSION CHANNEL SIZING.....2
5.0 REFERENCES.....4

LIST OF TABLES

Table B.1 Drainage Basin Characteristics and Peak Discharges
Table B.2 Peak Drainage Basin Discharges
Table B.3 Results of Diversion Channel Riprap Sizing Calculations
Table B.4 Results of Diversion Channel Sizing Calculations

LIST OF FIGURES

Figure B.1 Drainage Basin Layout Map
Figure B.2 Drainage Basin PMP Model Schematic

LIST OF ATTACHMENTS

Attachment B.1 HEC-HMS Calculation Output
Attachment B.2 Diversion Channels - Riprap and Channel Sizing Calculations

1.0 INTRODUCTION

This appendix outlines the hydrologic analysis and evaluation of diversion channels associated with the general configuration of the Primary and Secondary Impoundments. This evaluation has been prepared as an update to the 2005 Decommissioning and Reclamation Plan, associated with revision of the diversion channel alignment (Figure B.1).

2.0 PROBABLE MAXIMUM PRECIPITATION (PMP)

As outlined in NRC (1990) and Johnson (1999), the design event for evaluation of long-term erosional stability of the reclaimed tailings impoundments is the PMP. The PMP events selected by MFG (2005) for calculation of peak runoff were the 6-hour duration PMP (totaling 22.5 inches) and the 1-hour duration PMP (totaling 11.25 inches). The PMP events were determined for the project site using HMR 55A (NOAA, 1988). The PMP storm depths have not changed since the MFG analysis, as the calculation method and references for this area has not changed since 1988.

The SCS Type II precipitation distribution was selected for rainfall-runoff analysis by MFG (2005), WWL (1990), and ESCI (1995). The SCS precipitation distributions were developed by the Natural Resources Conservation Service and are used to estimate peak runoff based on geographic region. The SCS Type II distribution is applicable for the state of Colorado. However, the State of Colorado Division of Water Resources – Dam Safety Division recommends the frequency storm method. Therefore, the frequency storm method is selected for the hydrologic analysis using the HEC-HMS program.

3.0 DESIGN FLOW CALCULATION

The design flow estimates were performed using the HEC-HMS program (U.S. Army Corps of Engineers, 2010), using basin parameters and antecedent soil moisture conditions consistent with an extreme storm event (the design storm event). A curve number of 83 and an initial abstraction as a function of the curve number were used to represent basin runoff characteristics with low infiltration. A time step of 5 minutes was used in HEC-HMS model. These characteristics represent higher runoff quantities and flow velocities.

The drainage basin delineation is shown in Figure B.1, and is similar to the delineation used in WWL (1990) and MFG (2005). The drainage basins shown in Figure B.1 would discharge into primary and secondary diversion channels along the edge of the Primary and Secondary Impoundments, and a secondary outlet channel north of the Secondary Impoundment. The current proposed channel configuration closely follows the configuration presented in the MFG (2005) report. Flows are effectively split between the primary and secondary diversion channels with a small portion of flow from the Secondary Impoundment draining into a secondary outlet channel. The primary diversion channel travels along the inside edge of the Impoundments, the secondary diversion channel travels along the western edge of the Secondary Impoundment, and the secondary outlet channel connects to an existing drainage north of the Secondary Impoundment. To estimate the peak drainage basin discharge, the 6-hour PMP and 1-hour PMP were used in the HEC-HMS simulations as per MFG (2005) design criteria. The 6-hour PMP event produced the highest peak discharge of the two duration events and was therefore used to evaluate the erosional stability and size of the diversion channels.

The peak runoff values for the major drainage basins contributing to the diversion channels resulting from the 6-hour PMP event are shown on Figure B.2 and are presented in Table B.1.

Table B.1 Drainage Basin Characteristics and Peak Discharges

Drainage Basin	Drainage Area (acres)	Runoff Curve Number	Peak Discharge (cfs)	Time to Peak Discharge (minutes)
S1	27.2	83	822	190
S2	23.0	83	688	190
S3	44.8	83	1,106	190
S4	76.0	83	718	230
S5	45.6	83	1,050	195
S6	134.4	83	2,248	205
S7	32.7	83	599	200
S8	33.5	83	865	190
S9	52.0	83	1,074	195
S10	58.7	83	1,118	200
S11	31.1	83	915	190

The peak runoff values to be used for the diversion channel sizing, resulting from the 6-hour PMP event, are shown on Figure B.2 and are presented in Table B.2. Due to the relatively short length of the proposed channels, routing was not considered in our analysis.

Table B.2 Peak Drainage Basin Discharges

Channel	Peak Discharge (cfs)	Time of Peak Discharge (minutes)
Primary Diversion Channel	6,848	195
Secondary Diversion Channel	2,616	190
Secondary Outlet Channel	718	230

4.0 DIVERSION CHANNEL SIZING

The channel depths and erosion protection for the diversion channels are based on the peak discharge values from the 6-hour PMP storm presented in Table B.1 along the various sections of the diversion channels. The diversion channels will have bottom widths ranging from 40 to 160 feet, an inside side slope (cover side) of 5H:1V (horizontal:vertical), and an outside side slope of 3H:1V.

Normal flow depths and velocities were calculated using Manning's equation. The Mannings "n" roughness value was calculated using the following equation from Abt et al. (1987):

$$n = 0.0456*(S*D_{50})^{0.159}$$

Where S is the slope of the channel and D_{50} is the size of the riprap in the channel.

The required riprap sizes were determined using the Abt and Johnson Method as well as the CSU Safety Factor Method. The safety factor method was not used for channel sections steeper than 10%. Normal depth and riprap sizing calculations are provided in Attachment B.2. A summary of the required riprap sizes and factors of safety is included in Table B.3. A summary of the channel sizes is included in Table B.4.

