



MWH

November 5, 2004

Mr. Gary Janosko, Chief
Fuel Cycle Facilities Branch
Division of Fuel Cycle Safety and Safeguards
Office of Nuclear Material Safety and Safeguards
Two White Flint North
11545 Rockville Pike
Rockville, Maryland 20852

RE: EROSION PROTECTION DESIGN CONCERNS IDENTIFIED AT RECENT SITE
VISIT (TAC NO. L52459) - *Docket 40-8907*

Dear Mr. Janosko:

On behalf of United Nuclear Corporation (UNC) enclosed is the engineering evaluation and proposed reclamation alternatives for the areas of concern identified at the Church Rock Mine Tailings Impoundment in the memorandum from the NRC dated January 7, 2003.

If you have any questions please feel free to contact Larry Bush at UNC or me at the number below.

Sincerely,

MWH

Jed Thompson
Associate Engineer

Enclosures

cc: Bill Von Till, NRC
Arthur Kleinrath, DOE
Mark Purcell, EPA Region 6
Roy Blickwedel, GECE
Larry Bush, UNC

NMSS01

Prepared for:

UNITED NUCLEAR CORPORATION

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Gallup, New Mexico 87301

**EROSION AND SEDIMENTATION EVALUATION AT THE
UNITED NUCLEAR CORPORATION
CHURCH ROCK URANIUM MILL TAILING SITE**

November 2004

Prepared by:

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1.0 INTRODUCTION AND PROJECT BACKGROUND

The Church Rock Site is located 17 miles northeast of Gallup, New Mexico in McKinley County. Uranium ore was processed at the site and tailings were generated from 1977 to 1982. A reclamation plan for the uranium mill tailings impoundment was approved by the NRC in 1991. Initial reclamation activities, including completion of a majority of the tailings impoundment cover, was completed from 1994 through 1996.

During a field visit by the Nuclear Regulatory Commission (NRC) on June 13, 2002, several areas of concern were identified relating to erosion and sedimentation at the Church Rock Site. Erosion and sedimentation issues at the Church Rock Uranium Mill Tailings identified by the NRC were presented in a January 7, 2003 letter, detailing the site inspection. The NRC's concerns included: 1) sedimentation in the branch swales on the tailings impoundment surface; 2) sedimentation in the north upstream diversion channel, and degradation of the berm adjacent to the channel; and 3) damage to the riprap jetty which protects the tailings impoundment and surface evaporation ponds from Pipeline Arroyo. An eroded area at the southwest end of the tailings impoundment embankment and differential settlement on the top surface of the east central portion of the tailings impoundment were also identified by the NRC, however UNC has committed to repair these areas and no further engineering review by MWH was performed.

A site reconnaissance and characterization of sedimentation was performed by MWH from September 15-16, 2003. The visit included a general site tour, discussions of the operational history and NRC inspection with UNC's site manager, and inspections and field analyses in the areas of concern raised by the NRC. Photographs from the site reconnaissance are included in Appendix A.

An engineering evaluation was completed for each of the areas of sedimentation identified in the NRC's letter. Engineering evaluations performed for the Branch Swales and North Upstream Diversion Channel were completed using guidelines presented in NUREG-1623, *Design of Erosion Protection for Long-term Stabilization*. Analyses of the Branch Swales, North Upstream Diversion Channel, Access Road/Berm and Jetty are further described on an individual basis below.

This report responds to each area of concern raised by the NRC. It presents data gathered by MWH during the site reconnaissance performed from September 15-16, 2003, discuss our evaluation of, and summarize possible alternatives to address each item. Supporting figures and appendices follow the text.

2.0 SITE RECONNAISSANCE AND ENGINEERING EVALUATION

2.1 SEDIMENT IN BRANCH SWALES (ON-PILE COLLECTION CHANNELS)

2.1.1 Evaluation of Existing Conditions

A visual inspection of Branch Swales A through G was performed to determine the impact of sediment in each swale. Sedimentation was noted in the lower portions of Swales C and D and in the majority of the length of Swale E as shown on Figure 1. Cross sections were measured in the areas of sedimentation and the existing bed slope was measured at each cross section location. The locations of cross sections for the branch swales are shown on Figure 2. These cross sections were used to estimate sediment volumes and calculate available flow capacity.

Sedimentation in the lower portions of Swales C and D is occurring on the left side slope of the swale, looking downstream, with sediment depths decreasing across the channel bottom. On the right side slope there is little or no deposition. The location of deposited sediment within each cross section is shown on Figure 3.

A profile of the sediment depth was measured at each cross section to be used for estimation of deposited sediment volumes of approximately 100 tons in Swale C and 60 tons in Swale D. Sedimentation in Swale C is shown in Photo 1. Sedimentation in Swale E is generally greatest on the right sideslope (looking downstream), with dunes in excess of one foot in depth present in the upper two-thirds of the swale. The volume of sediment in Swale E was estimated to be approximately 760 tons using sediment depths measured during the field analyses. A typical cross section of deposited sediment is shown on Figure 3, and Photo 2 shows the sedimentation in Swale E.

Mechanisms of sediment transport into the sediment-impacted areas of Swales C, D and E were evaluated during the field analyses. The consistent pattern of sedimentation on the upwind sideslopes of the swales indicates that wind is the predominant mechanism of sediment transport. A high-intensity thunderstorm had occurred at the site just prior to the MWH field visit, and there was evidence that runoff had been conveyed in the swales. However, there were no sediment deltas in the swales or rills on overbank areas, both of which would be typical indicators of runoff-based erosion and sedimentation.

2.1.2 Engineering Analyses of Existing Conditions

Hydrologic and hydraulic analyses were performed on Branch Swales C, D, and E using surveyed cross section and bed slope data obtained during the field visit.

Peak flow rates for the 10-year, 24-hour and 100-year, 24-hour storms were calculated utilizing the TR-55 method used in the approved Reclamation Plan. The peak flow for each swale resulting from the Probable Maximum Flood (PMF) was previously determined and presented in the Reclamation Plan. Precipitation depths for the 10-year and 100-year storms were obtained from NOAA Atlas 14, which was published to update and supersede NOAA Atlas 2. Hydrologic properties such as contributing basin areas and times of concentration were obtained from the Reclamation Plan.

Flow capacity, average velocity and flow depth were calculated for each swale cross section in sediment-impacted reaches for the 10-year, 100-year, and PMF discharges using the Normal Depth method with Manning's Equation. Results of these analyses for sediment-impacted swales are presented in Table 1.

| TABLE 1 RESULTS OF HYDROLOGIC AND HYDRAULIC ANALYSES FOR SWALES C, D, AND E | | | | | |
|--|-----------|---------|-------------------|--------------------|--------------------|
| Swale ID (% Slope) | Event | Q (cfs) | Velocity (ft/sec) | Depth of Flow (ft) | Shear Stress (psf) |
| Swale C (0.49%) | 10-year | 5 | 1.35 | 0.57 | 0.17 |
| | 100-year | 15 | 1.96 | 0.87 | 0.27 |
| | PMF | 75 | 3.20 | 1.78 | 0.54 |
| Swale D (0.41%) | 10-year | 5 | 1.26 | 0.52 | 0.13 |
| | 100-year | 16 | 1.88 | 0.86 | 0.22 |
| | PMF | 68 | 2.93 | 1.70 | 0.43 |
| Swale E (0.15%) | 10-year | 6 | 0.89 | 0.88 | 0.08 |
| | 100-year | 17 | 1.26 | 1.34 | 0.13 |
| | PMF | 85 | Overtopped | -- | -- |
| | Full-Flow | 37 | 1.61 | 1.90 | 0.18 |

Swales C and D currently have the capacity to pass the PMF discharge with the existing sediment in the swales, however Swale E would be overtopped. The capacity of Swale E is approximately 37 cfs, slightly less than half of the PMF flow rate.

Sediment samples were obtained from each sediment-impacted swale and from the North Upstream Diversion Channel to be used to estimate erosional stability parameters of permissible velocity and allowable shear stress. The sediment was found to be characteristic of a non-colloidal sandy loam, corresponding to a permissible velocity of approximately 2.5 feet per second and an allowable shear stress of approximately 0.075 pounds per square foot. The calculated shear stresses presented in Table 1 exceed the allowable shear stress for all of the sediment-impacted swales for both the 10-year and 100-year storms, indicating that these flows have the potential for detaching deposited sediment. However, flow velocities for the 10-year and 100-year flows are well below the limiting velocity of 2.5 feet per second, demonstrating that the detached sediment may only be mobilized and flushed during storms larger than the 100-year event.

Details of the hydrologic and hydraulic analyses are included in Appendix B.

2.2 SEDIMENT IN NORTH UPSTREAM DIVERSION CHANNEL AND POOR CONDITION OF THE ROAD

2.2.1 Evaluation of North Upstream Diversion Channel Existing Conditions

The North Upstream Diversion Channel was inspected to characterize sedimentation noted by the NRC. Downstream of the access road/berm the channel was constructed by cutting through a small ridge, and the channel has incised down to the sandstone bedrock as shown on Photo 3. Just upstream from this reach the channel bed consists of deposited sands and silts with a small pilot channel scouring into the main channel bed. The pilot channel is shown on Photo 4. Just upstream from the pilot channel the bottom width increases to approximately 40 feet, with a well-defined flow path approximately 6-8 feet wide as shown on Photo 5. Between this reach and the pilot channel, a headcut has developed to a depth of approximately 2-3 feet. Cross sections were surveyed immediately downstream of the headcut at the pilot channel and upstream of the headcut where the channel bottom width increases. The locations of these North Upstream Diversion Channel cross sections are shown on Figure 2.

The channel bed slope was surveyed at each cross section location, and approximately 100 feet upstream and downstream of the cross section, with the slope calculated by dividing the total change in elevation by the distance between the upstream and downstream measurements. The channel bed slopes above and below the headcut were measured to be approximately 0.0051 ft/ft and 0.0031 ft/ft, respectively.

Sedimentation in the channel downstream of the headcut is limited to minor amounts of sand and silt that have deposited on top of the sandstone bedrock at the upstream end of the cut through the ridge. Upstream of the headcut there did not appear to be significant sedimentation in the floodplain, and only small, localized deltas have formed where two small tributaries enter the area east of the berm/access road.

2.2.2 Evaluation of Berm/Access Road Existing Conditions

The berm east of the tailings impoundment adjacent to the North Upstream Diversion Channel was constructed to prevent runoff from the eastern basins from impacting the reclaimed impoundment, and currently serves as a site access road. The berm was inspected to quantify concerns of erosional and long-term stability raised by the NRC.

Erosion on the berm is limited to minor rilling on both the east and west embankments, with only a few areas of localized minor headcutting occurring where runoff from the road becomes concentrated. Rilling on the berm sideslope is shown on Photo 6. A cross section was surveyed in approximately the center of the berm to measure the existing embankment slopes, top width and height of the berm above the existing ground to the east and west. The berm sideslopes were measured to be approximately 1.6H:1V and 1.5H:1V on the east and west sides, respectively, and the top width was measured to be approximately 38 feet. The berm cross section is shown on Figure 3.

2.2.3 Engineering Analyses of the North Upstream Diversion Channel

Similar to the Branch Swales, hydrologic and hydraulic analyses were performed on the North Upstream Diversion Channel using the cross section and bed slope data obtained during the field visit. Peak flow rates for the 5-year, 1-hour and 10-year, 1-hour storms were calculated using the SCS Triangular Unit Hydrograph method, consistent with analyses used in the Reclamation Plan to determine the 100-year storm peak flow rate.

Precipitation depths for the 5-year and 10-year storms were obtained from NOAA Atlas 14, and basin areas and times of concentration were obtained from the Reclamation Plan.

Debris on the channel overbanks was used to estimate the peak depth of flow from the September 9-10, 2003 storm. This depth was then used to estimate a peak flow of approximately 76 cfs through the pilot channel section of the North Upstream Diversion Channel using Manning's Equation. This discharge corresponds to a storm that was between a 5-year and 10-year event over the contributing basin. Results of the analyses for the 5-year, 10-year and September 9-10, 2003 storms are shown in Table 2.

| TABLE 2 RESULTS OF HYDROLOGIC AND HYDRAULIC ANALYSES FOR THE NORTH UPSTREAM DIVERSION CHANNEL | | | | | |
|---|----------|---------|----------------------|-----------------------|-----------------------|
| Cross Section ID (% Slope) | Event | Q (cfs) | Velocity (ft/sec) | Depth of Flow (ft) | Shear Stress (psf) |
| (pilot) (0.34%) | 5-year | 58 | 2.58 | 3.36 | 0.71 |
| | 10-year | 125 | 3.06 | 4.17 | 0.88 |
| | 100-year | 296 | 4.15 | 5.14 | 1.09 |
| | 9/10/03 | 76 | 3.03 | 3.50 | 0.74 |
| (wide) (0.51%) | 5-year | 58 | 2.23 | 0.65 | 0.21 |
| | 10-year | 125 | 3.01 | 1.04 | 0.33 |
| | 100-year | 296 | 4.19 | 1.76 | 0.56 |
| | 9/10/03 | 76 | 2.48 | 0.77 | 0.25 |

A sample of deposited sediment was taken from Cross Section 5, the wide section of the channel, and the material was found to be a non-colloidal sandy loam, similar to the sediment collected from the swales. A permissible velocity of 2.5 feet per second and an allowable tractive force of 0.075 pounds per square foot used in the analyses of the swales were also used for the North Upstream Diversion Channel.

Hydraulic analyses for the pilot channel portion of the North Upstream Diversion indicate that smaller return period storms, such as the 5-year event, will have sufficient depth of flow and velocity to periodically flush sediment. For the steeper, wider section just upstream of the pilot section, shear stresses from smaller flow events will be sufficient to detach sediment, however it will take storms equal to or greater than the 10-year event to mobilize and flush the sediment.

As-built information for the North Upstream Diversion Channel, such as channel width and depth, is not available and thus the current impact on channel dimensions of sedimentation can not be accurately characterized. Shrubs and grasses are becoming established in the wide channel area west of the berm/access road, however there is currently a well-defined flow path in the invert of this area. As previously noted, between the pilot channel section and the wider, steeper section upstream of the pilot there is currently a 2- to 3-foot headcut in the channel bed. The presence of the headcut demonstrates that the downstream pilot channel will continue to progress upstream into the steeper, wider section, removing any accumulated sediment and transporting it downstream. The previous analyses also demonstrate that sediment will be regularly removed from the channel.

Details of the hydrologic and hydraulic analyses are included in Appendix B.

2.2.4 Berm Stability Analysis

During the berm inspection, a sample of the material used to construct the berm was taken to estimate the geotechnical properties. The soil was found to be very similar to sediment samples taken in the Branch Swales, though slightly coarser and more cohesive. Although the berm side slopes are slightly steeper than the angle of repose of the material, signs of geotechnical failure such as surface sloughing or bulges at the toe were not noted during the inspection.

Degradation of the berm was found to be limited to minor rilling with only a few small headcuts present along the entire length. Placement of a layer of riprap over both the east and west embankments will prevent further erosion.

Riprap for the embankments was sized to be stable under the PMF using the Abt and Johnson Method as detailed in Appendix D of NUREG-1623. The peak discharge was calculated assuming that all of the runoff from the top of the road would be concentrated into a flow path on only one of the embankments and would have a width of 100 feet. Although the runoff would likely occur as

sheet flow over the embankment, a concentration factor of 3 was used corresponding to channelized flow. Using these assumptions, a minimum D_{50} of 1.2 inches would be required to prevent further erosion of the embankments.

Riprap sizing calculations are included in Appendix B.

2.3 DAMAGE TO THE RIPRAP "JETTY"

2.3.1 Evaluation and Analysis of Existing Jetty Conditions

The displaced riprap on the jetty was inspected to determine the extent of the current damage caused by recent storms. The majority of the jetty is performing as designed, and damage to the riprap is confined to an area approximately 20 to 30 feet in length on the western end as shown in Photo 7.

As-built grainsize analyses for the jetty riprap were reviewed and indicated that the majority of the riprap used to construct the jetty met the required gradation specifications. Rock that was not within the required tolerances was slightly oversized.

The jetty was designed and constructed for runoff to flow over a width of at least 200 feet. In the area where the riprap has been eroded there is evidence that flows over the rock are highly concentrated into small flow paths caused by the establishment of small shrubs and vegetation upstream of the jetty. As seen in Photo 7, this concentration is causing the flow depths and velocities from storms smaller than the design storm to exceed the design flow depth and velocity in localized areas, mobilizing the riprap.

3.0 ALTERNATIVES AND RECOMMENDATIONS FOR AREAS OF CONCERN

3.1 BRANCH SWALES

Currently Swale E will not pass the design PMF discharge, and at the current rate of windblown sedimentation in Swales C and D, it is likely that these swales will also eventually be limited in flow capacity. None of the swales currently has the ability to flush sediment during smaller, more frequent storms such as the 10-year event. The NRC inspection report stated that removal of sediment from the swales using heavy equipment would be difficult and would cause damage to the lining with the small size of the riprap that currently lines the swales. MWH agrees that removal of the sediment with heavy equipment would damage or disturb the channel lining.

Three alternatives for resolution of the sedimentation in the Branch Swales were given by the NRC in their January 7, 2003 letter: 1) redesign the swales; 2) demonstrate that sedimentation is not problematic; and 3) provide funding for sediment removal. Redesigning the swales, potentially making them steeper to flush sediment, would not be possible given the limited drop in elevation currently available on the impoundment. As previously discussed, sedimentation is problematic and the swales do not have the ability to flush sediment.

MWH recommends that control measures for windblown sediment, such as constructing small rock berms upwind of the swales in order to deposit windblown sediment before it can deposit in the swales be used. This rock berm would be placed on the cover surface so that it would cause deposition of windblown sediment on an area of the tailings cover that could be accessed by equipment for more cost effective removal. UNC will complete removal of the windblown sediment from the swales, design and construct rock berms to manage wind blown sediment deposition, and bond for removal of windblown sediment deposited by the berms on an periodic ongoing basis.

Costs for construction of the berms and removal of the sediment from the swales is presented in Table 3. Berm heights were developed using the U.S. Army Corps of Engineers *Coastal Engineering Manual – Part III* (EM 1110-2-1100, 2002). Berm height and bonding calculations for ongoing sediment removal from behind the rock berms are presented in Appendix C. A maximum berm height of three feet results and a maintenance frequency of 15 years is recommended. This design has a net present value of \$119,800.

| TABLE 3 BRANCH SWALE SEDIMENT REMOVAL COSTS | |
|--|----------|
| Item | Cost |
| Construction of Rock Berm | \$10,200 |
| Sediment Removal from Swales | \$18,900 |

UNC proposes to design berms to control windblown sediment, followed by review of the design by the NRC, with construction of the berms in the summer construction season of 2005. Sediment in the swales would be removed following construction of the rock berms.

3.2 NORTH UPSTREAM DIVERSION CHANNEL AND ACCESS ROAD

The analyses performed on the North Upstream Diversion Channel indicate that sediment is being mobilized and flushed during frequent, smaller storms. The NRC's inspection report noted that deposited sediment adjacent to the berm/roadway was being stabilized by vegetation. Though there is established vegetation in the area, the presence of a 2- to 3-foot headcut in the natural channel adjacent to the north end of the roadway demonstrate that runoff still has the potential for scouring

the sandy, silty sediments. Additionally, the slope of the channel bed below the headcut is flatter than the slope of the channel upstream of the headcut. The headcut will continue to move upstream and will continue to remove accumulated sediments as demonstrated by similar naturally occurring headcuts in other ephemeral stream channels. Thus, in response to the NRC's comments, the preceding analyses have demonstrated that long-term sedimentation in the North Upstream Diversion Channel will not be problematic.