Table B.3 Results of Diversion Channel Riprap Sizing Calculations

Channel	Stations	Design Discharge (cfs)	Bed Slope (ft/ft)	Maximum Flow Depth (ft)	Velocity (fps)	Riprap D50 (in)	Safety Factor
Primary Diversion	0+39 to 10+89	3,072	0.02	3.0	12.7	12	1.01
	10+89 to 35+34	6,848	0.0025	6.9	10.2	6	1.37
	35+34 to 43+28	6,848	0.02	3.0	13.4	12	1.00
Secondary Diversion	0+00 to 20+00	1,106	0.01	2.4	9.1	6	1.14
	20+00 to 30+00	1,794	0.01	2.9	10.2	6	1.03
	30+00 to 56+68	2,616	0.01	3.0	10.8	6	1.01
Secondary Outlet	1+00 to 2+50	718	0.28	0.6	12.3	12	-
	2+50 to 5+25	718	0.032	0.9	8.1	6	1.00

Table B.4 Results of Diversion Channel Sizing Calculations

Channel	Channel Length (ft)	Design Discharge (cfs)	Bed Slope (ft/ft)	Channel Bottom Width (ft)	Channel Top Width (ft)	Riprap D50 (in)
Primary Diversion	1,050	3,072	0.04	70	83	12
	2,445	6,848	0.0025	70	125	6
	794	6,848	0.02	160	184	12
Secondary Diversion	2,000	1,106	0.01	40	60	6
	1,000	1,794	0.01	50	73	6
	2,668	2,616	0.01	70	94	6
Secondary Outlet	150	718	0.28	90	95	12
	275	718	0.032	90	98	6

Based on the assumption that the base native soil will be similar to the Northwest Borrow soil, and consists of a sandy clay with 53% passing the No. 200 sieve, preliminary calculations indicate that two filters may be required. The characteristics of the filters are as follows:

- Filter #1 has a maximum D_{50} of 2 mm (0.079 inches) (medium sand), with a minimum filter thickness of 6 inches.
- Filter #2 has a maximum D_{50} of 70 mm (2.8 inches), with a minimum filter thickness of 6 inches.

5.0 REFERENCES

Abt et al. "Development of Riprap Design Criteria by Riprap testing in Flumes: Phase I." NUREG/CR-4651. 1987.

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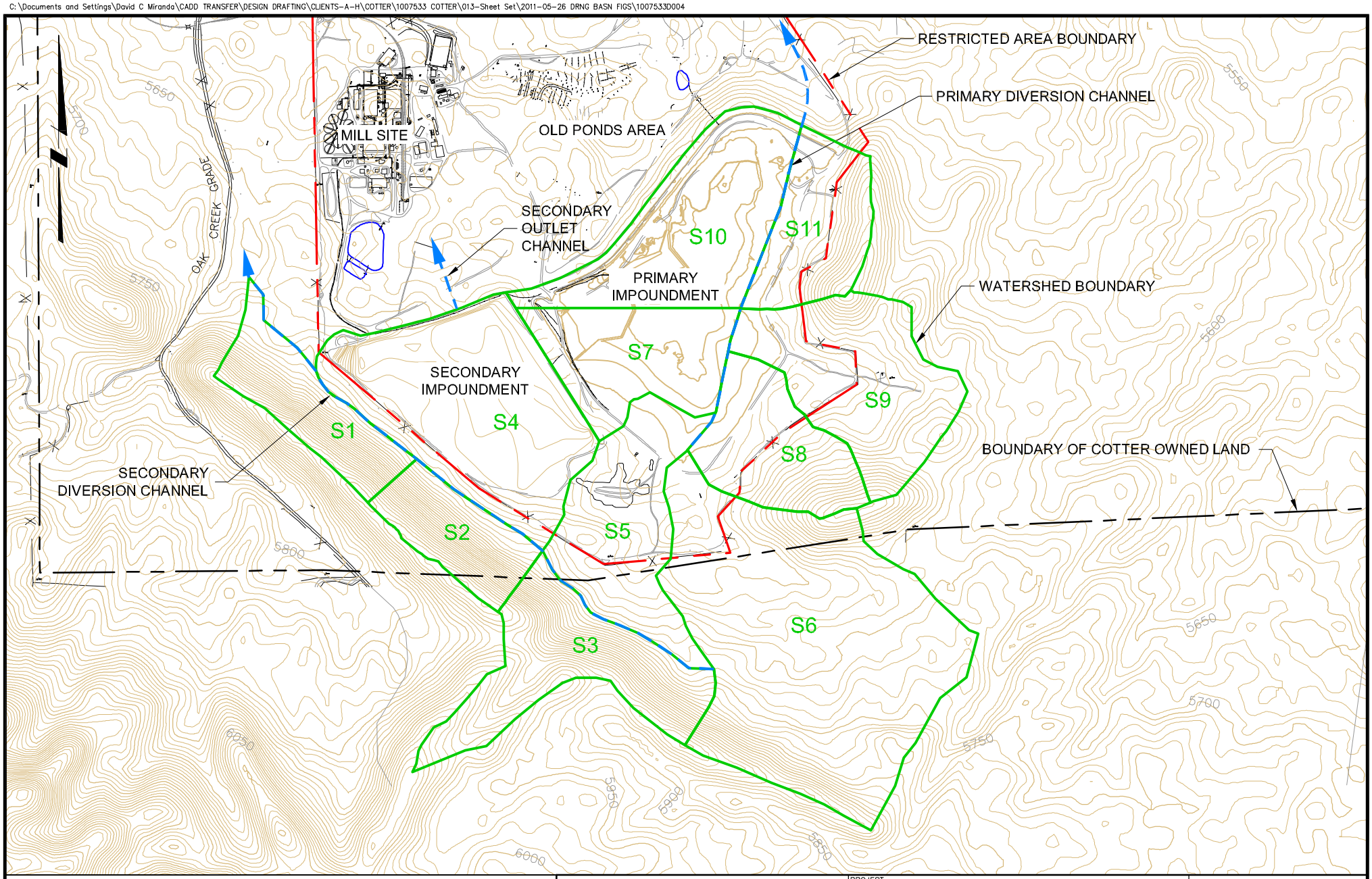

REFERENCE:
- EXISTING GROUND CONTOURS FROM USGS (SEAMLESS.USGS.GOV).
- SITE TOPOGRAPHY FROM COTTER CORPORATION (2007).

SCALE
1200 0 1200 FT

COTTER CORPORATION (N.S.L.)

PROJECT: CANON CITY MILLING FACILITY

TITLE: DRAINAGE BASIN LAYOUT MAP

MWH

DATE: JUNE 2011

FIGURE B.1

FILE NAME: 1007533D004

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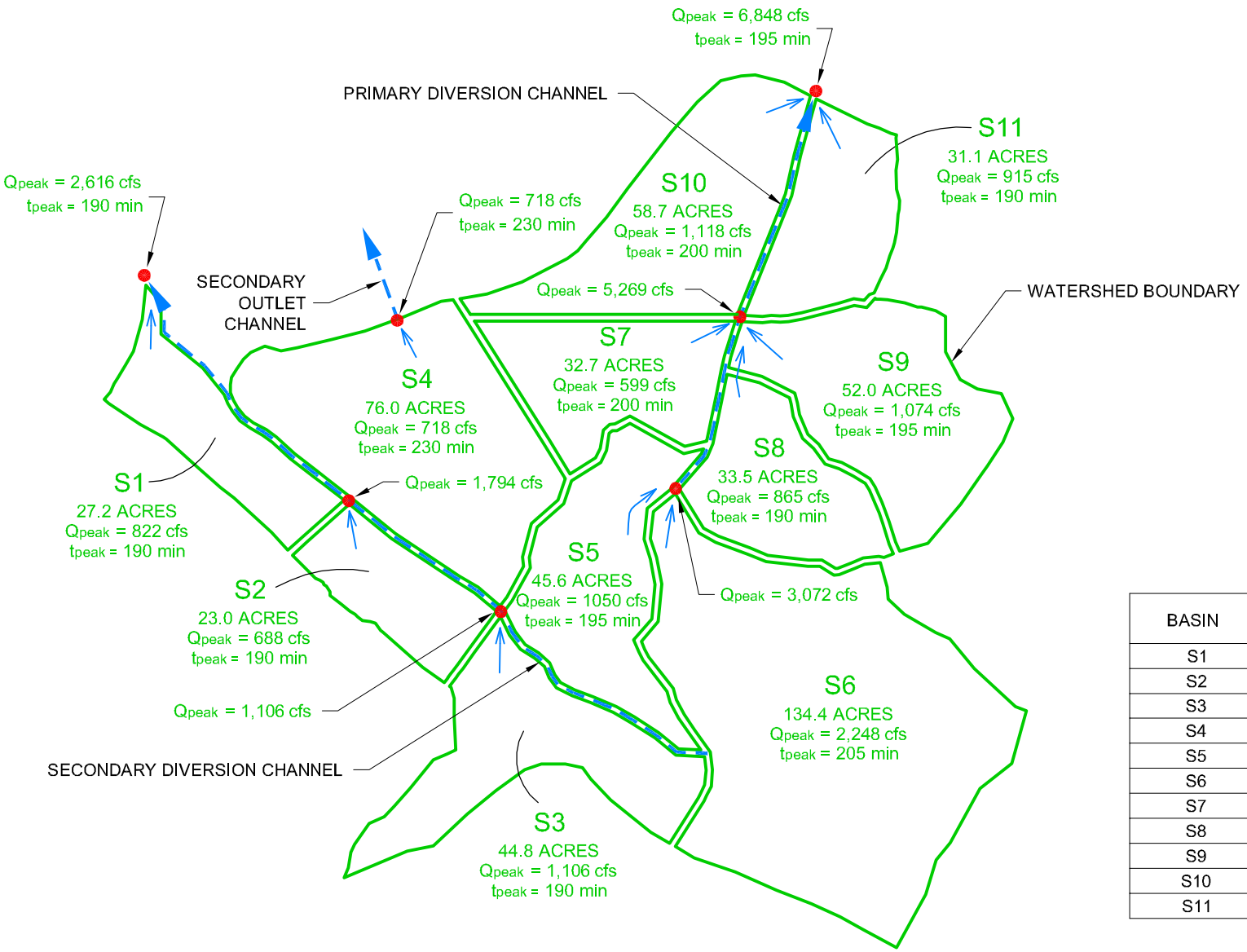

BASIN	AREA	
	SQUARE MILES	ACRES
S1	0.043	27.2
S2	0.036	23.0
S3	0.070	44.8
S4	0.119	76.0
S5	0.071	45.6
S6	0.210	134.4
S7	0.051	32.7
S8	0.052	33.5
S9	0.081	52.0
S10	0.092	58.7
S11	0.049	31.1

COTTER CORPORATION (N.S.L.)