Placement of riprap on the east and west embankments of the access road will stop the minor rilling and headcutting that is currently occurring and will prevent future erosion. The minimum required D_{50} of the riprap is 1.2 inches, and it should be placed in a layer thickness of at least 3 inches. If larger riprap is used, it should be placed with a thickness of at least two times the D_{50} . Any riprap that is placed should be keyed into the toe of the slope a minimum of 3 feet to prevent scour at the toe and undercutting of the riprap. The extent and details of riprap placement are shown on Figure 4. Riprap used on the embankments will be sized to meet the gradation specifications shown in Table 4.

| Rock Size | Percent Finer |
|----------------|---------------|
| $1.5 * D_{50}$ | 75 - 100 |
| D_{50} | 30 - 70 |
| $0.5 * D_{50}$ | 0 - 25 |

3.3 RIPRAP JETTY

The three alternatives for resolution of degradation of the riprap jetty discussed by the NRC in their January, 2003 letter were as follows: 1) redesign the riprap; 2) demonstrate that the rock has been adequately sized; and 3) provide funding for long-term maintenance of the arroyo and rock jetty by estimating the amount of rock movement on an annual basis.

The review of the existing design and as-built data for the site by MWH revealed that the jetty was constructed using rock that met or exceeded the design requirements presented in the approved Reclamation Plan. During the site inspection, it was noted that established vegetation is causing the runoff from smaller return-period storms to become concentrated over parts of the western end of the jetty. The jetty riprap could be redesigned to account for these flow concentrations, however the riprap would likely be very large and the overall cost would be prohibitive. Mobilization of the in-place rock indicates that it is not properly sized for the concentrated flows that are currently occurring with storms much smaller than the PMF design event.

The overall damage to the jetty is minor, and MWH believes that it would be cost-effective to bond for annual repairs to the jetty, Option 3 above. During the field visit it was estimated that less than 10 cubic yards of riprap has become mobilized since reclamation was completed in 1996, and nearly all of the mobilized riprap has remained in the immediate vicinity of the jetty and could easily be placed back on the jetty. Therefore, the costs for ongoing repairing the riprap would be low. An additional cost-effective option that could be considered would be to remove the existing vegetation and bond for the cost of herbicides to be applied to prevent vegetation from becoming established in the future. Bonding calculations for annual monitoring and repair of the rock jetty and herbicide for control of vegetation upstream of the Jetty to prevent concentrated flow are presented in Appendix C with a net present value of \$140,550.

Drawings



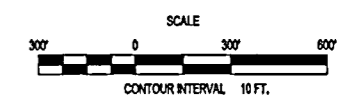
MWH

MONTGOMERY WATSON HARZA



LEGEND

- SWALE/CHANNEL CENTERLINE (Approximate)
- ▨ AREA OF SEDIMENT DEPOSITION



| | | | | | |
|----------|-------------------|-------|------------|----------|------------------------|
| 1 | Issued for Report | 11/04 | J.Thompson | K.Covath | J.Redmond |
| 0 | Issued for Review | 10/03 | M.Ross | K.Covath | M.Ross |
| REV. No. | REVISIONS | DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |



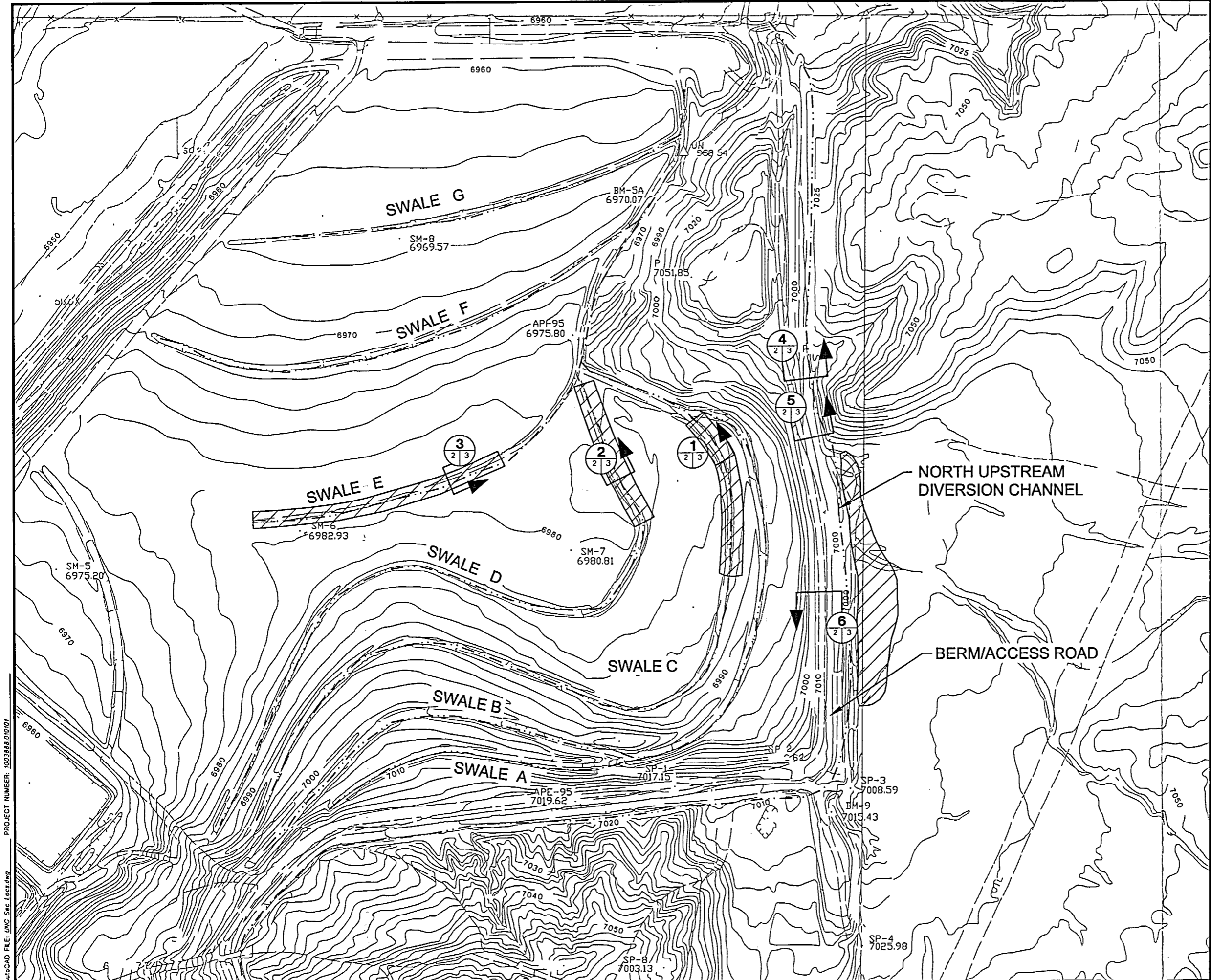
P.O. BOX 3077
Gallup, New Mexico 87305-3077

PROJECT:
CHURCH ROCK SEDIMENT EVALUATION

DRAWING TITLE:
FACILITIES MAP AND LOCATIONS OF SEDIMENT DEPOSITION



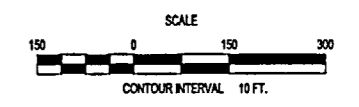
Sheet 1 of 1 Sheets
SCALE: 1"=600'
FIGURE No. 1



LEGEND

- SWALE/CHANNEL CENTERLINE (Approximate)
- ▨ AREA OF SEDIMENT DEPOSITION
- ③ CROSS SECTION LOCATION

DETAIL/SECTION NUMBER
 DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
 DRAWING No. WHERE DETAIL/SECTION IS SHOWN



| | | | | | |
|----------|-------------------|-------|------------|----------|------------------------|
| 1 | Issued for Report | 11/04 | J.Thompson | K.Cowan | J.Redmond |
| 0 | Issued for Review | 10/03 | M.Ross | K.Cowan | M.Ross |
| REV. No. | REVISIONS | DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |

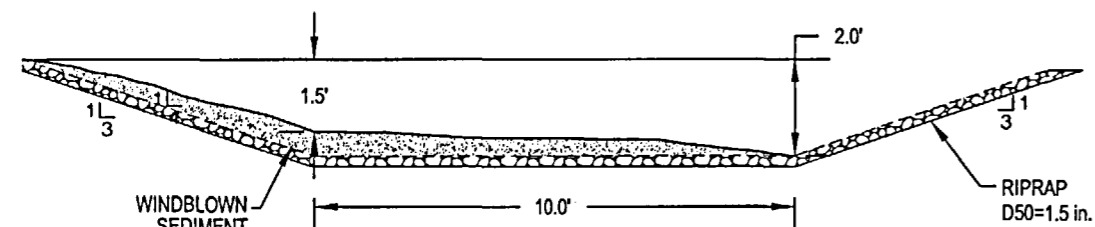


PROJECT: **CHURCH ROCK SEDIMENT EVALUATION**
 DRAWING TITLE: **SURVEYED CROSS SECTION LOCATIONS**

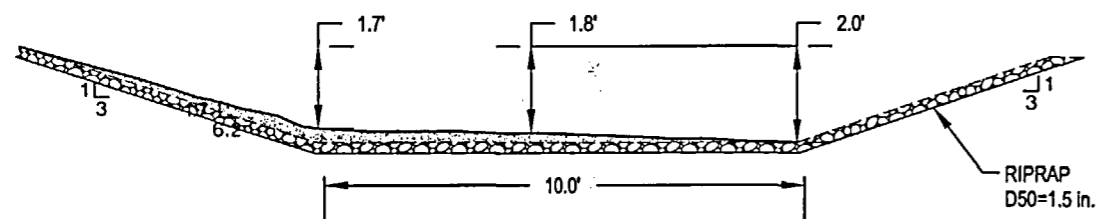


Sheet 1 of 1 Sheets
 SCALE: As Shown
 FIGURE No. 2

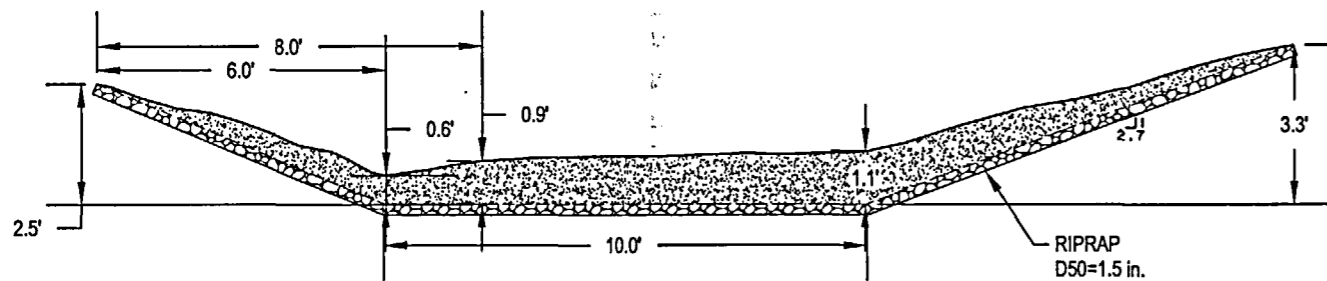
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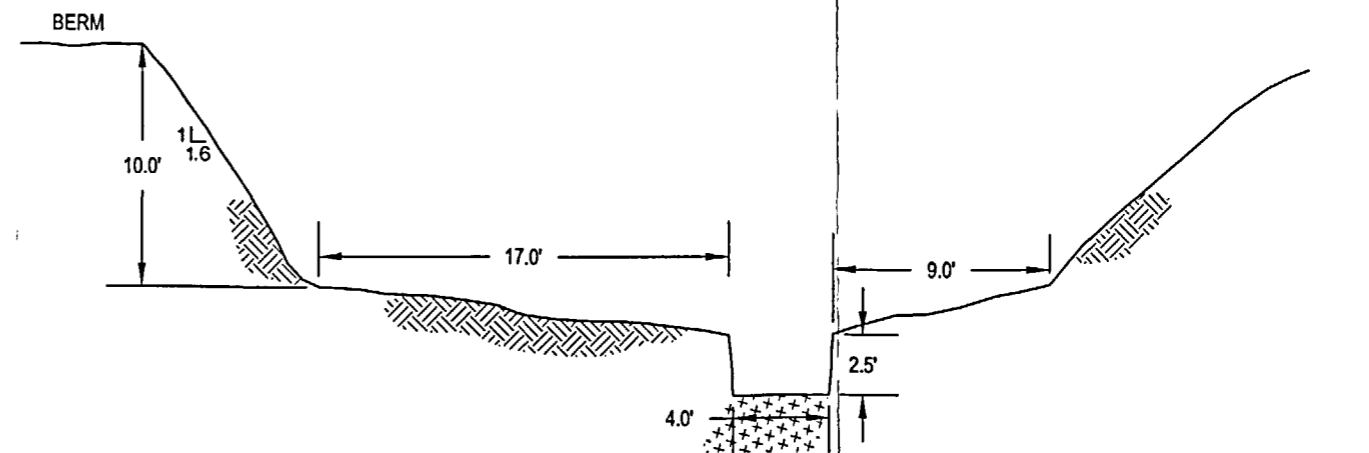
1 SWALE C CROSS-SECTION
 (BED SLOPE = 0.49%)
 HORIZONTAL SCALE
 0 2 4'
 VERTICAL SCALE
 0 2 4'



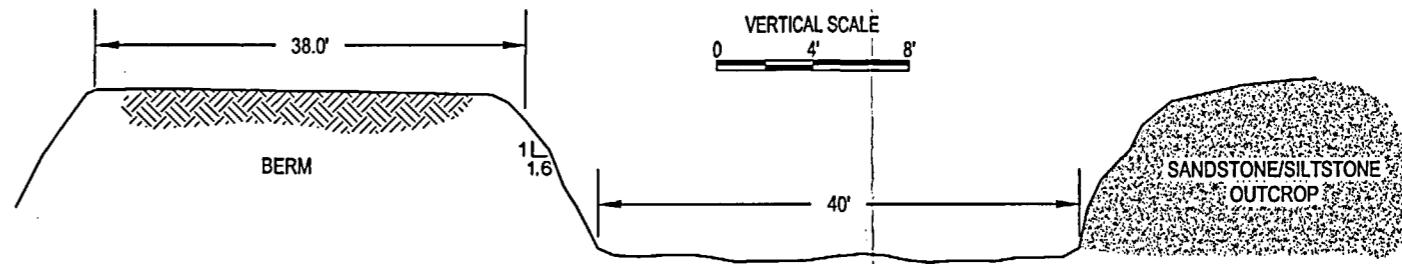
2 SWALE D CROSS-SECTION
 (BED SLOPE = 0.41%)
 HORIZONTAL SCALE
 0 2 4'
 VERTICAL SCALE
 0 2 4'



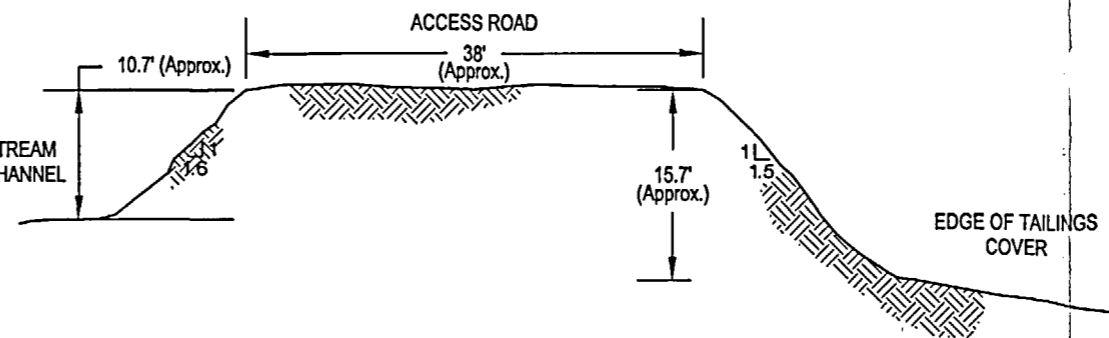
3 SWALE E CROSS-SECTION
 (BED SLOPE = 0.15%)
 HORIZONTAL SCALE
 0 2 4'
 VERTICAL SCALE
 0 2 4'



4 NORTH UPSTREAM DIVERSION CHANNEL PILOT CHANNEL CROSS-SECTION
 (BED SLOPE = 0.34%)
 HORIZONTAL SCALE
 0 4 8'
 VERTICAL SCALE
 0 4 8'



5 NORTH UPSTREAM DIVERSION CHANNEL WIDE CHANNEL CROSS-SECTION
 (BED SLOPE = 0.51%)
 HORIZONTAL SCALE
 0 8 16'
 VERTICAL SCALE
 0 8 16'



6 BERM/ACCESS ROAD CROSS-SECTION
 HORIZONTAL SCALE
 0 8 16'
 VERTICAL SCALE
 0 8 16'

DETAIL/SECTION NUMBER
A
 6 | 6

DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
 DRAWING No. WHERE DETAIL/SECTION IS SHOWN

| REV. No. | REVISIONS | DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|----------|-------------------|-------|------------|----------|------------------------|
| 1 | Issued for Report | 11/04 | J.Thompson | K.Cowath | J.Redmond |
| 0 | Issued for Review | 10/03 | M.Ross | K.Cowath | M.Ross |