PROJECT: CANON CITY MILLING FACILITY

TITLE: DRAINAGE BASIN PMP MODEL SCHEMATIC

MWH

DATE: JUNE 2011

FIGURE B.2

FILE NAME: 1007533D005

ATTACHMENT B.1

HEC-HMS Calculation Output

Cotter – Canyon City Milling Facility
HEC-HMS Model Input Parameters

Model Assumptions:
* Design storm: 6-hour PMP
* Curve Number: 83
* Initial Abstraction = f (CN)

Site:	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
Area (ft2)	1,184,847	1,001,773	1,951,115	3,311,721	1,987,144	5,855,697	1,425,839	1,461,167	2,266,111	2,557,397	1,355,655
Area (mi2)	0.043	0.036	0.070	0.119	0.071	0.210	0.051	0.052	0.081	0.092	0.049
Area (acres)	27.2	23.0	44.8	76.0	45.6	134.4	32.7	33.5	52.0	58.7	31.1
Length (ft)	538	661	2170	2365	1846	4039	1476	1765	2178	1506	1005
Max Elev (ft)	5,950	5,995	6,070	5,662	5,720	5,870	5,610	5,850	5,710	5,613	5,790
Min Elev (ft)	5,695	5,700	5,720	5,650	5,590	5,590	5,582	5,582	5,580	5,580	5,590
Slope (%)	47.40	44.63	16.13	0.51	7.04	6.93	1.90	15.18	5.97	2.19	19.90
CN	83	83	83	83	83	83	83	83	83	83	83
S (CN)	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Lag Time (hrs)	0.03	0.03	0.13	0.81	0.18	0.33	0.29	0.12	0.22	0.27	0.06
Lag Time (minutes)	1.53	1.86	8.01	48.37	10.65	20.08	17.16	7.00	13.20	16.22	3.90
Tc (hrs)	0.04	0.05	0.22	1.34	0.30	0.56	0.48	0.19	0.37	0.45	0.11
Time Step (min)	0.46	0.56	2.40	14.51	3.20	6.02	5.15	2.10	3.96	4.87	1.17

dT = 5 min selected for modeling

HEC-HMS Model

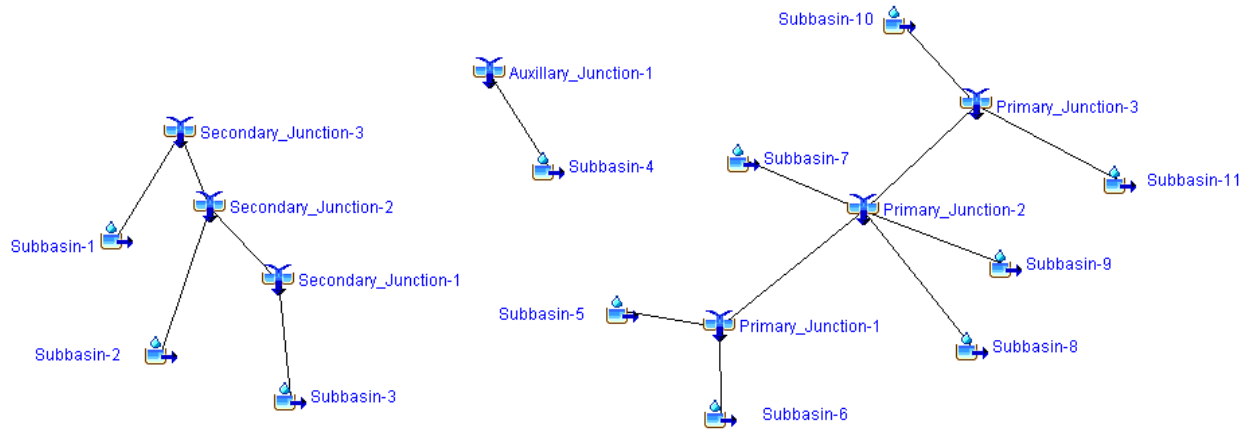

Figure 1. Sub-Basin Schematic

Subbasin Area [Configuration 2]

Show Elements: All Elements

Subbasin	Area (MI2)
Subbasin-1	0.043
Subbasin-10	0.092
Subbasin-11	0.049
Subbasin-2	0.036
Subbasin-3	0.070
Subbasin-4	0.119
Subbasin-5	0.071
Subbasin-6	0.210
Subbasin-7	0.051
Subbasin-8	0.052
Subbasin-9	0.081

Figure 2. Sub-basin Areas

Curve Number Loss [Configuration 2]

Show Elements: All Elements

Subbasin	Initial Abstraction (IN)	Curve Number	Impervious (%)
Subbasin-1		83	0.0
Subbasin-10		83	0.0
Subbasin-11		83	0.0
Subbasin-2		83	0.0
Subbasin-3		83	0.0
Subbasin-4		83	0.0
Subbasin-5		83	0.0
Subbasin-6		83	0.0
Subbasin-7		83	0.0
Subbasin-8		83	0.0
Subbasin-9		83	0.0

Figure 3. Curve Number Loss

SCS Transform[Configuration 2]

Show Elements: All Elements

Subbasin	Lag Time (MIN)
Subbasin-1	1.53
Subbasin-10	16.22
Subbasin-11	3.90
Subbasin-2	1.86
Subbasin-3	8.01
Subbasin-4	48.37
Subbasin-5	10.65
Subbasin-6	20.08
Subbasin-7	17.16
Subbasin-8	7.00
Subbasin-9	13.2

Figure 4. SCS Lag Time

Precipitation

Met Name: Frequency Storm_6hr

Probability:	1 Percent
Input Type:	Partial Duration
Output Type:	Annual Duration
Intensity Duration:	15 Minutes
Storm Duration:	6 Hours
Intensity Position:	50 Percent
Storm Area (MI2)	0.86
5 Minutes (IN)	
*15 Minutes (IN)	7.6500
*1 Hour (IN)	11.250
*2 Hours (IN)	13.050
*3 Hours (IN)	13.840
*6 Hours (IN)	22.500
12 Hours (IN)	
1 day (IN)	
2 Days (IN)	
4 Days (IN)	
7 Days (IN)	
10 Days (IN)	

Figure 5. Frequency Storm Distribution

Global Summary Results for Run "2) PMP_6hr_Freq Storm (2)"

Project: Cotter - Canon City Simulation Run: 2) PMP_6hr_Freq Storm (2)

Start of Run: 01Jan2011, 00:00 Basin Model: Configuration 2
End of Run: 02Jan2011, 00:05 Meteorologic Model: Frequency Storm_6hr
Compute Time: 20Jun2011, 10:32:41 Control Specifications: 5-MIN

Show Elements: All Elements Volume Units: IN AC-FT

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Auxillary_Junction-1	0.119	718.2	01Jan2011, 03:50	20.17
Primary_Junction-1	0.281	3072.2	01Jan2011, 03:20	20.17
Primary_Junction-2	0.465	5268.5	01Jan2011, 03:15	20.17
Primary_Junction-3	0.606	6848.3	01Jan2011, 03:15	20.17
Secondary_Junction-1	0.070	1105.5	01Jan2011, 03:10	20.17
Secondary_Junction-2	0.106	1793.9	01Jan2011, 03:10	20.17
Secondary_Junction-3	0.149	2616.2	01Jan2011, 03:10	20.17
Subbasin-1	0.043	822.3	01Jan2011, 03:10	20.17
Subbasin-10	0.092	1118.2	01Jan2011, 03:20	20.17
Subbasin-11	0.049	915.2	01Jan2011, 03:10	20.17
Subbasin-2	0.036	688.4	01Jan2011, 03:10	20.17
Subbasin-3	0.070	1105.5	01Jan2011, 03:10	20.17
Subbasin-4	0.119	718.2	01Jan2011, 03:50	20.17
Subbasin-5	0.071	1050.1	01Jan2011, 03:15	20.17
Subbasin-6	0.210	2247.5	01Jan2011, 03:25	20.17
Subbasin-7	0.051	599.4	01Jan2011, 03:20	20.17
Subbasin-8	0.052	865.0	01Jan2011, 03:10	20.17
Subbasin-9	0.081	1073.7	01Jan2011, 03:15	20.17

Figure 6. HEC-HMS Output Summary – Design

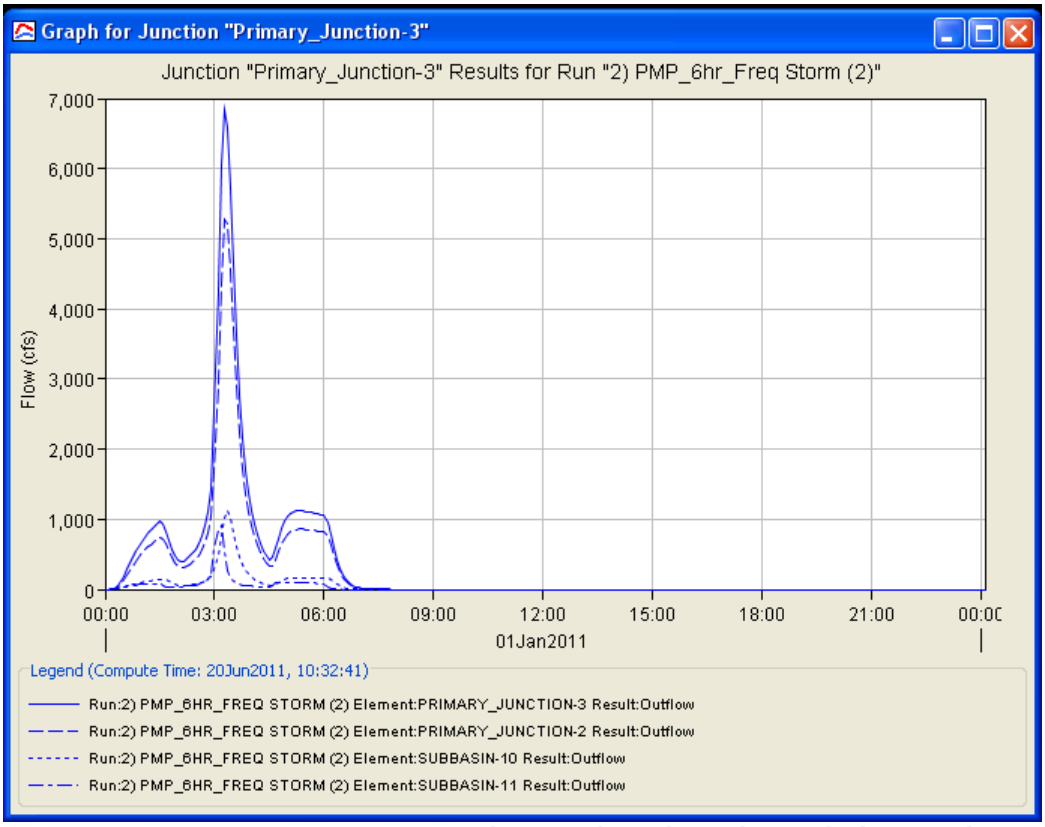

Figure 7. HEC-HMS Output Summary – Primary Diversion Channel Time Series - Design