UNC
 P.O. BOX 3077
 Gallup, New Mexico 87305-3077

PROJECT:
CHURCH ROCK SEDIMENT EVALUATION
 DRAWING TITLE:
SURVEYED CROSS SECTION DETAILS

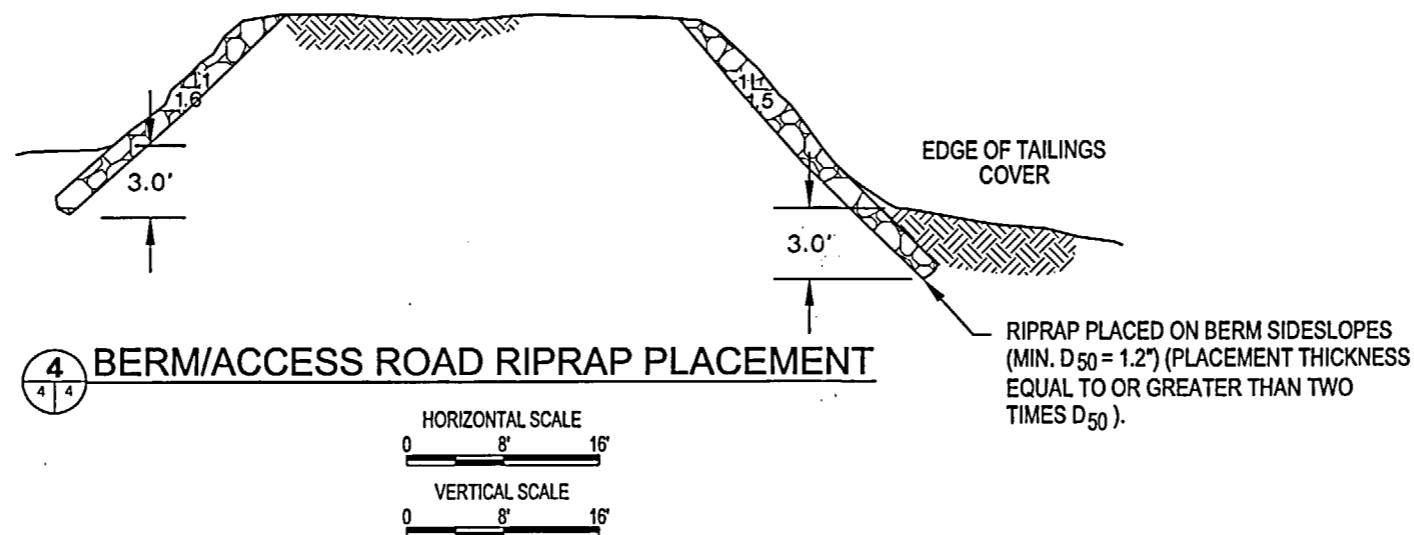
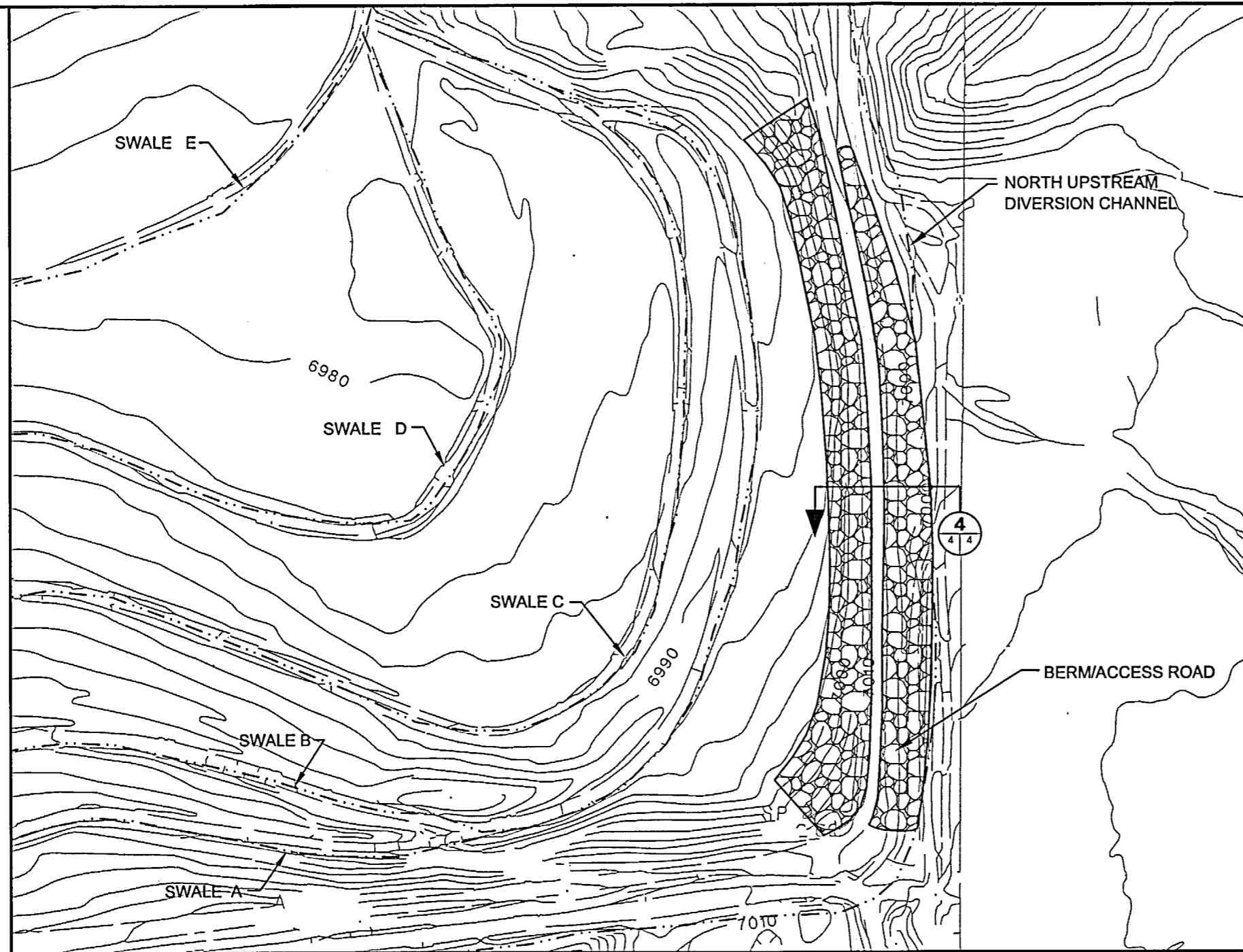
MWH

Sheet ___ Of ___ Sheets
 SCALE: 3

NOTE: ALL SCALES ARE APPROXIMATE.

AutoCAD FILE: UNC_CROSS_SECTIONS.dwg PROJECT NUMBER:

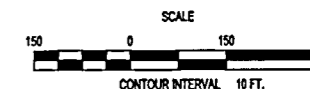
AutoCAD FILE: UNC Riprap Details.dwg PROJECT NUMBER: 1010193.011801



LEGEND

- SWALE/CHANNEL CENTERLINE (Approximate)
- [Hatched Box] RIPRAP PLACED FOR EROSION PROTECTION
- 4
4 4 CROSS SECTION LOCATION

DETAIL/SECTION NUMBER
A
6 6
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN



| REV. No. | REVISIONS | DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|----------|-------------------|-------|------------|----------|------------------------|
| 1 | Issued for Report | 11/04 | J.Thompson | K.Covath | J.Redmond |
| 0 | Issued for Review | 03/04 | M.Ross | K.Covath | M.Ross |

UNC P.O. BOX 3077
Gallup, New Mexico 87305-3077

PROJECT: **CHURCH ROCK SEDIMENT EVALUATION**
DRAWING TITLE: **BERM/ACCESS ROAD RIPRAP PLACEMENT DETAILS**

MWH

Sheet 1 of 1 Sheets
SCALE: As Shown
FIGURE No: 4

Appendix A



MWH

APPENDIX A

**SEPTEMBER, 2003
SITE VISIT PHOTOS**



Photo 1 Sedimentation in Swale C



Photo 2 Sedimentation in Swale E

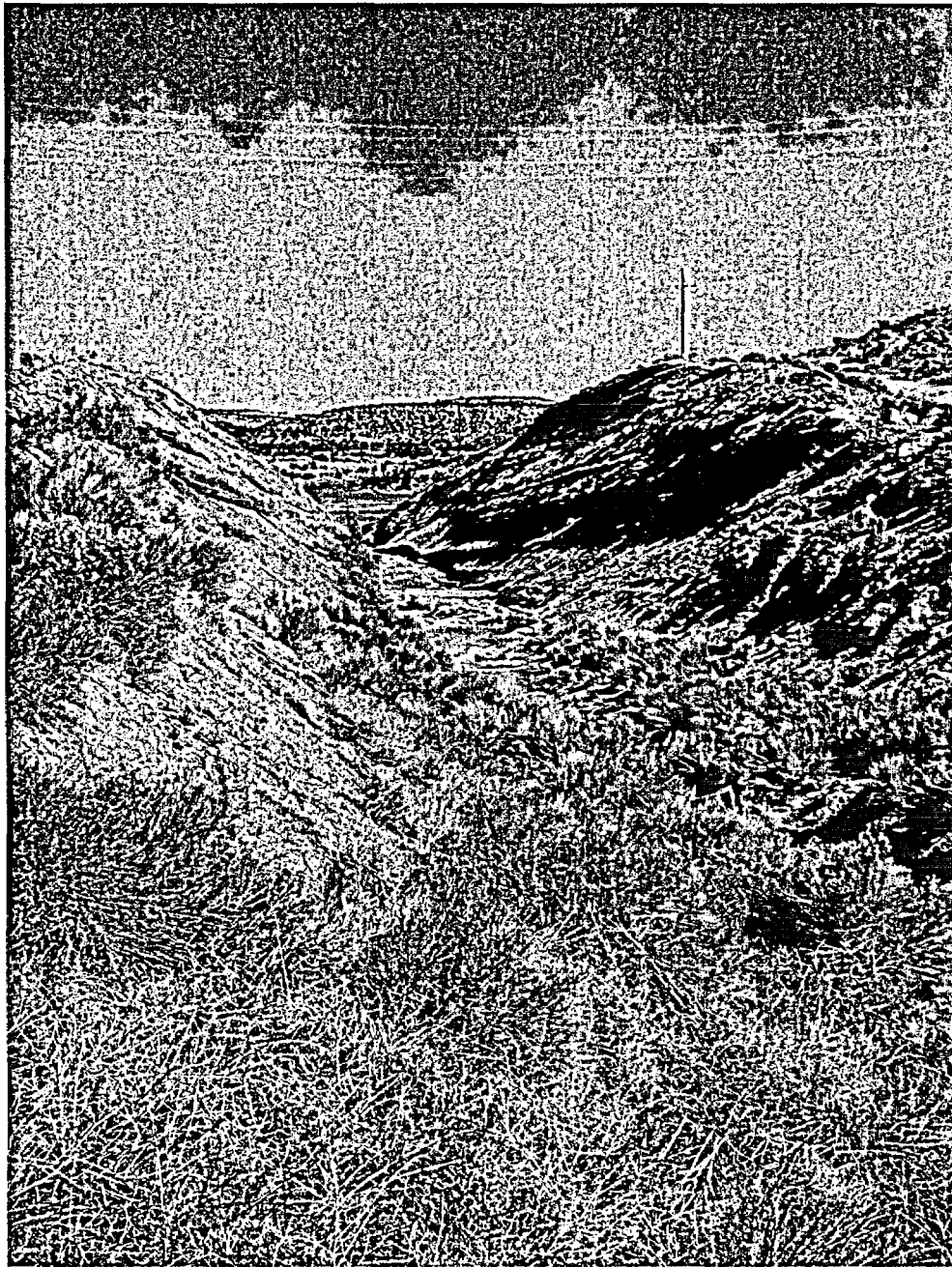


Photo 3 North Upstream Diversion Channel Outlet Incised to Bedrock



Photo 4 Pilot Channel at the Lower End of the North Upstream Diversion Channel



Photo 5 Well-defined Flow Path in the North Upstream Diversion Channel

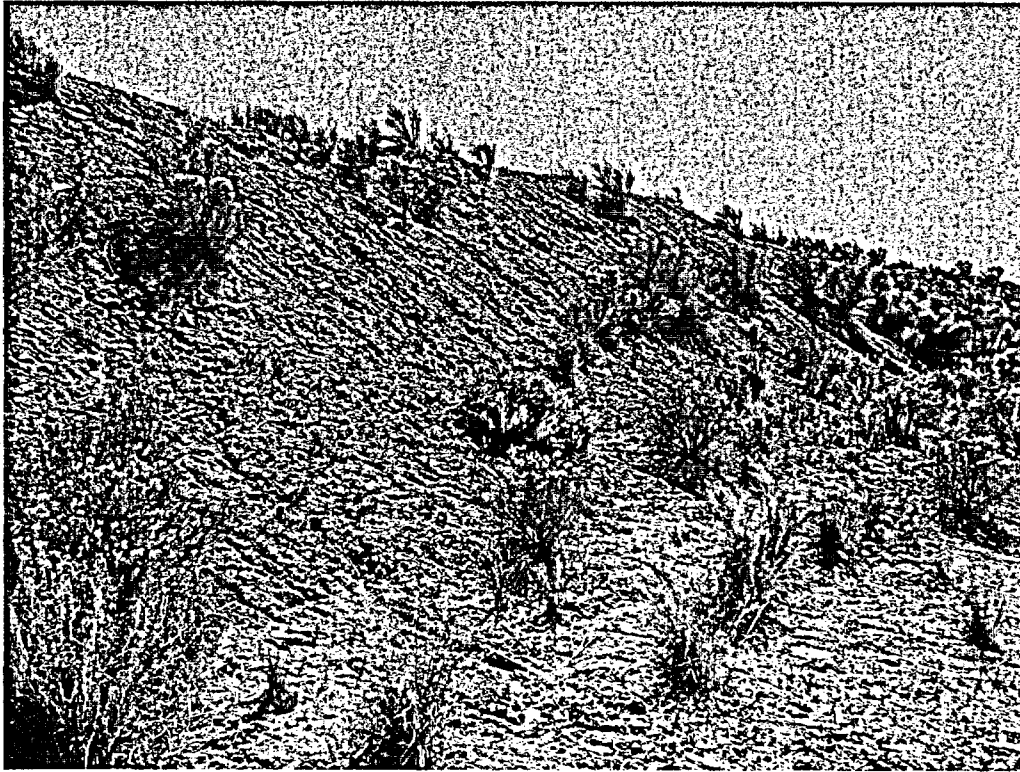


Photo 6 Minor Rilling on the East Sideslope of the Berm/access Road

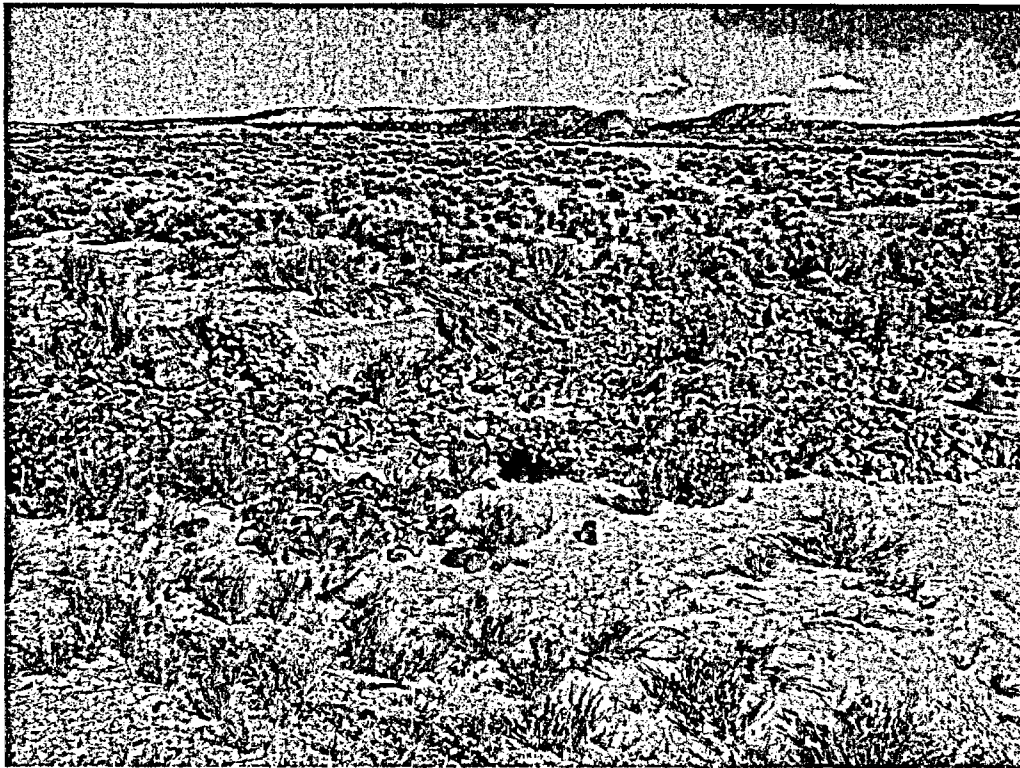


Photo 7 Eroded Riprap at the Western end of the Jetty

Appendix B



MWH

APPENDIX B

**HYDROLOGIC ANALYSIS AND
HYDRAULIC DESIGN INFORMATION**



PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14



New Mexico 35.700°N 108.467°W 7198 feet
Site-specific Estimates

| Confidence Limits | | Seasonality | | Location Maps | | Other Info | | Grids | | Maps | | Help | | | | | | |
|--|-------|-------------|--------|---------------|--------|------------|------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|
| Precipitation Frequency Estimates (inches) Version: ver2 | | | | | | | | | | | | | | | | | | |
| return period | 5 min | 10 min | 15 min | 30 min | 60 min | 120 min | 3 hr | 6 hr | 12 hr | 24 hr | 48 hr | 4 day | 7 day | 10 day | 20 day | 30 day | 45 day | 60 day |
| 2 | 0.20 | 0.30 | 0.38 | 0.51 | 0.63 | 0.73 | 0.78 | 0.90 | 1.03 | 1.13 | 1.25 | 1.46 | 1.71 | 1.94 | 2.53 | 3.08 | 3.75 | 4.30 |
| 5 | 0.29 | 0.45 | 0.55 | 0.74 | 0.92 | 1.05 | 1.11 | 1.24 | 1.40 | 1.55 | 1.71 | 1.99 | 2.32 | 2.62 | 3.41 | 4.14 | 5.01 | 5.73 |
| 10 | 0.36 | 0.55 | 0.69 | 0.92 | 1.14 | 1.29 | 1.35 | 1.49 | 1.65 | 1.85 | 2.02 | 2.34 | 2.72 | 3.06 | 3.99 | 4.82 | 5.82 | 6.62 |
| 25 | 0.46 | 0.70 | 0.87 | 1.17 | 1.45 | 1.63 | 1.68 | 1.82 | 1.99 | 2.25 | 2.44 | 2.79 | 3.22 | 3.61 | 4.72 | 5.65 | 6.79 | 7.69 |
| 50 | 0.54 | 0.82 | 1.02 | 1.37 | 1.70 | 1.91 | 1.95 | 2.09 | 2.24 | 2.57 | 2.75 | 3.14 | 3.60 | 4.01 | 5.25 | 6.25 | 7.49 | 8.44 |
| 100 | 0.62 | 0.95 | 1.18 | 1.59 | 1.96 | 2.21 | 2.25 | 2.38 | 2.51 | 2.90 | 3.08 | 3.48 | 3.98 | 4.41 | 5.78 | 6.83 | 8.15 | 9.15 |
| 200 | 0.72 | 1.09 | 1.35 | 1.82 | 2.25 | 2.53 | 2.57 | 2.69 | 2.81 | 3.24 | 3.42 | 3.83 | 4.35 | 4.80 | 6.29 | 7.39 | 8.77 | 9.81 |
| 500 | 0.85 | 1.29 | 1.60 | 2.16 | 2.67 | 3.00 | 3.04 | 3.13 | 3.25 | 3.72 | 3.87 | 4.30 | 4.84 | 5.31 | 6.97 | 8.10 | 9.56 | 10.64 |
| 1000 | 0.96 | 1.46 | 1.81 | 2.44 | 3.02 | 3.40 | 3.44 | 3.52 | 3.64 | 4.10 | 4.23 | 4.66 | 5.21 | 5.68 | 7.47 | 8.62 | 10.11 | 11.22 |

text version of table

These precipitation frequency estimates are based on annual maxima. Please refer to the documentation for conversion to partial duration series estimates.