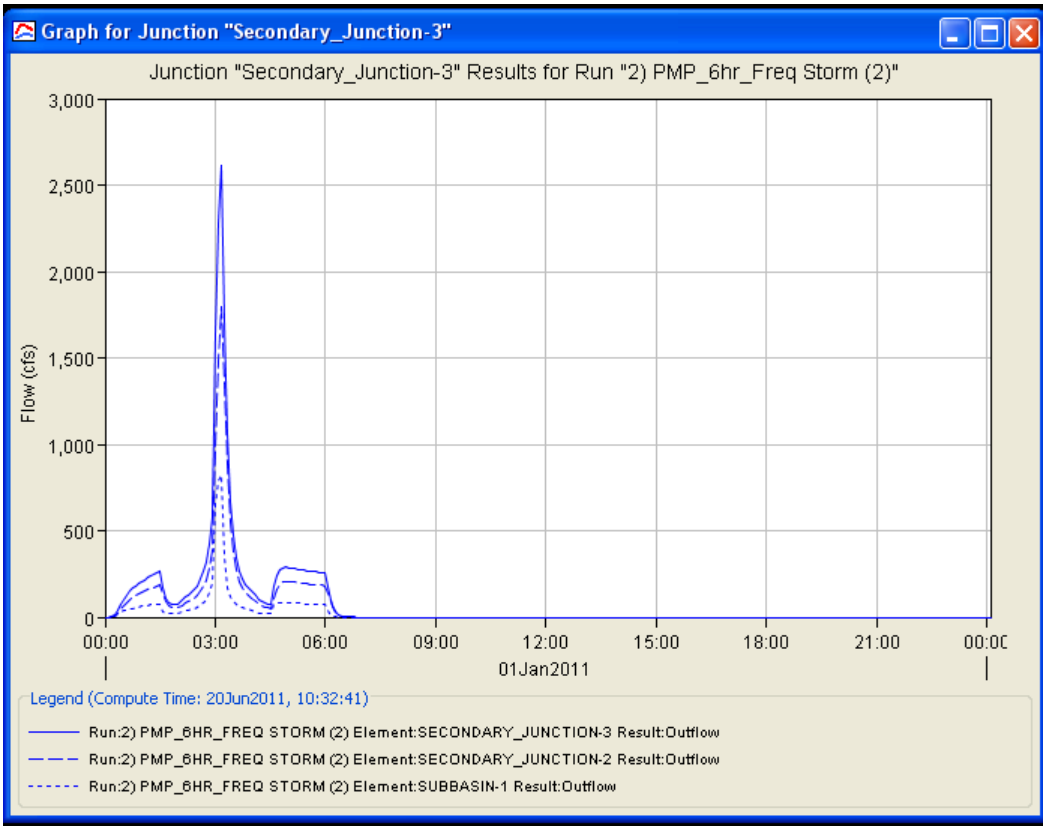

Figure 8. HEC-HMS Output Summary – Secondary Diversion Channel Time Series – Design

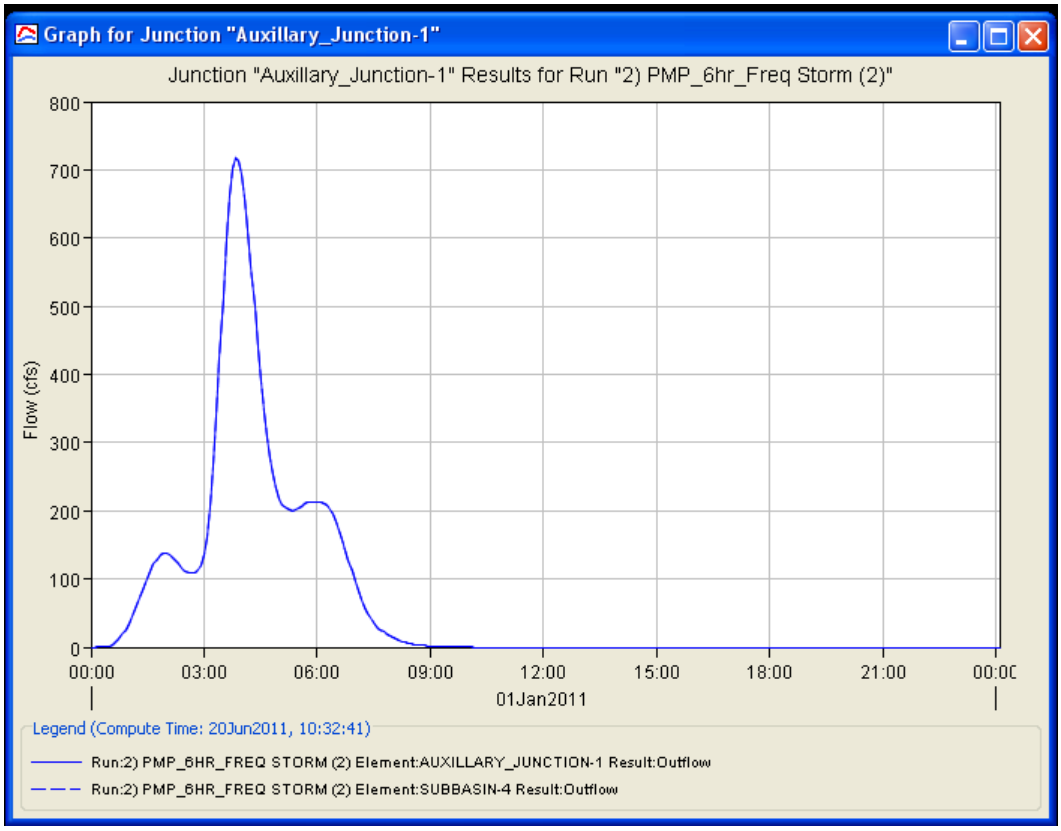

Figure 9. HEC-HMS Output Summary – Auxiliary Diversion Channel Time Series – Design

ATTACHMENT B.2

Diversion Channels - Riprap and Channel Sizing Calculations

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	3072	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.02	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	70	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	3072	cfs	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0363	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.031	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	242.38	ft^2	
Wetted Perimeter Slope 1 (P1)	15.09	ft	
Wetted Perimeter Slope 2 (P2)	9.45	ft	
Hydraulic Radius (R)	2.56	ft	
Top Width (T)	93.8	ft	
Maximum depth of flow (d)	2.96	ft	**iterate with d until Q calc equals Q design**
Q calc	3077.6	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	12.7	fps	
unit discharge	37.52	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	50.65		
D50 required	8.8	in	**iterate with D50 until assumed D50 is equal to D50 required**

Safety Factor Method

Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	3072		
design flow over rock (cfs/ft)	3072	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0363	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.031		
Area of flow (A)	242.38	ft^2	
Wetted Perimeter Slope 1 (P1)	15.09	ft	
Wetted Perimeter Slope 2 (P2)	9.45	ft	
Hydraulic Radius (R)	2.56	ft	
Top Width (T)	93.8	ft	
Maximum depth of flow (d)	2.96	ft	**iterate with d until Q calc equals Q design**
Q calc	3077.6	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	3.69	psf	
Stability number for rock, η	0.753		
β	0.732		
Stability number for rock, η'	0.628		
Factor of Safety for rock #1	1.01		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	6848	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.0025	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	70	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	6848	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0234	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.022	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	671.65	ft^2	
Wetted Perimeter Slope 1 (P1)	35.08	ft	
Wetted Perimeter Slope 2 (P2)	21.95	ft	
Hydraulic Radius (R)	5.29	ft	
Top Width (T)	125.2	ft	
Maximum depth of flow (d)	6.88	ft	**iterate with d until Q calc equals Q design**
Q calc	6857.8	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	10.2	fps	
unit discharge	70.15	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	94.70		
D50 required	5.1	in	**iterate with D50 until assumed D50 is equal to D50 required**

Safety Factor Method

Angle of repose of rock (degees)	37		See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1		Typically between 1.1 to 3.2 for slopes. Set to 1 for channel
design flow (cfs)	6848		
design flow over rock (cfs/ft)	6848		assumes negligible flow through rock
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0234	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.022		
Area of flow (A)	671.65	ft^2	
Wetted Perimeter Slope 1 (P1)	35.08	ft	
Wetted Perimeter Slope 2 (P2)	21.95	ft	
Hydraulic Radius (R)	5.29	ft	
Top Width (T)	125.2	ft	
Maximum depth of flow (d)	6.88	ft	**iterate with d until Q calc equals Q design**
Q calc	6857.8	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	1.07	psf	
Stability number for rock, η	0.438		
β	0.481		
Stability number for rock, η'	0.320		
Factor of Safety for rock #1	1.37		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	6848	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.02	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	160	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	6848	cfs	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0363	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.031	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	512.46	ft^2	
Wetted Perimeter Slope 1 (P1)	15.20	ft	
Wetted Perimeter Slope 2 (P2)	9.51	ft	
Hydraulic Radius (R)	2.77	ft	
Top Width (T)	183.9	ft	
Maximum depth of flow (d)	2.98	ft	**iterate with d until Q calc equals Q design**
Q calc	6858.7	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	13.4	fps	
unit discharge	39.82	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	53.76		
D50 required	9.1	in	**iterate with D50 until assumed D50 is equal to D50 required**
Safety Factor Method			
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	6848		
design flow over rock (cfs/ft)	6848	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0363	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.031		
Area of flow (A)	512.46	ft^2	
Wetted Perimeter Slope 1 (P1)	15.20	ft	
Wetted Perimeter Slope 2 (P2)	9.51	ft	
Hydraulic Radius (R)	2.77	ft	
Top Width (T)	183.9	ft	
Maximum depth of flow (d)	2.98	ft	**iterate with d until Q calc equals Q design**
Q calc	6858.7	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	3.72	psf	
Stability number for rock, η	0.759		
β	0.735		
Stability number for rock, η'	0.634		
Factor of Safety for rock #1	1.00		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	1106	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.01	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	40	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	1106	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	121.50	ft^2	
Wetted Perimeter Slope 1 (P1)	12.44	ft	
Wetted Perimeter Slope 2 (P2)	7.79	ft	
Hydraulic Radius (R)	2.02	ft	
Top Width (T)	59.6	ft	
Maximum depth of flow (d)	2.44	ft	**iterate with d until Q calc equals Q design**
Q calc	1111.1	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	9.1	fps	
unit discharge	22.21	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	29.98		
D50 required	4.8	in	**iterate with D50 until assumed D50 is equal to D50 required**
Safety Factor Method			
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	1106		
design flow over rock (cfs/ft)	1106	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026		
Area of flow (A)	121.50	ft^2	
Wetted Perimeter Slope 1 (P1)	12.44	ft	
Wetted Perimeter Slope 2 (P2)	7.79	ft	
Hydraulic Radius (R)	2.02	ft	
Top Width (T)	59.6	ft	
Maximum depth of flow (d)	2.44	ft	**iterate with d until Q calc equals Q design**
Q calc	1111.1	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	1.52	psf	
Stability number for rock, η	0.621		
β	0.637		
Stability number for rock, η'	0.495		
Factor of Safety for rock #1	1.14		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	1794	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.01	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	50	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	1794	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	175.84	ft^2	
Wetted Perimeter Slope 1 (P1)	14.58	ft	
Wetted Perimeter Slope 2 (P2)	9.13	ft	
Hydraulic Radius (R)	2.39	ft	
Top Width (T)	73.0	ft	
Maximum depth of flow (d)	2.86	ft	**iterate with d until Q calc equals Q design**
Q calc	1798.2	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	10.2	fps	
unit discharge	29.18	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	39.39		
D50 required	5.6	in	**iterate with D50 until assumed D50 is equal to D50 required**
Safety Factor Method			
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	1794		
design flow over rock (cfs/ft)	1794	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026		
Area of flow (A)	175.84	ft^2	
Wetted Perimeter Slope 1 (P1)	14.58	ft	
Wetted Perimeter Slope 2 (P2)	9.13	ft	
Hydraulic Radius (R)	2.39	ft	
Top Width (T)	73.0	ft	
Maximum depth of flow (d)	2.86	ft	**iterate with d until Q calc equals Q design**
Q calc	1798.2	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	1.78	psf	
Stability number for rock, η	0.728		
β	0.715		
Stability number for rock, η'	0.603		
Factor of Safety for rock #1	1.03		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	2616	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.01	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	70	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	2616	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	243.32	ft^2	
Wetted Perimeter Slope 1 (P1)	15.14	ft	
Wetted Perimeter Slope 2 (P2)	9.48	ft	
Hydraulic Radius (R)	2.57	ft	
Top Width (T)	93.9	ft	
Maximum depth of flow (d)	2.97	ft	**iterate with d until Q calc equals Q design**
Q calc	2615.8	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	10.8	fps	
unit discharge	31.93	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	43.11		
D50 required	5.9	in	**iterate with D50 until assumed D50 is equal to D50 required**
Safety Factor Method			
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	2616		
design flow over rock (cfs/ft)	2616	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0292	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.026		
Area of flow (A)	243.32	ft^2	
Wetted Perimeter Slope 1 (P1)	15.14	ft	
Wetted Perimeter Slope 2 (P2)	9.48	ft	
Hydraulic Radius (R)	2.57	ft	
Top Width (T)	93.9	ft	
Maximum depth of flow (d)	2.97	ft	**iterate with d until Q calc equals Q design**
Q calc	2615.8	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	1.85	psf	
Stability number for rock, η	0.756		
β	0.733		
Stability number for rock, η'	0.631		
Factor of Safety for rock #1	1.01		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:	718	cfs	
Trapezoid or triangular channels			
slope (ft/ft)	0.28	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	90	ft	
Abt and Johnson Method	**D50=5.23*S^0.43*qd^0.56**		
Q	718	cfs	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0553	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.045	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	58.29	ft^2	
Wetted Perimeter Slope 1 (P1)	3.21	ft	
Wetted Perimeter Slope 2 (P2)	2.01	ft	
Hydraulic Radius (R)	0.61	ft	
Top Width (T)	95.1	ft	
Maximum depth of flow (d)	0.63	ft	**iterate with d until Q calc equals Q design**
Q calc	734.7	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	12.3	fps	
unit discharge	7.76	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	10.48		
D50 required	11.3	in	**iterate with D50 until assumed D50 is equal to D50 required**
Safety Factor Method			
Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channel	
design flow (cfs)	718		
design flow over rock (cfs/ft)	718	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	1.00	ft	
Assumed D50 on side slope (in)	12	in	
n riprap	0.0553	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.045		
Area of flow (A)	58.29	ft^2	
Wetted Perimeter Slope 1 (P1)	3.21	ft	
Wetted Perimeter Slope 2 (P2)	2.01	ft	
Hydraulic Radius (R)	0.61	ft	
Top Width (T)	95.1	ft	
Maximum depth of flow (d)	0.63	ft	**iterate with d until Q calc equals Q design**
Q calc	734.7	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	11.01	psf	
Stability number for rock, η	2.245		
β	1.213		
Stability number for rock, η'	2.174		
Factor of Safety for rock #1	0.41		**Iterate with D50 until FS equal or greater than 1.0**