BRANCH SWALES

Swale, Hydraulic/Hydrologic Analysis

- look @ Swales w/ Sed deposition

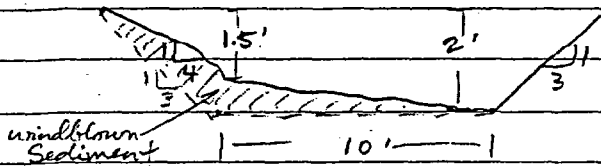
Swale C

From Rec Plan:

$$Area = 9.9 AC (0.0155 mi^2)$$

$$t_c = 0.2 hrs$$

XSEC from field survey:
(looking d/s)



slope meas. in field = 0.49%

From NOAA Atlas 14 (supersedes Atlas 2):

$$\left. \begin{array}{l} 10\text{-yr, 24 hr storm} = 1.85 \text{ in} \\ 100\text{-yr, 24 hr storm} = 2.90 \text{ in} \end{array} \right\} \begin{array}{l} \text{use for} \\ \text{all} \\ \text{swales} \end{array}$$

From TR-55 analysis:

$$Q_{10} = 5 \text{ cfs}$$

$$Q_{100} = 15 \text{ cfs}$$

$$Q_{pmf} = 75 \text{ cfs (presented in Rec Plan)}$$

| January 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| February 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| March 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| April 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | |
| May 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |
| June 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| July 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | 1 | 2 |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |
| August 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| September 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| October 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| November 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| December 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

Swale analysis (con't)
Swale C (con't)

from Barfield, et. al.:

$$\tau_{c11} = 0.075 \text{ psf (sandy loam, non-colloidal)}$$

$$V_{per} = 2.5 \text{ ft/Sec}$$

← use for all swales

Hydraulic Summary:

| Event | Q (cfs) | V (ft/s) | depth (ft) | $\tau = \gamma d S$ (psf) |
|--------|---------|----------|------------|---------------------------|
| 10-yr | 5 | 1.35 | 0.57 | 0.17 |
| 100-yr | 15 | 1.96 | 0.87 | 0.27 |
| PMF | 75 | 3.20 | 1.78 | 0.54 |

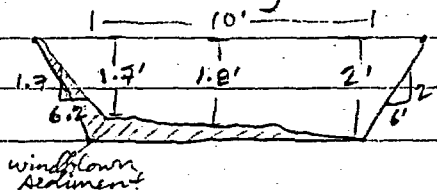
Swale D

From Rec Plan:

$$\text{Area} = 10.6 \text{ AC (0.0166 mi}^2\text{)}$$

$$t_c = 0.3 \text{ hrs}$$

XSEC from field survey
(looking d/s)



Slope meas. in field = 0.41%

January 2003

| | | | | | | | |
|----|----|----|----|----|----|----|---|
| S | S | M | T | W | Th | F | |
| | | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 | |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 | |

February 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |

March 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

April 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|---|---|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | | |
| 26 | 27 | 28 | 29 | 30 | | | | |

May 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|--|--|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 | | |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | | |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 | | |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 | | |
| 31 | | | | | | | | |

June 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|--|--|
| S | S | M | T | W | Th | F | | |
| 1 | 2 | 3 | 4 | 5 | 6 | | | |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 | | |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 | | |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | | |
| 28 | 29 | 30 | | | | | | |

July 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|---|---|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | | |
| 26 | 27 | 28 | 29 | 30 | 31 | | | |

August 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|--|--|
| S | S | M | T | W | Th | F | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | | |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 | | |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| 29 | 30 | 31 | | | | | | |

September 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|---|---|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | | |
| 26 | 27 | 28 | 29 | 30 | 31 | | | |

October 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|---|---|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | | |
| 26 | 27 | 28 | 29 | 30 | 31 | | | |

November 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|--|--|
| S | S | M | T | W | Th | F | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | | |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | | |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 | | |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| 29 | 30 | | | | | | | |

December 2003

| | | | | | | | | |
|----|----|----|----|----|----|----|---|---|
| S | S | M | T | W | Th | F | | |
| | | | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | | |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | | |
| 26 | 27 | 28 | 29 | 30 | 31 | | | |

Swale analysis (cont)
Swale D (cont)

From TR-55 analysis:

$$Q_{10} = 5 \text{ cfs}$$

$$Q_{100} = 16 \text{ cfs}$$

$$Q_{\text{pmf}} = 68 \text{ cfs (presented in Rec Plan)}$$

Hydraulic Summary

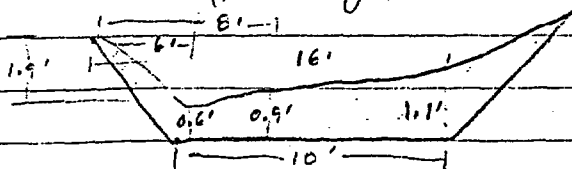
| Event | Q (cfs) | V (ft/s) | depth (ft) | $\tau = 8d^2S$ (psf) |
|--------|---------|----------|------------|----------------------|
| 10-yr | 5 | 1.26 | 0.52 | 0.13 |
| 100-yr | 16 | 1.88 | 0.86 | 0.22 |
| PMF | 68 | 2.93 | 1.70 | 0.43 |

Swale E

From Rec Plan:

$$\text{Area} = 13.3 \text{ Ac (0.0208 mi}^2\text{)}$$

$$t_c = 0.3 \text{ hrs}$$

XSEC from field survey (looking d/s)


slope meas in field = 0.15%

| January 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| February 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| March 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| April 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | |
| May 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| June 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| July 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| August 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| September 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| October 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| November 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| December 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

Swale Analysis (cont)
Swale E (cont)

From TR-55 analysis:

$$Q_{10} = 6 \text{ cfs}$$

$$Q_{100} = 17 \text{ cfs}$$

$$Q_{pmf} = 85 \text{ cfs (presented in Rec Plan)}$$

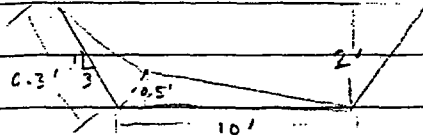
Hydraulic Summary

| Event | Q (cfs) | v (ft/s) | depth (ft) | $\tau = \gamma ds$ (psf) |
|------------------------|---------|-----------------------|------------|--------------------------|
| 10-yr | 6 | 0.89 | 0.88 | 0.08 |
| 100-yr | 17 | 1.26 | 1.34 | 0.13 |
| pmf | 85 | channel is overtopped | | |
| full-flow w/bed slopes | 37.6 | 1.61 | 1.9 | 0.18 |

| January 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| February 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| March 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| April 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| May 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| June 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| July 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| August 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| September 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| October 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| November 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| December 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

Swale Sediment Volumes
Swale C

Sed area:



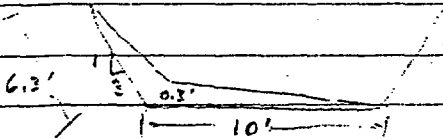
$$\text{Area} = \left(\frac{1}{2} \times 0.5' \times 10'\right) + \left(\frac{1}{2} \times 6.3' \times 0.5'\right) = 4.1 \text{ ft}^2$$

length of sediment-impacted reach = 500'

$$\text{Sed vol} = \frac{4.1 \text{ ft}^2}{1} \times \frac{500 \text{ ft}}{1} \times \frac{100 \text{ lb}}{\text{ft}^3} \times \frac{1 \text{ ton}}{2000 \text{ lb}} = 103 \text{ tons}$$

Swale D

Sed area:



$$\text{Area} = \left(\frac{1}{2} \times 0.3' \times 10'\right) + \left(\frac{1}{2} \times 6.3' \times 0.3'\right) = 2.45 \text{ ft}^2$$

length of sediment-impacted reach = 500'

$$\text{sed vol} = \frac{2.45 \text{ ft}^2}{1} \times \frac{500 \text{ ft}}{1} \times \frac{100 \text{ lb}}{\text{ft}^3} \times \frac{1 \text{ ton}}{2000 \text{ lb}} = 61 \text{ tons}$$

| January 2003 | | | | | | |
|--------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

| February 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |

| March 2003 | | | | | | |
|------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| April 2003 | | | | | | |
|------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

| May 2003 | | | | | | |
|----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |

| June 2003 | | | | | | |
|-----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

| July 2003 | | | | | | |
|-----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

| August 2003 | | | | | | |
|-------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

| September 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

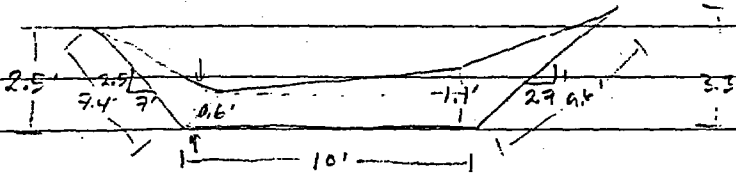
| October 2003 | | | | | | |
|--------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

| November 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

| December 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

Swale Sediment Volumes (con't)
Swale E

Sed area:



$$\text{Area} = \left(\frac{1}{2} \times 0.6' \times 7.4'\right) + (10' \times 0.6') + \left(\frac{1}{2} \times 0.5' \times 10'\right) + \left(\frac{1}{2} \times 1.1' \times 9.6'\right) = 16.0 \text{ ft}^2$$

length of sediment - impacted reach = 950'

$$\text{Sed vol} = \frac{16.0 \text{ ft}^2}{1} \times \frac{950 \text{ ft}}{1} \times \frac{100 \text{ lb}}{\text{ft}^3} \times \frac{1 \text{ ton}}{2000 \text{ lb}} = 760 \text{ tons}$$

| January 2003 | | | | | | |
|--------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| February 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | | | | | | |

| March 2003 | | | | | | |
|------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| April 2003 | | | | | | |
|------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

| May 2003 | | | | | | |
|----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| June 2003 | | | | | | |
|-----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| July 2003 | | | | | | |
|-----------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| August 2003 | | | | | | |
|-------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| September 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| October 2003 | | | | | | |
|--------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

| November 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

| December 2003 | | | | | | |
|---------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed

User: MKR

Date: 11-07-2003

County :

State:

Checked: _____

Date: _____

Subtitle: Swale C 10-year

Total watershed area: 0.015 sq mi Rainfall type: II Frequency: 10 years

----- Subareas -----

1
 Area(sq mi) 0.02
 Rainfall(in) 1.9
 Curve number 80
 Runoff(in) 0.47
 Tc (hrs) 0.20
 TimeToOutlet 0.00
 Ia/P 0.27

Time Total ----- Subarea Contribution to Total Flow (cfs) -----
 (hr) Flow 1

| | | |
|------|----|----|
| 11.0 | 0 | 0 |
| 11.3 | 0 | 0 |
| 11.6 | 0 | 0 |
| 11.9 | 0 | 0 |
| 12.0 | 2 | 2 |
| 12.1 | 4 | 4 |
| 12.2 | 5P | 5P |
| 12.3 | 4 | 4 |
| 12.4 | 2 | 2 |
| 12.5 | 1 | 1 |
| 12.6 | 1 | 1 |
| 12.7 | 1 | 1 |
| 12.8 | 1 | 1 |
| 13.0 | 1 | 1 |
| 13.2 | 1 | 1 |
| 13.4 | 1 | 1 |
| 13.6 | 0 | 0 |
| 13.8 | 0 | 0 |
| 14.0 | 0 | 0 |
| 14.3 | 0 | 0 |
| 14.6 | 0 | 0 |
| 15.0 | 0 | 0 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed

User: MKR

Date: 11-07-2003

County :

State:

Checked: _____

Date: _____

Subtitle: Swale C 100-year

Total watershed area: 0.015 sq mi Rainfall type: II Frequency: 100 years

----- Subareas -----

1
 Area(sq mi) 0.02
 Rainfall(in) 2.9
 Curve number 80
 Runoff(in) 1.18
 Tc (hrs) 0.20
 TimeToOutlet 0.00
 Ia/P 0.17
 (Used) 0.10

Time Total ----- Subarea Contribution to Total Flow (cfs) -----
 (hr) Flow 1

| | | |
|------|-----|-----|
| 11.0 | 0 | 0 |
| 11.3 | 1 | 1 |
| 11.6 | 1 | 1 |
| 11.9 | 4 | 4 |
| 12.0 | 7 | 7 |
| 12.1 | 13 | 13 |
| 12.2 | 15P | 15P |
| 12.3 | 9 | 9 |
| 12.4 | 5 | 5 |
| 12.5 | 3 | 3 |
| 12.6 | 2 | 2 |
| 12.7 | 2 | 2 |
| 12.8 | 2 | 2 |
| 13.0 | 1 | 1 |
| 13.2 | 1 | 1 |
| 13.4 | 1 | 1 |
| 13.6 | 1 | 1 |
| 13.8 | 1 | 1 |
| 14.0 | 1 | 1 |
| 14.3 | 1 | 1 |
| 14.6 | 1 | 1 |
| 15.0 | 1 | 1 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed
 County :
 Subtitle: Swale D 10-year

User: MKR
 Checked: _____

Date: 11-07-2003
 Date: _____

Total watershed area: 0.017 sq mi Rainfall type: II Frequency: 10 years

----- Subareas -----

1
 Area(sq mi) 0.02
 Rainfall(in) 1.9
 Curve number 80
 Runoff(in) 0.47
 Tc (hrs) 0.20
 TimeToOutlet 0.00
 Ia/P 0.27
 (Used) 0.30

Time Total ----- Subarea Contribution to Total Flow (cfs) -----
 (hr) Flow 1

| | | |
|------|----|----|
| 11.0 | 0 | 0 |
| 11.3 | 0 | 0 |
| 11.6 | 0 | 0 |
| 11.9 | 0 | 0 |
| 12.0 | 1 | 1 |
| 12.1 | 4 | 4 |
| 12.2 | 5P | 5P |
| 12.3 | 4 | 4 |
| 12.4 | 2 | 2 |
| 12.5 | 2 | 2 |
| 12.6 | 1 | 1 |
| 12.7 | 1 | 1 |
| 12.8 | 1 | 1 |
| 13.0 | 1 | 1 |
| 13.2 | 1 | 1 |
| 13.4 | 1 | 1 |
| 13.6 | 1 | 1 |
| 13.8 | 0 | 0 |
| 14.0 | 0 | 0 |
| 14.3 | 0 | 0 |
| 14.6 | 0 | 0 |
| 15.0 | 0 | 0 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed

User: MKR

Date: 11-07-2003

County :

State:

Checked: _____

Date: _____

Subtitle: Swale D 100-year

Total watershed area: 0.017 sq mi Rainfall type: II Frequency: 100 years

----- Subareas -----

| | |
|--------------|------|
| | 1 |
| Area(sq mi) | 0.02 |
| Rainfall(in) | 2.9 |
| Curve number | 80 |
| Runoff(in) | 1.18 |
| Tc (hrs) | 0.20 |
| TimeToOutlet | 0.00 |
| Ia/P | 0.17 |
| (Used) | 0.10 |

Time Total ----- Subarea Contribution to Total Flow (cfs) -----
 (hr) Flow 1

| | | |
|------|-----|-----|
| 11.0 | 0 | 0 |
| 11.3 | 1 | 1 |
| 11.6 | 1 | 1 |
| 11.9 | 4 | 4 |
| 12.0 | 8 | 8 |
| 12.1 | 14 | 14 |
| 12.2 | 16P | 16P |
| 12.3 | 9 | 9 |
| 12.4 | 5 | 5 |
| 12.5 | 3 | 3 |
| 12.6 | 2 | 2 |
| 12.7 | 2 | 2 |
| 12.8 | 2 | 2 |
| 13.0 | 1 | 1 |
| 13.2 | 1 | 1 |
| 13.4 | 1 | 1 |
| 13.6 | 1 | 1 |
| 13.8 | 1 | 1 |
| 14.0 | 1 | 1 |
| 14.3 | 1 | 1 |
| 14.6 | 1 | 1 |
| 15.0 | 1 | 1 |
| 15.5 | 1 | 1 |
| 16.0 | 0 | 0 |
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed
 County :
 Subtitle: Swale E 10-year

User: MKR
 Checked: _____

Date: 11-07-2003
 Date: _____

Total watershed area: 0.021 sq mi Rainfall type: II Frequency: 10 years
 ----- Subareas -----

1
 Area(sq mi) 0.02
 Rainfall(in) 1.9
 Curve number 80
 Runoff(in) 0.47
 Tc (hrs) 0.30
 TimeToOutlet 0.00
 Ia/P 0.27

| Time (hr) | Total Flow | Subarea Contribution to Total Flow (cfs) |
|-----------|------------|--|
| | | 1 |
| 11.0 | 0 | 0 |
| 11.3 | 0 | 0 |
| 11.6 | 0 | 0 |
| 11.9 | 0 | 0 |
| 12.0 | 1 | 1 |
| 12.1 | 3 | 3 |
| 12.2 | 5 | 5 |
| 12.3 | 6P | 6P |
| 12.4 | 4 | 4 |
| 12.5 | 3 | 3 |
| 12.6 | 2 | 2 |
| 12.7 | 2 | 2 |
| 12.8 | 1 | 1 |
| 13.0 | 1 | 1 |
| 13.2 | 1 | 1 |
| 13.4 | 1 | 1 |
| 13.6 | 1 | 1 |
| 13.8 | 1 | 1 |
| 14.0 | 1 | 1 |
| 14.3 | 0 | 0 |
| 14.6 | 0 | 0 |
| 15.0 | 0 | 0 |
| 15.5 | 0 | 0 |
| 16.0 | 0 | 0 |
| 16.5 | 0 | 0 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

TABULAR HYDROGRAPH METHOD

Version 2.10

Project : Church Rock Erosion and Sed
 County :
 Subtitle: Swale E 100-year

User: MKR
 State:
 Checked: _____

Date: 11-07-2003
 Date: _____

Total watershed area: 0.021 sq mi Rainfall type: II Frequency: 100 years

----- Subareas -----

1
 Area(sq mi) 0.02
 Rainfall(in) 2.9
 Curve number 80
 Runoff(in) 1.18
 Tc (hrs) 0.30
 TimeToOutlet 0.00
 Ia/P 0.17
 (Used) 0.10

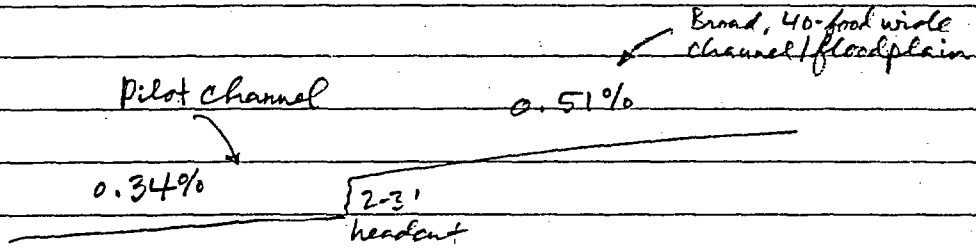
Time Total ----- Subarea Contribution to Total Flow (cfs) -----
 (hr) Flow 1

| | | |
|------|-----|-----|
| 11.0 | 0 | 0 |
| 11.3 | 1 | 1 |
| 11.6 | 1 | 1 |
| 11.9 | 3 | 3 |
| 12.0 | 6 | 6 |
| 12.1 | 11 | 11 |
| 12.2 | 17P | 17P |
| 12.3 | 17 | 17 |
| 12.4 | 11 | 11 |
| 12.5 | 7 | 7 |
| 12.6 | 5 | 5 |
| 12.7 | 4 | 4 |
| 12.8 | 3 | 3 |
| 13.0 | 2 | 2 |
| 13.2 | 2 | 2 |
| 13.4 | 1 | 1 |
| 13.6 | 1 | 1 |
| 13.8 | 1 | 1 |
| 14.0 | 1 | 1 |
| 14.3 | 1 | 1 |
| 14.6 | 1 | 1 |
| 15.0 | 1 | 1 |
| 15.5 | 1 | 1 |
| 16.0 | 1 | 1 |
| 16.5 | 1 | 1 |
| 17.0 | 0 | 0 |
| 17.5 | 0 | 0 |
| 18.0 | 0 | 0 |
| 19.0 | 0 | 0 |
| 20.0 | 0 | 0 |
| 22.0 | 0 | 0 |
| 26.0 | 0 | 0 |

P - Peak Flow

**NORTH UPSTREAM
DIVERSION CHANNEL**

N. channel @ berm Hydraulic Hydrologic Analysis



Pilot below headcut:

$Q @ 3.5' \text{ depth} = 76 \text{ cfs}$ (storm on 9/10)

$\tau = \gamma d S = (62.4)(3.5)(0.0034) = 0.74 \text{ psf}$

$V = 3 \text{ ft/sec}$

$\tau_{crit} = 0.075$ (sandy loam, non-colloidal)

$N_{per} = 2.5 \text{ ft/s}$

Broad channel above headcut:

width = 40', 1:1 sides, slope = 0.0051 ft/ft (normal depth):

$d = 0.76 \text{ ft}$

$V = 2.5 \text{ ft/s}$

$\tau = (62.4)(0.76)(0.0051) = 0.24 \text{ psf}$

Hydrologic analysis using SCS Triangular UH

From NOAA Atlas 14:

5yr - 1 hour = 0.92 in

10yr - 1 hour = 1.14 in

100 year, 1-hour = 1.81 in (from Rec Plan)