Client:	Cotter Corporation	**Job No.:**	1007533
Project:	Reclamation Plan	**Date:**	30-Jun-11
Detail:		**Computed By:**	JMC

Channel Sizing and Rock Sizing

Design flow:		718	cfs
Trapezoid or triangular channels			
slope (ft/ft)	0.032	ft/ft	
Channel Side Slope 1 (ft/ft)	0.2	ft/ft	
Channel Side Slope 2 (ft/ft)	0.33	ft/ft	
bottom width	90	ft	

Abt and Johnson Method **D50=5.23*S^0.43*qd^0.56**

Q	718	cfs	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0351	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.030	Note: This is if sides of channel and bottom of channel have different material	
Area of flow (A)	88.15	ft^2	
Wetted Perimeter Slope 1 (P1)	4.79	ft	
Wetted Perimeter Slope 2 (P2)	3.00	ft	
Hydraulic Radius (R)	0.90	ft	
Top Width (T)	97.5	ft	
Maximum depth of flow (d)	0.94	ft	**iterate with d until Q calc equals Q design**
Q calc	726.5	cfs	**this value should equal Design flow in cell D7**
average velocity (v)	8.1	fps	
unit discharge	7.66	cfs/ft	take as total Q divided by average flow width
Cr	1		1.0 for angular, 1.4 for rounded rock
Cf	1		flow concentration factor 1 to 3
Cm	1.35		coefficient of movement 1.35 for overtopping flow (slope protection)
design discharge	10.34		
D50 required	4.4	in	**iterate with D50 until assumed D50 is equal to D50 required**

Safety Factor Method

Angle of repose of rock (degees)	37	See Fig 4.1 of TAD or Fig 4.8 of NUREG 4620, typically between 32 and 42 for angular, 29 and 41 for rounded	
Angle of repose of rock (rad))	0.646		
Side Slope	3.0	XH:1V	
Angle of side slope (degrees)	18.435		
Angle of side slope (radians)	0.322		
Specific gravity of rock	2.65		
Concentration Factor	1	Typically between 1.1 to 3.2 for slopes. Set to 1 for channe	
design flow (cfs)	718		
design flow over rock (cfs/ft)	718	assumes negligible flow through rock	
Assumed D50 on side slope (ft)	0.50	ft	
Assumed D50 on side slope (in)	6	in	
n riprap	0.0351	Abt et al. 1987 as presented in UMTRA TAD pg. 69 developed for tailings piles	
n native soils	0.020		
weighted average n	0.030		
Area of flow (A)	88.15	ft^2	
Wetted Perimeter Slope 1 (P1)	4.79	ft	
Wetted Perimeter Slope 2 (P2)	3.00	ft	
Hydraulic Radius (R)	0.90	ft	
Top Width (T)	97.5	ft	
Maximum depth of flow (d)	0.94	ft	**iterate with d until Q calc equals Q design**
Q calc	726.5	cfs	**this value should equal Design flow in cell D7**
max shear stress, τ	1.88	psf	
Stability number for rock, η	0.766		
β	0.740		
Stability number for rock, η'	0.641		
Factor of Safety for rock #1	1.00		**Iterate with D50 until FS equal or greater than 1.0**