January 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

February 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

March 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

April 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

May 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

June 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

July 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

August 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

September 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

October 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

November 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |

December 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

N. channel Hydraulic Analysis (con't)
Hydrologic Analysis (con't)

SCS Triangular UH spreadsheet output:

$$Q_{5-yr} = 58 \text{ cfs}$$

$$Q_{10-yr} = 125 \text{ cfs}$$

$$Q_{100-yr} = 296 \text{ cfs (from Rec Plan Apdx E)}$$

⇒ 9/10/03 storm < 10-yr event

Hydraulic Summary

pilot:

| Event | Q (cfs) | v (ft/s) | depth (ft) | $\tau = \gamma d S$ (psf) |
|---------|---------|----------|------------|---------------------------|
| 5-yr | 58 | 2.58 | 3.36 | 0.71 |
| 10-yr | 125 | 3.06 | 4.17 | 0.88 |
| 100-yr | 296 | 4.15 | 5.14 | 1.09 |
| 9/10/03 | 76 | 3.03 | 3.50 | 0.74 |

wide chan.

| Event | Q (cfs) | v (ft/s) | depth (ft) | $\tau = \gamma d S$ (psf) |
|---------|---------|----------|------------|---------------------------|
| 5-yr | 58 | 2.23 | 0.65 | 0.21 |
| 10-yr | 125 | 3.01 | 1.04 | 0.33 |
| 100-yr | 296 | 4.19 | 1.76 | 0.56 |
| 9/10/03 | 76 | 2.48 | 0.77 | 0.25 |

January 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | 3 |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |

February 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |

March 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

April 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

May 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | 1 | 2 | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |

June 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | | | | |

July 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | 31 | | | |

August 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

September 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |

October 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |

November 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | | | | |

December 2003

| | | | | | | |
|----|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

NORMAL DEPTH CALCULATION

PROJECT: UNC Erosion and Sedimentation Evaluation

LOCATION: North Upstream Diversion above the pilot channel/headcut

Channel Hydraulic properties (input):

| | |
|------------------------|--------|
| Flow (cfs): | 76 |
| Manning's n: | 0.035 |
| Bottom Width (ft): | 40 |
| Right Side Slope, z:1 | 1 |
| Left Side Slope, z:1 | 1 |
| Channel Slope (ft/ft): | 0.0051 |

Solve

Solve: ctrl-s

| <u>Depth</u> | <u>Formula</u> |
|--------------|----------------|
| 0.756 | 0 |

Channel Hydraulic Results:

| | |
|---|-------------|
| Depth (ft) = | 0.756 |
| Hydraulic Radius (ft) = | 0.731 |
| Cross-sectional Area (ft ²) = | 30.80 |
| Average Velocity (ft ² /s) = | 2.47 |
| Topwidth (ft) = | 41.51 |
| Froude Number = | 0.51 |
| Flow condition: | SUBCRITICAL |

Pilot at North Diversion, 9/10/03 storm
Worksheet for Irregular Channel

| Project Description | |
|---------------------|---|
| Project File | c:\haestad\mw\project1.fm2 |
| Worksheet | Pilot at North Diversion, 9/10/03 event |
| Flow Element | Irregular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

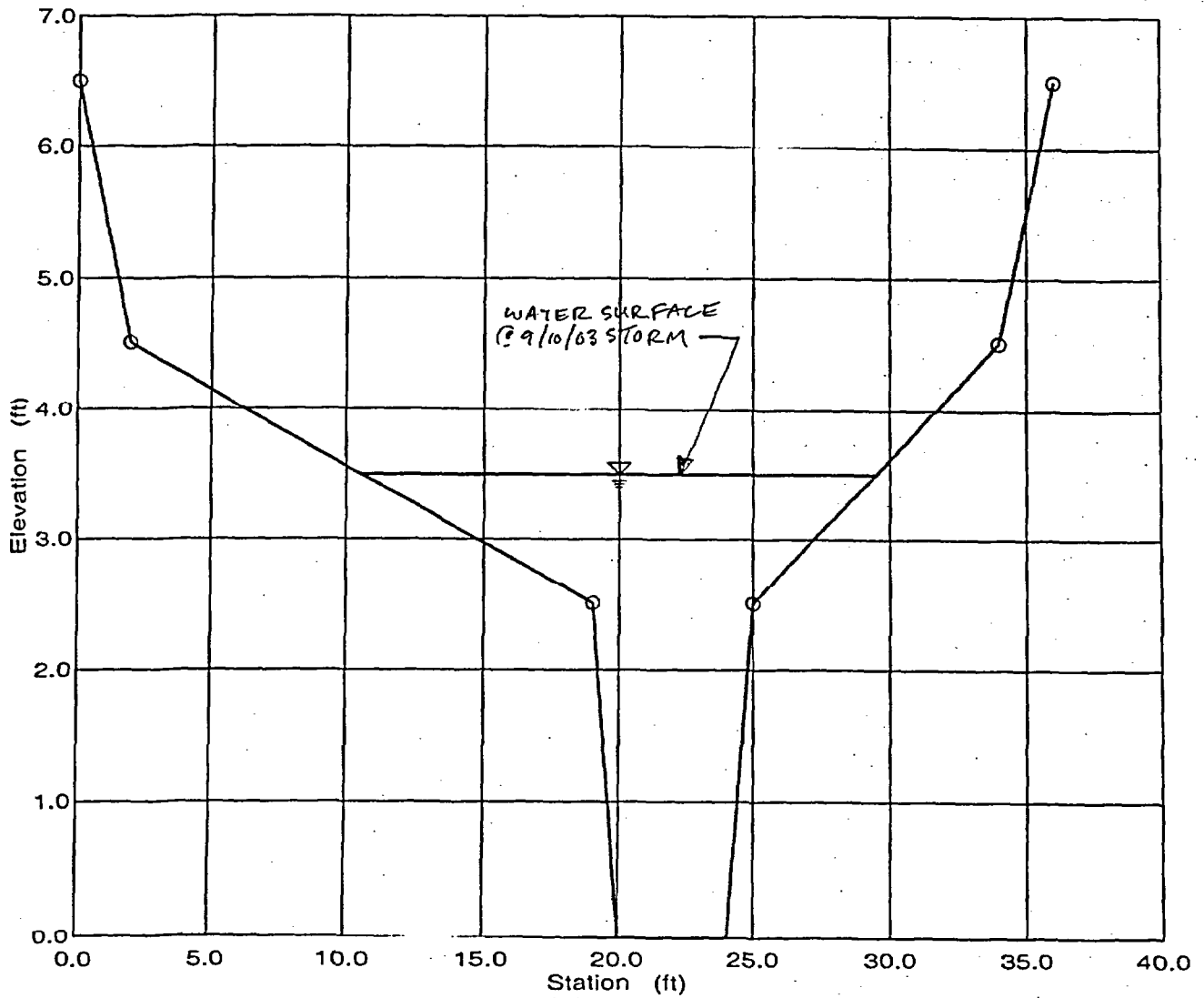
| Input Data | | | | |
|--------------------------------------|----------------|---------------|-------------|-----------|
| Channel Slope | 0.003400 ft/ft | | | |
| Water Surface Elevation | 3.50 ft | | | |
| Elevation range: 0.00 ft to 6.50 ft. | | | | |
| Station (ft) | Elevation (ft) | Start Station | End Station | Roughness |
| 0.00 | 6.50 | 0.00 | 2.00 | 0.030 |
| 2.00 | 4.50 | 2.00 | 19.00 | 0.040 |
| 19.00 | 2.50 | 19.00 | 25.00 | 0.030 |
| 20.00 | 0.00 | 25.00 | 34.00 | 0.040 |
| 24.00 | 0.00 | 34.00 | 36.00 | 0.030 |
| 25.00 | 2.50 | | | |
| 34.00 | 4.50 | | | |
| 36.00 | 6.50 | | | |

| Results | |
|---------------------------|-----------------------|
| Wtd. Mannings Coefficient | 0.031 |
| Discharge | 75.64 cfs |
| Flow Area | 25.00 ft ² |
| Wetted Perimeter | 22.55 ft |
| Top Width | 19.00 ft |
| Height | 3.50 ft |
| Critical Depth | 2.07 ft |
| Critical Slope | 0.018554 ft/ft |
| Velocity | 3.03 ft/s |
| Velocity Head | 0.14 ft |
| Specific Energy | 3.64 ft |
| Froude Number | 0.47 |
| Flow is subcritical. | |

Pilot at North Diversion, 9/10/03 storm
 Cross Section for Irregular Channel

| Project Description | |
|---------------------|---|
| Project File | c:\haestad\fmw\project1.fm2 |
| Worksheet | Pilot at North Diversion, 9/10/03 event |
| Flow Element | Irregular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

| Section Data | |
|---------------------------|----------------|
| Wtd. Mannings Coefficient | 0.031 |
| Channel Slope | 0.003400 ft/ft |
| Water Surface Elevation | 3.50 ft |
| Discharge | 75.64 cfs |



An alternative approach to designing stable, unlined channels is to use regime relationships. These relationships define equilibrium conditions between flow and the channel boundaries. Chapter 10 discusses this approach.

Example Problem 4.10 Erodible channel design

Design a channel to carry 20 cfs down a 0.5% slope. The channel material is to be an ordinary firm loam. The water will be transporting colloidal silts. The channel is to be trapezoidal with 3:1 side slopes. Use (a) the limiting velocity approach and (b) the limiting tractive force approach.

Solution:

(a) Limiting velocity approach. From Table 4.2, $v_p = 3.5$ fps, $n = 0.020$,

$$v_p = \frac{1.49}{n} R^{2/3} S^{1/2}$$

$$R = \left[\frac{v_p n}{1.49 S^{1/2}} \right]^{3/2} = \left[\frac{3.5(0.020)}{1.49(0.005)^{1/2}} \right]^{3/2} = 0.54$$

$$A = \frac{Q}{v_p} = \frac{20.00}{3.5} = 5.71$$

$$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = \frac{bd + 3d^2}{b + 6.32d} = 0.54 \quad (a)$$

$$A = bd + zd^2 = bd + 3d^2 = 5.71. \quad (b)$$

Substituting Eq. (b) into Eq. (a) yields

$$\frac{5.71}{b + 6.32d} = 0.54$$

or

$$b = 10.58 - 6.32d. \quad (c)$$

Substituting this into Eq. (b) yields

$$(10.58 - 6.32d)d + 3d^2 = 5.71$$

$$-3.32d^2 + 10.58d - 5.71 = 0.00.$$

This is a quadratic equation of the form

$$ax^2 + bx + c = 0,$$

which has as a solution

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Therefore

$$d = \frac{-10.58 \pm \sqrt{10.58^2 - 4(-3.32)(-5.71)}}{2(-3.32)}$$

$$d = \frac{-10.58 + 6.00}{-6.64} = 2.50; 0.69.$$

Table 4.2 Limiting Velocities and Tractive Forces for Open Channels (Straight after Aging)^a

| Material | n | Water transporting colloidal silts | | | |
|--|-------|------------------------------------|-------------------------|----------------------|-------------------------|
| | | For Clear Water | Tractive Velocity (fps) | Tractive force (psf) | Tractive Velocity (fps) |
| Fine sand colloidal | 0.020 | 1.50 | 0.027 | 2.50 | 0.075 |
| Sandy loam noncolloidal | 0.020 | 1.75 | 0.037 | 2.50 | 0.075 |
| Silt loam noncolloidal | 0.020 | 2.00 | 0.048 | 3.00 | 0.110 |
| Alluvial silts noncolloidal | 0.020 | 2.00 | 0.048 | 3.50 | 0.150 |
| Ordinary firm loam | 0.020 | 2.50 | 0.075 | 3.50 | 0.150 |
| Volcanic ash | 0.020 | 2.50 | 0.075 | 3.50 | 0.150 |
| Stiff clay very colloidal | 0.025 | 3.75 | 0.260 | 5.00 | 0.460 |
| Alluvial silts colloidal | 0.025 | 3.75 | 0.260 | 5.00 | 0.460 |
| Shales and hardpans | 0.025 | 6.00 | 0.670 | 6.00 | 0.670 |
| Fine gravel | 0.020 | 2.50 | 0.075 | 5.00 | 0.320 |
| Graded loam to cobbles when noncolloidal | 0.030 | 3.75 | 0.380 | 5.00 | 0.660 |
| Graded silts to cobbles when colloidal | 0.030 | 4.00 | 0.430 | 5.50 | 0.800 |
| Coarse gravel noncolloidal | 0.025 | 4.00 | 0.300 | 6.00 | 0.670 |
| Cobbles and shingles | 0.035 | 5.00 | 0.910 | 5.50 | 1.100 |

^aFrom Lane (1955).

If $d = 2.50$, then from Eq. (c) we get

$$b = 10.58 - 6.32(2.50) = -5.22,$$

which is clearly not possible. If $d = 0.69$, we get

$$b = 10.58 - 6.32(0.69) = 6.22.$$

Therefore the channel dimensions must be

$$b = 6.22 \text{ ft}, \quad d = 0.69 \text{ ft}, \quad z = 3.0.$$

Check:

$$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = \frac{6.22(0.69) + 3(0.69)^2}{6.22 + 2(0.69)\sqrt{10}} = 0.54$$

$$v = \frac{1.49}{n} R^{2/3} S^{1/2} = \frac{1.49}{0.02} (0.54)^{2/3} (0.005)^{1/2} = 3.5.$$

The velocity is OK.

$$A = bd + zd^2 = 6.22(0.69) + 3(0.69)^2 = 5.72$$

$$Q = vA = 3.50(5.72) = 20.00.$$

The capacity is OK.

Church Rock Erosion and Sedimentation
North Upstream Diversion Channel
Precipitation Calculation for SCS Triangular Unit Hydrograph

| | | | | |
|-----------------------------|--------|--------|----------|----------|
| 10-year, 1-hour Storm Depth | 1.14 | | | |
| Curve Number | 80 | | | |
| S | 2.5 | | | |
| Percent of 1-hour rainfall | 48 | 71 | 88 | 100 |
| Cum. Rainfall | 0.5472 | 0.8094 | 1.0032 | 1.14 |
| Incremental Rainfall | 0.5472 | 0.2622 | 0.1938 | 0.1368 |
| Sequence | 0.1938 | 0.2622 | 0.5472 | 0.1368 |
| Cum. Design Rainfall | 0.1938 | 0.4560 | 1.0032 | 1.14 |
| Cumulative Runoff | 0 | 0 | 0.084313 | 0.130446 |
| Incremental Runoff | 0 | 0 | 0.084313 | 0.046132 |

| | | | | |
|----------------------------|--------|--------|----------|----------|
| 5-year, 1-hour Storm Depth | 0.92 | | | |
| Curve Number | 80 | | | |
| S | 2.5 | | | |
| Percent of 1-hour rainfall | 48 | 71 | 88 | 100 |
| Cum. Rainfall | 0.4416 | 0.6532 | 0.8096 | 0.92 |
| Incremental Rainfall | 0.4416 | 0.2116 | 0.1564 | 0.1104 |
| Sequence | 0.1564 | 0.2116 | 0.4416 | 0.1104 |
| Cum. Design Rainfall | 0.1564 | 0.3680 | 0.8096 | 0.92 |
| Cumulative Runoff | 0 | 0 | 0.034116 | 0.060411 |
| Incremental Runoff | 0 | 0 | 0.034116 | 0.026295 |

| | | | | |
|----------------------------|----------|----------|----------|----------|
| 1-hour PMP Storm Depth | 8.42 | | | |
| Curve Number | 80 | | | |
| S | 2.5 | | | |
| Percent of 1-hour rainfall | 48 | 71 | 88 | 100 |
| Cum. Rainfall | 4.0416 | 5.9782 | 7.4096 | 8.42 |
| Incremental Rainfall | 4.0416 | 1.9366 | 1.4314 | 1.0104 |
| Sequence | 1.4314 | 1.9366 | 4.0416 | 1.0104 |
| Cum. Design Rainfall | 1.4314 | 3.3680 | 7.4096 | 8.42 |
| Cumulative Runoff | 0.252814 | 1.532307 | 5.073815 | 6.019808 |
| Incremental Runoff | 0.252814 | 1.279493 | 3.794322 | 2.225486 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel
Basin A1 5-year Peak Flow Calculation

Duration (hrs) 0.25
Flow Length (mi) 0.62
Basin Area (sq. mi) 0.15
Basin Vertical (ft) 200
Curve Number 80
1-hr rainfall (in) 1.14
tc (hr) 0.19
Adjusted tc 0.20
tt (hrs) 0.1211
tp (hrs) 0.25
base (hrs) 0.67
qp (cfs) 290

| t (hrs) | V/tp | q/qp | Incremental Rainfall (inches) | | | Total |
|---------|-------|--------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.034116 | |
| 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| 0.01 | 0.040 | 11.62 | 0.00 | | | 0.00 |
| 0.02 | 0.080 | 23.23 | 0.00 | | | 0.00 |
| 0.03 | 0.120 | 34.85 | 0.00 | | | 0.00 |
| 0.04 | 0.160 | 46.46 | 0.00 | | | 0.00 |
| 0.05 | 0.200 | 58.08 | 0.00 | | | 0.00 |
| 0.06 | 0.240 | 69.70 | 0.00 | | | 0.00 |
| 0.07 | 0.280 | 81.31 | 0.00 | | | 0.00 |
| 0.08 | 0.320 | 92.93 | 0.00 | | | 0.00 |
| 0.09 | 0.360 | 104.54 | 0.00 | | | 0.00 |
| 0.1 | 0.400 | 116.16 | 0.00 | | | 0.00 |
| 0.11 | 0.440 | 127.78 | 0.00 | | | 0.00 |
| 0.12 | 0.480 | 139.39 | 0.00 | | | 0.00 |
| 0.13 | 0.520 | 151.01 | 0.00 | | | 0.00 |
| 0.14 | 0.560 | 162.62 | 0.00 | | | 0.00 |
| 0.15 | 0.600 | 174.24 | 0.00 | | | 0.00 |
| 0.16 | 0.640 | 185.86 | 0.00 | | | 0.00 |
| 0.17 | 0.680 | 197.47 | 0.00 | | | 0.00 |
| 0.18 | 0.720 | 209.09 | 0.00 | | | 0.00 |
| 0.19 | 0.760 | 220.70 | 0.00 | | | 0.00 |
| 0.2 | 0.800 | 232.32 | 0.00 | | | 0.00 |
| 0.21 | 0.840 | 243.94 | 0.00 | | | 0.00 |
| 0.22 | 0.880 | 255.55 | 0.00 | | | 0.00 |
| 0.23 | 0.920 | 267.17 | 0.00 | | | 0.00 |
| 0.24 | 0.960 | 278.78 | 0.00 | | | 0.00 |
| 0.25 | 1.000 | 290.40 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 1.040 | 283.44 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 1.080 | 276.49 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 1.120 | 269.53 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 1.160 | 262.58 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 1.200 | 255.62 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 1.240 | 248.67 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.280 | 241.71 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.320 | 234.75 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.360 | 227.80 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.400 | 220.84 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.440 | 213.89 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.480 | 206.93 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.520 | 199.98 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.560 | 193.02 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.600 | 186.06 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.640 | 179.11 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.680 | 172.15 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.720 | 165.20 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.760 | 158.24 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 1.800 | 151.29 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 1.840 | 144.33 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 1.880 | 137.37 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 1.920 | 130.42 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 1.960 | 123.46 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 2.000 | 116.51 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 2.040 | 109.55 | 0.00 | 0.00 | 0.40 | 0.40 |
| 0.52 | 2.080 | 102.60 | 0.00 | 0.00 | 0.79 | 0.79 |
| 0.53 | 2.120 | 95.64 | 0.00 | 0.00 | 1.19 | 1.19 |
| 0.54 | 2.160 | 88.69 | 0.00 | 0.00 | 1.59 | 1.59 |
| 0.55 | 2.200 | 81.73 | 0.00 | 0.00 | 1.98 | 1.98 |
| 0.56 | 2.240 | 74.77 | 0.00 | 0.00 | 2.38 | 2.38 |
| 0.57 | 2.280 | 67.82 | 0.00 | 0.00 | 2.77 | 2.77 |
| 0.58 | 2.320 | 60.86 | 0.00 | 0.00 | 3.17 | 3.17 |
| 0.59 | 2.360 | 53.91 | 0.00 | 0.00 | 3.57 | 3.57 |
| 0.6 | 2.400 | 46.95 | 0.00 | 0.00 | 3.96 | 3.96 |
| 0.61 | 2.440 | 40.00 | 0.00 | 0.00 | 4.36 | 4.36 |
| 0.62 | 2.480 | 33.04 | 0.00 | 0.00 | 4.76 | 4.76 |
| 0.63 | 2.520 | 26.08 | 0.00 | 0.00 | 5.15 | 5.15 |

| | | | | | | | |
|------|-------|-------|------|------|------|------|-------|
| 0.64 | 2.560 | 19.13 | 0.00 | 0.00 | 5.55 | 5.55 | |
| 0.65 | 2.600 | 12.17 | 0.00 | 0.00 | 5.94 | 5.94 | |
| 0.66 | 2.640 | 5.22 | 0.00 | 0.00 | 6.34 | 6.34 | |
| 0.67 | 2.680 | 0.00 | 0.00 | 0.00 | 6.74 | 6.74 | |
| 0.68 | | | | 0.00 | 7.13 | 7.13 | |
| 0.69 | | | | 0.00 | 7.53 | 7.53 | |
| 0.7 | | | | 0.00 | 7.93 | 7.93 | |
| 0.71 | | | | 0.00 | 8.32 | 8.32 | |
| 0.72 | | | | 0.00 | 8.72 | 8.72 | |
| 0.73 | | | | 0.00 | 9.11 | 9.11 | |
| 0.74 | | | | 0.00 | 9.51 | 9.51 | |
| 0.75 | | | | 0.00 | 9.91 | 9.91 | |
| 0.76 | | | | 0.00 | 9.67 | 0.31 | 9.98 |
| 0.77 | | | | 0.00 | 9.43 | 0.61 | 10.04 |
| 0.78 | | | | 0.00 | 9.20 | 0.92 | 10.11 |
| 0.79 | | | | 0.00 | 8.96 | 1.22 | 10.18 |
| 0.8 | | | | 0.00 | 8.72 | 1.53 | 10.25 |
| 0.81 | | | | 0.00 | 8.48 | 1.83 | 10.32 |
| 0.82 | | | | 0.00 | 8.25 | 2.14 | 10.38 |
| 0.83 | | | | 0.00 | 8.01 | 2.44 | 10.45 |
| 0.84 | | | | 0.00 | 7.77 | 2.75 | 10.52 |
| 0.85 | | | | 0.00 | 7.53 | 3.05 | 10.59 |
| 0.86 | | | | 0.00 | 7.30 | 3.36 | 10.66 |
| 0.87 | | | | 0.00 | 7.06 | 3.67 | 10.72 |
| 0.88 | | | | 0.00 | 6.82 | 3.97 | 10.79 |
| 0.89 | | | | 0.00 | 6.59 | 4.28 | 10.86 |
| 0.9 | | | | 0.00 | 6.35 | 4.58 | 10.93 |
| 0.91 | | | | 0.00 | 6.11 | 4.89 | 11.00 |
| 0.92 | | | | 0.00 | 5.87 | 5.19 | 11.07 |
| 0.93 | | | | | 5.64 | 5.50 | 11.13 |
| 0.94 | | | | | 5.40 | 5.80 | 11.20 |
| 0.95 | | | | | 5.16 | 6.11 | 11.27 |
| 0.96 | | | | | 4.92 | 6.41 | 11.34 |
| 0.97 | | | | | 4.69 | 6.72 | 11.41 |
| 0.98 | | | | | 4.45 | 7.03 | 11.47 |
| 0.99 | | | | | 4.21 | 7.33 | 11.54 |
| 1 | | | | | 3.97 | 7.64 | 11.61 |
| 1.01 | | | | | 3.74 | 7.45 | 11.19 |
| 1.02 | | | | | 3.50 | 7.27 | 10.77 |
| 1.03 | | | | | 3.26 | 7.09 | 10.35 |
| 1.04 | | | | | 3.03 | 6.90 | 9.93 |
| 1.05 | | | | | 2.79 | 6.72 | 9.51 |
| 1.06 | | | | | 2.55 | 6.54 | 9.09 |
| 1.07 | | | | | 2.31 | 6.36 | 8.67 |
| 1.08 | | | | | 2.08 | 6.17 | 8.25 |
| 1.09 | | | | | 1.84 | 5.99 | 7.83 |
| 1.1 | | | | | 1.60 | 5.81 | 7.41 |
| 1.11 | | | | | 1.36 | 5.62 | 6.99 |
| 1.12 | | | | | 1.13 | 5.44 | 6.57 |
| 1.13 | | | | | 0.89 | 5.26 | 6.15 |
| 1.14 | | | | | 0.65 | 5.08 | 5.73 |
| 1.15 | | | | | 0.42 | 4.89 | 5.31 |
| 1.16 | | | | | 0.18 | 4.71 | 4.89 |
| 1.17 | | | | 0.00 | | 4.53 | 4.53 |
| 1.18 | | | | | | 4.34 | 4.34 |
| 1.19 | | | | | | 4.16 | 4.16 |
| 1.2 | | | | | | 3.98 | 3.98 |
| 1.21 | | | | | | 3.80 | 3.80 |
| 1.22 | | | | | | 3.61 | 3.61 |
| 1.23 | | | | | | 3.43 | 3.43 |
| 1.24 | | | | | | 3.25 | 3.25 |
| 1.25 | | | | | | 3.06 | 3.06 |
| 1.26 | | | | | | 2.88 | 2.88 |
| 1.27 | | | | | | 2.70 | 2.70 |
| 1.28 | | | | | | 2.51 | 2.51 |
| 1.29 | | | | | | 2.33 | 2.33 |
| 1.3 | | | | | | 2.15 | 2.15 |
| 1.31 | | | | | | 1.97 | 1.97 |
| 1.32 | | | | | | 1.78 | 1.78 |
| 1.33 | | | | | | 1.60 | 1.60 |
| 1.34 | | | | | | 1.42 | 1.42 |
| 1.35 | | | | | | 1.23 | 1.23 |
| 1.36 | | | | | | 1.05 | 1.05 |
| 1.37 | | | | | | 0.87 | 0.87 |
| 1.38 | | | | | | 0.69 | 0.69 |
| 1.39 | | | | | | 0.50 | 0.50 |
| 1.4 | | | | | | 0.32 | 0.32 |
| 1.41 | | | | | | 0.14 | 0.14 |
| 1.42 | | | | | | 0.00 | 0.00 |

Church Rock Erosion and Sedimentation
 North Upstream Diversion Channel
 Basin A1 10-year Peak Flow Calculation

Duration (hrs) 0.25
 Flow Length (mi) 0.62
 Basin Area (sq. mi) 0.15
 Basin Vertical (ft) 200
 Curve Number 80
 1-hr rainfall (in) 1.14
 tc (hr) 0.19
 Adjusted tc 0.20
 ti (hrs) 0.1211
 tp (hrs) 0.25
 base (hrs) 0.67
 qp (cfs) 290

| t (hrs) | t/tp | q/qp | Incremental Rainfall (inches) | | | Total |
|---------|-------|--------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.084313 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.040 | 11.62 | 0.00 | | | 0.00 |
| 0.02 | 0.080 | 23.23 | 0.00 | | | 0.00 |
| 0.03 | 0.120 | 34.85 | 0.00 | | | 0.00 |
| 0.04 | 0.160 | 46.46 | 0.00 | | | 0.00 |
| 0.05 | 0.200 | 58.08 | 0.00 | | | 0.00 |
| 0.06 | 0.240 | 69.70 | 0.00 | | | 0.00 |
| 0.07 | 0.280 | 81.31 | 0.00 | | | 0.00 |
| 0.08 | 0.320 | 92.93 | 0.00 | | | 0.00 |
| 0.09 | 0.360 | 104.54 | 0.00 | | | 0.00 |
| 0.1 | 0.400 | 116.16 | 0.00 | | | 0.00 |
| 0.11 | 0.440 | 127.78 | 0.00 | | | 0.00 |
| 0.12 | 0.480 | 139.39 | 0.00 | | | 0.00 |
| 0.13 | 0.520 | 151.01 | 0.00 | | | 0.00 |
| 0.14 | 0.560 | 162.62 | 0.00 | | | 0.00 |
| 0.15 | 0.600 | 174.24 | 0.00 | | | 0.00 |
| 0.16 | 0.640 | 185.86 | 0.00 | | | 0.00 |
| 0.17 | 0.680 | 197.47 | 0.00 | | | 0.00 |
| 0.18 | 0.720 | 209.09 | 0.00 | | | 0.00 |
| 0.19 | 0.760 | 220.70 | 0.00 | | | 0.00 |
| 0.2 | 0.800 | 232.32 | 0.00 | | | 0.00 |
| 0.21 | 0.840 | 243.94 | 0.00 | | | 0.00 |
| 0.22 | 0.880 | 255.55 | 0.00 | | | 0.00 |
| 0.23 | 0.920 | 267.17 | 0.00 | | | 0.00 |
| 0.24 | 0.960 | 278.78 | 0.00 | | | 0.00 |
| 0.25 | 1.000 | 290.40 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 1.040 | 283.44 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 1.080 | 276.49 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 1.120 | 269.53 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 1.160 | 262.58 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 1.200 | 255.62 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 1.240 | 248.67 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.280 | 241.71 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.320 | 234.75 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.360 | 227.80 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.400 | 220.84 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.440 | 213.89 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.480 | 206.93 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.520 | 199.98 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.560 | 193.02 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.600 | 186.06 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.640 | 179.11 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.680 | 172.15 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.720 | 165.20 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.760 | 158.24 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 1.800 | 151.29 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 1.840 | 144.33 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 1.880 | 137.37 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 1.920 | 130.42 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 1.960 | 123.46 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 2.000 | 116.51 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 2.040 | 109.55 | 0.00 | 0.00 | 0.98 | 0.98 |
| 0.52 | 2.080 | 102.60 | 0.00 | 0.00 | 1.96 | 1.96 |
| 0.53 | 2.120 | 95.64 | 0.00 | 0.00 | 2.94 | 2.94 |
| 0.54 | 2.160 | 88.69 | 0.00 | 0.00 | 3.92 | 3.92 |
| 0.55 | 2.200 | 81.73 | 0.00 | 0.00 | 4.90 | 4.90 |
| 0.56 | 2.240 | 74.77 | 0.00 | 0.00 | 5.88 | 5.88 |
| 0.57 | 2.280 | 67.82 | 0.00 | 0.00 | 6.86 | 6.86 |
| 0.58 | 2.320 | 60.86 | 0.00 | 0.00 | 7.84 | 7.84 |
| 0.59 | 2.360 | 53.91 | 0.00 | 0.00 | 8.81 | 8.81 |
| 0.6 | 2.400 | 46.95 | 0.00 | 0.00 | 9.79 | 9.79 |
| 0.61 | 2.440 | 40.00 | 0.00 | 0.00 | 10.77 | 10.77 |
| 0.62 | 2.480 | 33.04 | 0.00 | 0.00 | 11.75 | 11.75 |
| 0.63 | 2.520 | 26.08 | 0.00 | 0.00 | 12.73 | 12.73 |

| | | | | | | |
|------|-------|-------|------|------|-------|-------------|
| 0.64 | 2.560 | 19.13 | 0.00 | 0.00 | 13.71 | 13.71 |
| 0.65 | 2.600 | 12.17 | 0.00 | 0.00 | 14.69 | 14.69 |
| 0.66 | 2.640 | 5.22 | 0.00 | 0.00 | 15.67 | 15.67 |
| 0.67 | 2.680 | 0.00 | 0.00 | 0.00 | 16.65 | 16.65 |
| 0.68 | | | | 0.00 | 17.63 | 17.63 |
| 0.69 | | | | 0.00 | 18.61 | 18.61 |
| 0.7 | | | | 0.00 | 19.59 | 19.59 |
| 0.71 | | | | 0.00 | 20.57 | 20.57 |
| 0.72 | | | | 0.00 | 21.55 | 21.55 |
| 0.73 | | | | 0.00 | 22.53 | 22.53 |
| 0.74 | | | | 0.00 | 23.51 | 23.51 |
| 0.75 | | | | 0.00 | 24.48 | 24.48 |
| 0.76 | | | | 0.00 | 23.90 | 0.54 24.43 |
| 0.77 | | | | 0.00 | 23.31 | 1.07 24.38 |
| 0.78 | | | | 0.00 | 22.73 | 1.61 24.33 |
| 0.79 | | | | 0.00 | 22.14 | 2.14 24.28 |
| 0.8 | | | | 0.00 | 21.55 | 2.68 24.23 |
| 0.81 | | | | 0.00 | 20.97 | 3.22 24.18 |
| 0.82 | | | | 0.00 | 20.38 | 3.75 24.13 |
| 0.83 | | | | 0.00 | 19.79 | 4.29 24.08 |
| 0.84 | | | | 0.00 | 19.21 | 4.82 24.03 |
| 0.85 | | | | 0.00 | 18.62 | 5.36 23.98 |
| 0.86 | | | | 0.00 | 18.03 | 5.89 23.93 |
| 0.87 | | | | 0.00 | 17.45 | 6.43 23.88 |
| 0.88 | | | | 0.00 | 16.86 | 6.97 23.83 |
| 0.89 | | | | 0.00 | 16.27 | 7.50 23.78 |
| 0.9 | | | | 0.00 | 15.68 | 8.04 23.73 |
| 0.91 | | | | 0.00 | 15.10 | 8.57 23.68 |
| 0.92 | | | | 0.00 | 14.51 | 9.11 23.62 |
| 0.93 | | | | 0.00 | 13.93 | 9.65 23.57 |
| 0.94 | | | | | 13.34 | 10.18 23.52 |
| 0.95 | | | | | 12.76 | 10.72 23.47 |
| 0.96 | | | | | 12.17 | 11.25 23.42 |
| 0.97 | | | | | 11.58 | 11.79 23.37 |
| 0.98 | | | | | 11.00 | 12.33 23.32 |
| 0.99 | | | | | 10.41 | 12.86 23.27 |
| 1 | | | | | 9.82 | 13.40 23.22 |
| 1.01 | | | | | 9.24 | 13.08 22.31 |
| 1.02 | | | | | 8.65 | 12.76 21.41 |
| 1.03 | | | | | 8.06 | 12.43 20.50 |
| 1.04 | | | | | 7.48 | 12.11 19.59 |
| 1.05 | | | | | 0.09 | 11.79 18.68 |
| 1.06 | | | | | 6.30 | 11.47 17.78 |
| 1.07 | | | | | 5.72 | 11.15 16.87 |
| 1.08 | | | | | 5.13 | 10.83 15.96 |
| 1.09 | | | | | 4.55 | 10.51 15.05 |
| 1.1 | | | | | 3.96 | 10.19 14.15 |
| 1.11 | | | | | 3.37 | 9.87 13.24 |
| 1.12 | | | | | 2.79 | 9.55 12.33 |
| 1.13 | | | | | 2.20 | 9.23 11.42 |
| 1.14 | | | | | 1.61 | 8.90 10.52 |
| 1.15 | | | | | 1.03 | 8.58 9.61 |
| 1.16 | | | | | 0.44 | 8.26 8.70 |
| 1.17 | | | | | 0.00 | 7.94 7.94 |
| 1.18 | | | | | | 7.62 7.62 |
| 1.19 | | | | | | 7.30 7.30 |
| 1.2 | | | | | | 6.98 6.98 |
| 1.21 | | | | | | 6.66 6.66 |
| 1.22 | | | | | | 6.34 6.34 |
| 1.23 | | | | | | 6.02 6.02 |
| 1.24 | | | | | | 5.70 5.70 |
| 1.25 | | | | | | 5.37 5.37 |
| 1.26 | | | | | | 5.05 5.05 |
| 1.27 | | | | | | 4.73 4.73 |
| 1.28 | | | | | | 4.41 4.41 |
| 1.29 | | | | | | 4.09 4.09 |
| 1.3 | | | | | | 3.77 3.77 |
| 1.31 | | | | | | 3.45 3.45 |
| 1.32 | | | | | | 3.13 3.13 |
| 1.33 | | | | | | 2.81 2.81 |
| 1.34 | | | | | | 2.49 2.49 |
| 1.35 | | | | | | 2.17 2.17 |
| 1.36 | | | | | | 1.85 1.85 |
| 1.37 | | | | | | 1.52 1.52 |
| 1.38 | | | | | | 1.20 1.20 |
| 1.39 | | | | | | 0.88 0.88 |
| 1.4 | | | | | | 0.56 0.56 |
| 1.41 | | | | | | 0.24 0.24 |
| 1.42 | | | | | | 0.00 0.00 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel
Basin A2 5-year Peak Flow Calculation

Duration (hrs) 0.25
Flow Length (mi) 0.62
Basin Area (sq. mi) 0.12
Basin Vertical (ft) 360
Curve Number 80
1-hr rainfall (in) 1.81
tc (hr) 0.15
Adjusted tc 0.16
tl (hrs) 0.0966
tp (hrs) 0.22
base (hrs) 0.5916
qp (cfs) 262

| t (hrs) | V/tp | q/qp | Incremental Rainfall (inches) | | | Total |
|---------|------|--------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.034116 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.05 | 11.83 | 0.00 | | | 0.00 |
| 0.02 | 0.09 | 23.66 | 0.00 | | | 0.00 |
| 0.03 | 0.14 | 35.49 | 0.00 | | | 0.00 |
| 0.04 | 0.18 | 47.33 | 0.00 | | | 0.00 |
| 0.05 | 0.23 | 59.16 | 0.00 | | | 0.00 |
| 0.06 | 0.27 | 70.99 | 0.00 | | | 0.00 |
| 0.07 | 0.32 | 82.82 | 0.00 | | | 0.00 |
| 0.08 | 0.36 | 94.65 | 0.00 | | | 0.00 |
| 0.09 | 0.41 | 106.48 | 0.00 | | | 0.00 |
| 0.1 | 0.45 | 118.31 | 0.00 | | | 0.00 |
| 0.11 | 0.50 | 130.15 | 0.00 | | | 0.00 |
| 0.12 | 0.54 | 141.98 | 0.00 | | | 0.00 |
| 0.13 | 0.59 | 153.81 | 0.00 | | | 0.00 |
| 0.14 | 0.63 | 165.64 | 0.00 | | | 0.00 |
| 0.15 | 0.68 | 177.47 | 0.00 | | | 0.00 |
| 0.16 | 0.72 | 189.30 | 0.00 | | | 0.00 |
| 0.17 | 0.77 | 201.13 | 0.00 | | | 0.00 |
| 0.18 | 0.81 | 212.97 | 0.00 | | | 0.00 |
| 0.19 | 0.86 | 224.80 | 0.00 | | | 0.00 |
| 0.2 | 0.90 | 236.63 | 0.00 | | | 0.00 |
| 0.21 | 0.95 | 248.46 | 0.00 | | | 0.00 |
| 0.22 | 0.99 | 260.29 | 0.00 | | | 0.00 |
| 0.23 | 1.04 | 253.21 | 0.00 | | | 0.00 |
| 0.24 | 1.08 | 246.12 | 0.00 | | | 0.00 |
| 0.25 | 1.13 | 239.04 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 1.17 | 231.95 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 1.22 | 224.87 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 1.26 | 217.78 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 1.31 | 210.70 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 1.35 | 203.61 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 1.40 | 196.53 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.44 | 189.44 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.49 | 182.36 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.53 | 175.27 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.58 | 168.19 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.62 | 161.11 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.67 | 154.02 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.72 | 146.94 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.76 | 139.85 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.81 | 132.77 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.85 | 125.68 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.90 | 118.60 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.94 | 111.51 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.99 | 104.43 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 2.03 | 97.34 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 2.08 | 90.26 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 2.12 | 83.17 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 2.17 | 76.09 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 2.21 | 69.00 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 2.26 | 61.92 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 2.30 | 54.84 | 0.00 | 0.00 | 0.40 | 0.40 |
| 0.52 | 2.35 | 47.75 | 0.00 | 0.00 | 0.81 | 0.81 |
| 0.53 | 2.39 | 40.67 | 0.00 | 0.00 | 1.21 | 1.21 |
| 0.54 | 2.44 | 33.58 | 0.00 | 0.00 | 1.61 | 1.61 |
| 0.55 | 2.48 | 26.50 | 0.00 | 0.00 | 2.02 | 2.02 |
| 0.56 | 2.53 | 19.41 | 0.00 | 0.00 | 2.42 | 2.42 |
| 0.57 | 2.57 | 12.33 | 0.00 | 0.00 | 2.83 | 2.83 |
| 0.58 | 2.62 | 5.24 | 0.00 | 0.00 | 3.23 | 3.23 |
| 0.59 | 2.66 | 0.00 | 0.00 | 0.00 | 3.63 | 3.63 |

| | | | | |
|------|------|------|------|------|
| 0.6 | 0.00 | 4.04 | | 4.04 |
| 0.61 | 0.00 | 4.44 | | 4.44 |
| 0.62 | 0.00 | 4.84 | | 4.84 |
| 0.63 | 0.00 | 5.25 | | 5.25 |
| 0.64 | 0.00 | 5.65 | | 5.65 |
| 0.65 | 0.00 | 6.05 | | 6.05 |
| 0.66 | 0.00 | 6.40 | | 6.46 |
| 0.67 | 0.00 | 6.86 | | 6.86 |
| 0.68 | 0.00 | 7.27 | | 7.27 |
| 0.69 | 0.00 | 7.67 | | 7.67 |
| 0.7 | 0.00 | 8.07 | | 8.07 |
| 0.71 | 0.00 | 8.48 | | 8.48 |
| 0.72 | 0.00 | 8.88 | | 8.88 |
| 0.73 | 0.00 | 8.64 | | 8.64 |
| 0.74 | 0.00 | 8.40 | | 8.40 |
| 0.75 | 0.00 | 8.15 | 0.00 | 8.15 |
| 0.76 | 0.00 | 7.91 | 0.31 | 8.22 |
| 0.77 | 0.00 | 7.67 | 0.62 | 8.29 |
| 0.78 | 0.00 | 7.43 | 0.93 | 8.36 |
| 0.79 | 0.00 | 7.19 | 1.24 | 8.43 |
| 0.8 | 0.00 | 6.95 | 1.56 | 8.50 |
| 0.81 | 0.00 | 6.70 | 1.87 | 8.57 |
| 0.82 | 0.00 | 6.46 | 2.18 | 8.64 |
| 0.83 | 0.00 | 6.22 | 2.49 | 8.71 |
| 0.84 | 0.00 | 5.98 | 2.80 | 8.78 |
| 0.85 | | 5.74 | 3.11 | 8.85 |
| 0.86 | | 5.50 | 3.42 | 8.92 |
| 0.87 | | 5.25 | 3.73 | 8.99 |
| 0.88 | | 5.01 | 4.04 | 9.06 |
| 0.89 | | 4.77 | 4.36 | 9.13 |
| 0.9 | | 4.53 | 4.67 | 9.20 |
| 0.91 | | 4.29 | 4.98 | 9.27 |
| 0.92 | | 4.05 | 5.29 | 9.33 |
| 0.93 | | 3.80 | 5.60 | 9.40 |
| 0.94 | | 3.56 | 5.91 | 9.47 |
| 0.95 | | 3.32 | 6.22 | 9.54 |
| 0.96 | | 3.08 | 6.53 | 9.61 |
| 0.97 | | 2.84 | 6.84 | 9.68 |
| 0.98 | | 2.60 | 6.66 | 9.25 |
| 0.99 | | 2.35 | 6.47 | 8.83 |
| 1 | | 2.11 | 6.29 | 8.40 |
| 1.01 | | 1.87 | 6.10 | 7.97 |
| 1.02 | | 1.63 | 5.91 | 7.54 |
| 1.03 | | 1.39 | 5.73 | 7.11 |
| 1.04 | | 1.15 | 5.54 | 6.69 |
| 1.05 | | 0.90 | 5.35 | 6.26 |
| 1.06 | | 0.66 | 5.17 | 5.83 |
| 1.07 | | 0.42 | 4.98 | 5.40 |
| 1.08 | | 0.18 | 4.80 | 4.97 |
| 1.09 | | 0.00 | 4.61 | 4.61 |
| 1.1 | | | 4.42 | 4.42 |
| 1.11 | | | 4.24 | 4.24 |
| 1.12 | | | 4.05 | 4.05 |
| 1.13 | | | 3.86 | 3.86 |
| 1.14 | | | 3.68 | 3.68 |
| 1.15 | | | 3.49 | 3.49 |
| 1.16 | | | 3.30 | 3.30 |
| 1.17 | | | 3.12 | 3.12 |
| 1.18 | | | 2.93 | 2.93 |
| 1.19 | | | 2.75 | 2.75 |
| 1.2 | | | 2.56 | 2.56 |
| 1.21 | | | 2.37 | 2.37 |
| 1.22 | | | 2.19 | 2.19 |
| 1.23 | | | 2.00 | 2.00 |
| 1.24 | | | 1.81 | 1.81 |
| 1.25 | | | 1.63 | 1.63 |
| 1.26 | | | 1.44 | 1.44 |
| 1.27 | | | 1.26 | 1.26 |
| 1.28 | | | 1.07 | 1.07 |
| 1.29 | | | 0.88 | 0.88 |
| 1.3 | | | 0.70 | 0.70 |
| 1.31 | | | 0.51 | 0.51 |
| 1.32 | | | 0.32 | 0.32 |
| 1.33 | | | 0.14 | 0.14 |
| 1.34 | | | 0.00 | 0.00 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel

Basin A2 10-year Peak Flow Calculation

| | |
|---------------------|--------|
| Duration (hrs) | 0.25 |
| Flow Length (mi) | 0.62 |
| Basin Area (sq. mi) | 0.12 |
| Basin Vertical (ft) | 360 |
| Curve Number | 80 |
| 1-hr rainfall (in) | 1.81 |
| tc (hr) | 0.15 |
| Adjusted tc | 0.16 |
| tl (hrs) | 0.0966 |
| tp (hrs) | 0.22 |
| base (hrs) | 0.5916 |
| qp (cfs) | 262 |

| t (hrs) | t/tp | q/qp | Incremental Rainfall (inches) | | | Total |
|---------|------|--------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.084313 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.05 | 11.83 | 0.00 | | | 0.00 |
| 0.02 | 0.09 | 23.66 | 0.00 | | | 0.00 |
| 0.03 | 0.14 | 35.49 | 0.00 | | | 0.00 |
| 0.04 | 0.18 | 47.33 | 0.00 | | | 0.00 |
| 0.05 | 0.23 | 59.16 | 0.00 | | | 0.00 |
| 0.06 | 0.27 | 70.99 | 0.00 | | | 0.00 |
| 0.07 | 0.32 | 82.82 | 0.00 | | | 0.00 |
| 0.08 | 0.36 | 94.65 | 0.00 | | | 0.00 |
| 0.09 | 0.41 | 106.48 | 0.00 | | | 0.00 |
| 0.1 | 0.45 | 118.31 | 0.00 | | | 0.00 |
| 0.11 | 0.50 | 130.15 | 0.00 | | | 0.00 |
| 0.12 | 0.54 | 141.98 | 0.00 | | | 0.00 |
| 0.13 | 0.59 | 153.81 | 0.00 | | | 0.00 |
| 0.14 | 0.63 | 165.64 | 0.00 | | | 0.00 |
| 0.15 | 0.68 | 177.47 | 0.00 | | | 0.00 |
| 0.16 | 0.72 | 189.30 | 0.00 | | | 0.00 |
| 0.17 | 0.77 | 201.13 | 0.00 | | | 0.00 |
| 0.18 | 0.81 | 212.97 | 0.00 | | | 0.00 |
| 0.19 | 0.86 | 224.80 | 0.00 | | | 0.00 |
| 0.2 | 0.90 | 236.63 | 0.00 | | | 0.00 |
| 0.21 | 0.95 | 248.46 | 0.00 | | | 0.00 |
| 0.22 | 0.99 | 260.29 | 0.00 | | | 0.00 |
| 0.23 | 1.04 | 253.21 | 0.00 | | | 0.00 |
| 0.24 | 1.08 | 246.12 | 0.00 | | | 0.00 |
| 0.25 | 1.13 | 239.04 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 1.17 | 231.95 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 1.22 | 224.87 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 1.26 | 217.78 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 1.31 | 210.70 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 1.35 | 203.61 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 1.40 | 196.53 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.44 | 189.44 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.49 | 182.36 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.53 | 175.27 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.58 | 168.19 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.62 | 161.11 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.67 | 154.02 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.72 | 146.94 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.76 | 139.85 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.81 | 132.77 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.85 | 125.68 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.90 | 118.60 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.94 | 111.51 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.99 | 104.43 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 2.03 | 97.34 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 2.08 | 90.26 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 2.12 | 83.17 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 2.17 | 76.09 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 2.21 | 69.00 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 2.26 | 61.92 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 2.30 | 54.84 | 0.00 | 0.00 | 1.00 | 1.00 |
| 0.52 | 2.35 | 47.75 | 0.00 | 0.00 | 2.00 | 2.00 |
| 0.53 | 2.39 | 40.67 | 0.00 | 0.00 | 2.99 | 2.99 |
| 0.54 | 2.44 | 33.58 | 0.00 | 0.00 | 3.99 | 3.99 |
| 0.55 | 2.48 | 26.50 | 0.00 | 0.00 | 4.99 | 4.99 |
| 0.56 | 2.53 | 19.41 | 0.00 | 0.00 | 5.99 | 5.99 |
| 0.57 | 2.57 | 12.33 | 0.00 | 0.00 | 6.98 | 6.98 |
| 0.58 | 2.62 | 5.24 | 0.00 | 0.00 | 7.98 | 7.98 |
| 0.59 | 2.66 | 0.00 | 0.00 | 0.00 | 8.98 | 8.98 |

| | | | | |
|------|------|-------|-------|-------|
| 0.6 | 0.00 | 9.98 | | 9.98 |
| 0.61 | 0.00 | 10.97 | | 10.97 |
| 0.62 | 0.00 | 11.97 | | 11.97 |
| 0.63 | 0.00 | 12.97 | | 12.97 |
| 0.64 | 0.00 | 13.97 | | 13.97 |
| 0.65 | 0.00 | 14.96 | | 14.96 |
| 0.66 | 0.00 | 16.96 | | 15.96 |
| 0.67 | 0.00 | 16.96 | | 16.96 |
| 0.68 | 0.00 | 17.96 | | 17.96 |
| 0.69 | 0.00 | 18.95 | | 18.95 |
| 0.7 | 0.00 | 19.95 | | 19.95 |
| 0.71 | 0.00 | 20.95 | | 20.95 |
| 0.72 | 0.00 | 21.95 | | 21.95 |
| 0.73 | 0.00 | 21.35 | | 21.35 |
| 0.74 | 0.00 | 20.75 | | 20.75 |
| 0.75 | 0.00 | 20.15 | 0.00 | 20.15 |
| 0.76 | 0.00 | 19.56 | 0.55 | 20.10 |
| 0.77 | 0.00 | 18.96 | 1.09 | 20.05 |
| 0.78 | 0.00 | 18.36 | 1.64 | 20.00 |
| 0.79 | 0.00 | 17.76 | 2.18 | 19.95 |
| 0.8 | 0.00 | 17.17 | 2.73 | 19.90 |
| 0.81 | 0.00 | 16.57 | 3.27 | 19.84 |
| 0.82 | 0.00 | 15.97 | 3.82 | 19.79 |
| 0.83 | 0.00 | 15.38 | 4.37 | 19.74 |
| 0.84 | 0.00 | 14.78 | 4.91 | 19.69 |
| 0.85 | | 14.10 | 5.46 | 19.64 |
| 0.86 | | 13.58 | 6.00 | 19.59 |
| 0.87 | | 12.99 | 6.55 | 19.54 |
| 0.88 | | 12.39 | 7.10 | 19.48 |
| 0.89 | | 11.79 | 7.64 | 19.43 |
| 0.9 | | 11.19 | 8.19 | 19.38 |
| 0.91 | | 10.60 | 8.73 | 19.33 |
| 0.92 | | 10.00 | 9.28 | 19.28 |
| 0.93 | | 9.40 | 9.82 | 19.23 |
| 0.94 | | 8.80 | 10.37 | 19.18 |
| 0.95 | | 8.21 | 10.92 | 19.12 |
| 0.96 | | 7.61 | 11.46 | 19.07 |
| 0.97 | | 7.01 | 12.01 | 19.02 |
| 0.98 | | 6.42 | 11.68 | 18.10 |
| 0.99 | | 5.82 | 11.35 | 17.17 |
| 1 | | 5.22 | 11.03 | 16.25 |
| 1.01 | | 4.62 | 10.70 | 15.32 |
| 1.02 | | 4.03 | 10.37 | 14.40 |
| 1.03 | | 3.43 | 10.05 | 13.48 |
| 1.04 | | 2.83 | 9.72 | 12.55 |
| 1.05 | | 2.23 | 9.39 | 11.63 |
| 1.06 | | 1.64 | 9.07 | 10.70 |
| 1.07 | | 1.04 | 8.74 | 9.78 |
| 1.08 | | 0.44 | 8.41 | 8.85 |
| 1.09 | | 0.00 | 8.09 | 8.09 |
| 1.1 | | | 7.76 | 7.76 |
| 1.11 | | | 7.43 | 7.43 |
| 1.12 | | | 7.11 | 7.11 |
| 1.13 | | | 6.78 | 6.78 |
| 1.14 | | | 6.45 | 6.45 |
| 1.15 | | | 6.12 | 6.12 |
| 1.16 | | | 5.80 | 5.80 |
| 1.17 | | | 5.47 | 5.47 |
| 1.18 | | | 5.14 | 5.14 |
| 1.19 | | | 4.82 | 4.82 |
| 1.2 | | | 4.49 | 4.49 |
| 1.21 | | | 4.16 | 4.16 |
| 1.22 | | | 3.84 | 3.84 |
| 1.23 | | | 3.51 | 3.51 |
| 1.24 | | | 3.18 | 3.18 |
| 1.25 | | | 2.86 | 2.86 |
| 1.26 | | | 2.53 | 2.53 |
| 1.27 | | | 2.20 | 2.20 |
| 1.28 | | | 1.88 | 1.88 |
| 1.29 | | | 1.55 | 1.55 |
| 1.3 | | | 1.22 | 1.22 |
| 1.31 | | | 0.90 | 0.90 |
| 1.32 | | | 0.57 | 0.57 |
| 1.33 | | | 0.24 | 0.24 |
| 1.34 | | | 0.00 | 0.00 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel
Basin B 5-year Peak Flow Calculation

| | |
|---------------------|--------|
| Duration (hrs) | 0.25 |
| Flow Length (mi) | 1.23 |
| Basin Area (sq. mi) | 0.57 |
| Basin Vertical (ft) | 440 |
| Curve Number | 80 |
| 1-hr rainfall (in) | 1.14 |
| tc (hr) | 0.32 |
| Adjusted tc | 0.32 |
| t1 (hrs) | 0.1896 |
| tp (hrs) | 0.31 |
| base (hrs) | 0.8400 |
| qp (cfs) | 877 |

| t (hrs) | V/p | q/qp | Incremental Rainfall (Inches) | | | Total |
|---------|------|---------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.034116 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.03 | 27.87 | 0.00 | | | 0.00 |
| 0.02 | 0.06 | 55.75 | 0.00 | | | 0.00 |
| 0.03 | 0.10 | 83.62 | 0.00 | | | 0.00 |
| 0.04 | 0.13 | 111.49 | 0.00 | | | 0.00 |
| 0.05 | 0.16 | 139.37 | 0.00 | | | 0.00 |
| 0.06 | 0.19 | 167.24 | 0.00 | | | 0.00 |
| 0.07 | 0.22 | 195.11 | 0.00 | | | 0.00 |
| 0.08 | 0.25 | 222.99 | 0.00 | | | 0.00 |
| 0.09 | 0.29 | 250.86 | 0.00 | | | 0.00 |
| 0.1 | 0.32 | 278.73 | 0.00 | | | 0.00 |
| 0.11 | 0.35 | 306.61 | 0.00 | | | 0.00 |
| 0.12 | 0.38 | 334.48 | 0.00 | | | 0.00 |
| 0.13 | 0.41 | 362.36 | 0.00 | | | 0.00 |
| 0.14 | 0.45 | 390.23 | 0.00 | | | 0.00 |
| 0.15 | 0.48 | 418.10 | 0.00 | | | 0.00 |
| 0.16 | 0.51 | 445.98 | 0.00 | | | 0.00 |
| 0.17 | 0.54 | 473.85 | 0.00 | | | 0.00 |
| 0.18 | 0.57 | 501.72 | 0.00 | | | 0.00 |
| 0.19 | 0.60 | 529.60 | 0.00 | | | 0.00 |
| 0.2 | 0.64 | 557.47 | 0.00 | | | 0.00 |
| 0.21 | 0.67 | 585.34 | 0.00 | | | 0.00 |
| 0.22 | 0.70 | 613.22 | 0.00 | | | 0.00 |
| 0.23 | 0.73 | 641.09 | 0.00 | | | 0.00 |
| 0.24 | 0.76 | 668.96 | 0.00 | | | 0.00 |
| 0.25 | 0.79 | 696.84 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 0.83 | 724.71 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 0.86 | 752.58 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 0.89 | 780.46 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 0.92 | 808.33 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 0.95 | 836.20 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 0.99 | 864.08 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.02 | 891.95 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.05 | 919.83 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.08 | 947.70 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.11 | 975.58 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.14 | 1003.45 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.18 | 1031.33 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.21 | 1059.20 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.24 | 1087.08 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.27 | 1114.95 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.30 | 1142.83 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.34 | 1170.70 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.37 | 1198.58 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.40 | 1226.45 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 1.43 | 1254.33 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 1.46 | 1282.20 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 1.49 | 1310.08 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 1.53 | 1337.95 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 1.56 | 1365.83 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 1.59 | 1393.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 1.62 | 1421.58 | 0.00 | 0.00 | 0.95 | 0.95 |
| 0.52 | 1.65 | 1449.45 | 0.00 | 0.00 | 1.90 | 1.90 |
| 0.53 | 1.68 | 1477.33 | 0.00 | 0.00 | 2.85 | 2.85 |
| 0.54 | 1.72 | 1505.20 | 0.00 | 0.00 | 3.80 | 3.80 |
| 0.55 | 1.75 | 1533.08 | 0.00 | 0.00 | 4.75 | 4.75 |
| 0.56 | 1.78 | 1560.95 | 0.00 | 0.00 | 5.71 | 5.71 |
| 0.57 | 1.81 | 1588.83 | 0.00 | 0.00 | 6.66 | 6.66 |
| 0.58 | 1.84 | 1616.70 | 0.00 | 0.00 | 7.61 | 7.61 |
| 0.59 | 1.88 | 1644.58 | 0.00 | 0.00 | 8.56 | 8.56 |

| | | | | | |
|------|------|--------|------|-------|-------|
| 0.6 | 1.91 | 380.05 | 0.00 | 9.51 | 9.51 |
| 0.61 | 1.94 | 363.36 | 0.00 | 10.46 | 10.46 |
| 0.62 | 1.97 | 346.67 | 0.00 | 11.41 | 11.41 |
| 0.63 | 2.00 | 329.98 | 0.00 | 12.36 | 12.36 |
| 0.64 | 2.03 | 313.28 | 0.00 | 13.31 | 13.31 |
| 0.65 | 2.07 | 296.59 | 0.00 | 14.26 | 14.26 |
| 0.66 | 2.10 | 279.90 | 0.00 | 15.21 | 15.21 |
| 0.67 | 2.13 | 263.21 | 0.00 | 16.17 | 16.17 |
| 0.68 | 2.16 | 246.52 | 0.00 | 17.12 | 17.12 |
| 0.69 | 2.19 | 229.83 | 0.00 | 18.07 | 18.07 |
| 0.7 | 2.23 | 213.14 | 0.00 | 19.02 | 19.02 |
| 0.71 | 2.26 | 196.45 | 0.00 | 19.97 | 19.97 |
| 0.72 | 2.29 | 179.76 | 0.00 | 20.92 | 20.92 |
| 0.73 | 2.32 | 163.07 | 0.00 | 21.87 | 21.87 |
| 0.74 | 2.35 | 146.38 | 0.00 | 22.82 | 22.82 |
| 0.75 | 2.38 | 129.69 | 0.00 | 23.77 | 0.00 |
| 0.76 | 2.42 | 113.00 | 0.00 | 24.72 | 0.73 |
| 0.77 | 2.45 | 96.31 | 0.00 | 25.68 | 1.47 |
| 0.78 | 2.48 | 79.61 | 0.00 | 26.63 | 2.20 |
| 0.79 | 2.51 | 62.92 | 0.00 | 27.58 | 2.93 |
| 0.8 | 2.54 | 46.23 | 0.00 | 28.53 | 3.66 |
| 0.81 | 2.57 | 29.54 | 0.00 | 29.48 | 4.40 |
| 0.82 | 2.61 | 12.85 | 0.00 | 28.91 | 5.13 |
| 0.83 | 2.64 | 0.00 | 0.00 | 28.34 | 5.86 |
| 0.84 | | | | 27.77 | 6.60 |
| 0.85 | | | | 27.20 | 7.33 |
| 0.86 | | | | 26.63 | 8.06 |
| 0.87 | | | | 26.06 | 8.80 |
| 0.88 | | | | 25.49 | 9.53 |
| 0.89 | | | | 24.92 | 10.26 |
| 0.9 | | | | 24.35 | 10.99 |
| 0.91 | | | | 23.78 | 11.73 |
| 0.92 | | | | 23.22 | 12.46 |
| 0.93 | | | | 22.65 | 13.19 |
| 0.94 | | | | 22.08 | 13.93 |
| 0.95 | | | | 21.51 | 14.66 |
| 0.96 | | | | 20.94 | 15.39 |
| 0.97 | | | | 20.37 | 16.12 |
| 0.98 | | | | 19.80 | 16.86 |
| 0.99 | | | | 19.23 | 17.59 |
| 1 | | | | 18.66 | 18.32 |
| 1.01 | | | | 18.09 | 19.06 |
| 1.02 | | | | 17.52 | 19.79 |
| 1.03 | | | | 16.95 | 20.52 |
| 1.04 | | | | 16.38 | 21.25 |
| 1.05 | | | | 15.81 | 21.99 |
| 1.06 | | | | 15.24 | 22.72 |
| 1.07 | | | | 14.67 | 22.28 |
| 1.08 | | | | 14.10 | 21.84 |
| 1.09 | | | | 13.54 | 21.40 |
| 1.1 | | | | | 20.97 |
| 1.11 | | | | | 20.53 |
| 1.12 | | | | | 20.09 |
| 1.13 | | | | | 19.65 |
| 1.14 | | | | | 19.21 |
| 1.15 | | | | | 18.77 |
| 1.16 | | | | | 18.33 |
| 1.17 | | | | | 17.89 |
| 1.18 | | | | | 17.45 |
| 1.19 | | | | | 17.02 |
| 1.2 | | | | | 16.58 |
| 1.21 | | | | | 16.14 |
| 1.22 | | | | | 15.70 |
| 1.23 | | | | | 15.26 |
| 1.24 | | | | | 14.82 |
| 1.25 | | | | | 14.38 |
| 1.26 | | | | | 13.94 |
| 1.27 | | | | | 13.50 |
| 1.28 | | | | | 13.07 |
| 1.29 | | | | | 12.63 |
| 1.3 | | | | | 12.19 |
| 1.31 | | | | | 11.75 |
| 1.32 | | | | | 11.31 |
| 1.33 | | | | | 10.87 |
| 1.34 | | | | | 10.43 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel

Basin B 10-year Peak Flow Calculation

| | |
|---------------------|--------|
| Duration (hrs) | 0.25 |
| Flow Length (mi) | 1.23 |
| Basin Area (sq. mi) | 0.57 |
| Basin Vertical (ft) | 440 |
| Curve Number | 80 |
| 1-hr rainfall (in) | 1.14 |
| tc (hr) | 0.32 |
| Adjusted tc | 0.32 |
| tf (hrs) | 0.1896 |
| tp (hrs) | 0.31 |
| base (hrs) | 0.8400 |
| qp (cfs) | 877 |

| t (hrs) | V/tp | q/gp | Incremental Rainfall (inches) | | | Total |
|---------|------|--------|-------------------------------|------|----------|-------|
| | | | 0.0000 | 0 | 0.084313 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.03 | 27.87 | 0.00 | | | 0.00 |
| 0.02 | 0.06 | 55.75 | 0.00 | | | 0.00 |
| 0.03 | 0.10 | 83.62 | 0.00 | | | 0.00 |
| 0.04 | 0.13 | 111.49 | 0.00 | | | 0.00 |
| 0.05 | 0.16 | 139.37 | 0.00 | | | 0.00 |
| 0.06 | 0.19 | 167.24 | 0.00 | | | 0.00 |
| 0.07 | 0.22 | 195.11 | 0.00 | | | 0.00 |
| 0.08 | 0.25 | 222.99 | 0.00 | | | 0.00 |
| 0.09 | 0.29 | 250.86 | 0.00 | | | 0.00 |
| 0.1 | 0.32 | 278.73 | 0.00 | | | 0.00 |
| 0.11 | 0.35 | 306.61 | 0.00 | | | 0.00 |
| 0.12 | 0.38 | 334.48 | 0.00 | | | 0.00 |
| 0.13 | 0.41 | 362.36 | 0.00 | | | 0.00 |
| 0.14 | 0.45 | 390.23 | 0.00 | | | 0.00 |
| 0.15 | 0.48 | 418.10 | 0.00 | | | 0.00 |
| 0.16 | 0.51 | 445.98 | 0.00 | | | 0.00 |
| 0.17 | 0.54 | 473.85 | 0.00 | | | 0.00 |
| 0.18 | 0.57 | 501.72 | 0.00 | | | 0.00 |
| 0.19 | 0.60 | 529.60 | 0.00 | | | 0.00 |
| 0.2 | 0.64 | 557.47 | 0.00 | | | 0.00 |
| 0.21 | 0.67 | 585.34 | 0.00 | | | 0.00 |
| 0.22 | 0.70 | 613.22 | 0.00 | | | 0.00 |
| 0.23 | 0.73 | 641.09 | 0.00 | | | 0.00 |
| 0.24 | 0.76 | 668.96 | 0.00 | | | 0.00 |
| 0.25 | 0.79 | 696.84 | 0.00 | 0.00 | | 0.00 |
| 0.26 | 0.83 | 724.71 | 0.00 | 0.00 | | 0.00 |
| 0.27 | 0.86 | 752.58 | 0.00 | 0.00 | | 0.00 |
| 0.28 | 0.89 | 780.46 | 0.00 | 0.00 | | 0.00 |
| 0.29 | 0.92 | 808.33 | 0.00 | 0.00 | | 0.00 |
| 0.3 | 0.95 | 836.20 | 0.00 | 0.00 | | 0.00 |
| 0.31 | 0.99 | 864.08 | 0.00 | 0.00 | | 0.00 |
| 0.32 | 1.02 | 847.39 | 0.00 | 0.00 | | 0.00 |
| 0.33 | 1.05 | 830.70 | 0.00 | 0.00 | | 0.00 |
| 0.34 | 1.08 | 814.01 | 0.00 | 0.00 | | 0.00 |
| 0.35 | 1.11 | 797.32 | 0.00 | 0.00 | | 0.00 |
| 0.36 | 1.14 | 780.62 | 0.00 | 0.00 | | 0.00 |
| 0.37 | 1.18 | 763.93 | 0.00 | 0.00 | | 0.00 |
| 0.38 | 1.21 | 747.24 | 0.00 | 0.00 | | 0.00 |
| 0.39 | 1.24 | 730.55 | 0.00 | 0.00 | | 0.00 |
| 0.4 | 1.27 | 713.86 | 0.00 | 0.00 | | 0.00 |
| 0.41 | 1.30 | 697.17 | 0.00 | 0.00 | | 0.00 |
| 0.42 | 1.34 | 680.48 | 0.00 | 0.00 | | 0.00 |
| 0.43 | 1.37 | 663.79 | 0.00 | 0.00 | | 0.00 |
| 0.44 | 1.40 | 647.10 | 0.00 | 0.00 | | 0.00 |
| 0.45 | 1.43 | 630.41 | 0.00 | 0.00 | | 0.00 |
| 0.46 | 1.46 | 613.72 | 0.00 | 0.00 | | 0.00 |
| 0.47 | 1.49 | 597.03 | 0.00 | 0.00 | | 0.00 |
| 0.48 | 1.53 | 580.34 | 0.00 | 0.00 | | 0.00 |
| 0.49 | 1.56 | 563.65 | 0.00 | 0.00 | | 0.00 |
| 0.5 | 1.59 | 546.95 | 0.00 | 0.00 | 0.00 | 0.00 |
| 0.51 | 1.62 | 530.26 | 0.00 | 0.00 | 2.35 | 2.35 |
| 0.52 | 1.65 | 513.57 | 0.00 | 0.00 | 4.70 | 4.70 |
| 0.53 | 1.68 | 496.88 | 0.00 | 0.00 | 7.05 | 7.05 |
| 0.54 | 1.72 | 480.19 | 0.00 | 0.00 | 9.40 | 9.40 |
| 0.55 | 1.75 | 463.50 | 0.00 | 0.00 | 11.75 | 11.75 |
| 0.56 | 1.78 | 446.81 | 0.00 | 0.00 | 14.10 | 14.10 |
| 0.57 | 1.81 | 430.12 | 0.00 | 0.00 | 16.45 | 16.45 |
| 0.58 | 1.84 | 413.43 | 0.00 | 0.00 | 18.80 | 18.80 |
| 0.59 | 1.88 | 396.74 | 0.00 | 0.00 | 21.15 | 21.15 |

| | | | | | | |
|------|------|--------|------|-------|-------|-------|
| 0.6 | 1.91 | 390.05 | 0.00 | 23.50 | | 23.50 |
| 0.61 | 1.94 | 363.36 | 0.00 | 25.85 | | 25.85 |
| 0.62 | 1.97 | 346.67 | 0.00 | 28.20 | | 28.20 |
| 0.63 | 2.00 | 329.98 | 0.00 | 30.55 | | 30.55 |
| 0.64 | 2.03 | 313.28 | 0.00 | 32.90 | | 32.90 |
| 0.65 | 2.07 | 296.59 | 0.00 | 35.25 | | 35.25 |
| 0.66 | 2.10 | 279.90 | 0.00 | 37.60 | | 37.60 |
| 0.67 | 2.13 | 263.21 | 0.00 | 39.95 | | 39.95 |
| 0.68 | 2.16 | 246.52 | 0.00 | 42.30 | | 42.30 |
| 0.69 | 2.19 | 229.83 | 0.00 | 44.65 | | 44.65 |
| 0.7 | 2.23 | 213.14 | 0.00 | 47.00 | | 47.00 |
| 0.71 | 2.26 | 196.45 | 0.00 | 49.35 | | 49.35 |
| 0.72 | 2.29 | 179.76 | 0.00 | 51.70 | | 51.70 |
| 0.73 | 2.32 | 163.07 | 0.00 | 54.05 | | 54.05 |
| 0.74 | 2.35 | 146.38 | 0.00 | 56.40 | | 56.40 |
| 0.75 | 2.38 | 129.69 | 0.00 | 58.75 | 0.00 | 58.75 |
| 0.76 | 2.42 | 113.00 | 0.00 | 61.10 | 1.29 | 62.39 |
| 0.77 | 2.45 | 96.31 | 0.00 | 63.45 | 2.57 | 66.02 |
| 0.78 | 2.48 | 79.61 | 0.00 | 65.80 | 3.86 | 69.66 |
| 0.79 | 2.51 | 62.92 | 0.00 | 68.15 | 5.14 | 73.30 |
| 0.8 | 2.54 | 46.23 | 0.00 | 70.50 | 6.43 | 76.93 |
| 0.81 | 2.57 | 29.54 | 0.00 | 72.85 | 7.72 | 80.57 |
| 0.82 | 2.61 | 12.85 | 0.00 | 71.45 | 9.00 | 80.45 |
| 0.83 | 2.64 | 0.00 | 0.00 | 70.04 | 10.29 | 80.33 |
| 0.84 | | | | 68.63 | 11.57 | 80.20 |
| 0.85 | | | | 67.22 | 12.86 | 80.08 |
| 0.86 | | | | 65.82 | 14.14 | 79.96 |
| 0.87 | | | | 64.41 | 15.43 | 79.84 |
| 0.88 | | | | 63.00 | 16.72 | 79.72 |
| 0.89 | | | | 61.60 | 18.00 | 79.60 |
| 0.9 | | | | 60.19 | 19.29 | 79.48 |
| 0.91 | | | | 58.78 | 20.57 | 79.35 |
| 0.92 | | | | 57.37 | 21.86 | 79.23 |
| 0.93 | | | | 55.97 | 23.15 | 79.11 |
| 0.94 | | | | 54.56 | 24.43 | 78.99 |
| 0.95 | | | | 53.15 | 25.72 | 78.87 |
| 0.96 | | | | 51.74 | 27.00 | 78.75 |
| 0.97 | | | | 50.34 | 28.29 | 78.63 |
| 0.98 | | | | 48.93 | 29.58 | 78.51 |
| 0.99 | | | | 47.52 | 30.06 | 78.39 |
| 1 | | | | 46.12 | 32.15 | 78.26 |
| 1.01 | | | | 44.71 | 33.43 | 78.14 |
| 1.02 | | | | 43.30 | 34.72 | 78.02 |
| 1.03 | | | | 41.89 | 36.00 | 77.90 |
| 1.04 | | | | 40.49 | 37.29 | 77.78 |
| 1.05 | | | | 39.08 | 38.58 | 77.66 |
| 1.06 | | | | 37.67 | 39.86 | 77.53 |
| 1.07 | | | | 36.26 | 39.09 | 75.36 |
| 1.08 | | | | 34.86 | 38.32 | 73.18 |
| 1.09 | | | | 33.45 | 37.55 | 71.00 |
| 1.1 | | | | | 36.78 | 36.78 |
| 1.11 | | | | | 36.01 | 36.01 |
| 1.12 | | | | | 35.24 | 35.24 |
| 1.13 | | | | | 34.47 | 34.47 |
| 1.14 | | | | | 33.70 | 33.70 |
| 1.15 | | | | | 32.93 | 32.93 |
| 1.16 | | | | | 32.16 | 32.16 |
| 1.17 | | | | | 31.39 | 31.39 |
| 1.18 | | | | | 30.62 | 30.62 |
| 1.19 | | | | | 29.85 | 29.85 |
| 1.2 | | | | | 29.08 | 29.08 |
| 1.21 | | | | | 28.31 | 28.31 |
| 1.22 | | | | | 27.54 | 27.54 |
| 1.23 | | | | | 26.77 | 26.77 |
| 1.24 | | | | | 26.00 | 26.00 |
| 1.25 | | | | | 25.23 | 25.23 |
| 1.26 | | | | | 24.46 | 24.46 |
| 1.27 | | | | | 23.69 | 23.69 |
| 1.28 | | | | | 22.92 | 22.92 |
| 1.29 | | | | | 22.15 | 22.15 |
| 1.3 | | | | | 21.38 | 21.38 |
| 1.31 | | | | | 20.61 | 20.61 |
| 1.32 | | | | | 19.84 | 19.84 |
| 1.33 | | | | | 19.07 | 19.07 |
| 1.34 | | | | | 18.30 | 18.30 |

Church Rock Erosion and Sedimentation

North Upstream Diversion Channel
5-year Peak Flow Calculation

| Time Step (hrs) | Basin A1 Flow (cfs) | Basin A2 Flow (cfs) | Basin B Flow (cfs) | Total Flow (cfs) | Time Step (hrs) | Basin A1 Flow (cfs) | Basin A2 Flow (cfs) | Basin B Flow (cfs) | Total Flow (cfs) |
|-----------------|---------------------|---------------------|--------------------|------------------|-----------------|---------------------|---------------------|--------------------|------------------|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 8.72 | 8.88 | 20.92 | 38.52 |
| 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 | 9.11 | 8.64 | 21.87 | 39.62 |
| 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 | 9.51 | 8.40 | 22.82 | 40.73 |
| 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.75 | 9.91 | 8.15 | 23.77 | 41.84 |
| 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.76 | 9.98 | 8.22 | 25.46 | 43.66 |
| 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 10.04 | 8.29 | 27.14 | 45.48 |
| 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.78 | 10.11 | 8.36 | 28.82 | 47.30 |
| 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.79 | 10.18 | 8.43 | 30.51 | 49.12 |
| 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.8 | 10.25 | 8.50 | 32.19 | 50.94 |
| 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.81 | 10.32 | 8.57 | 33.88 | 52.76 |
| 0.1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 10.38 | 8.64 | 34.04 | 53.07 |
| 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 10.45 | 8.71 | 34.20 | 53.37 |
| 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.84 | 10.52 | 8.78 | 34.37 | 53.67 |
| 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 | 10.59 | 8.85 | 34.53 | 53.97 |
| 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 | 10.66 | 8.92 | 34.69 | 54.27 |
| 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.87 | 10.72 | 8.99 | 34.86 | 54.57 |
| 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 | 10.79 | 9.06 | 35.02 | 54.87 |
| 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 10.88 | 9.13 | 35.18 | 55.17 |
| 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.9 | 10.93 | 9.20 | 35.35 | 55.47 |
| 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 11.00 | 9.27 | 35.51 | 55.77 |
| 0.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 | 11.07 | 9.33 | 35.68 | 56.08 |
| 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 11.13 | 9.40 | 35.84 | 56.38 |
| 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 11.20 | 9.47 | 36.00 | 56.68 |
| 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 11.27 | 9.54 | 36.17 | 56.98 |
| 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 11.34 | 9.61 | 36.33 | 57.28 |
| 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.97 | 11.41 | 9.68 | 36.49 | 57.58 |
| 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.98 | 11.47 | 9.75 | 36.66 | 57.38 |
| 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 11.54 | 8.83 | 36.82 | 57.19 |
| 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 1 | 11.61 | 8.40 | 36.98 | 66.99 |
| 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 | 11.19 | 7.97 | 37.15 | 56.31 |
| 0.3 | 0.00 | 0.00 | 0.00 | 0.00 | 1.02 | 10.77 | 7.54 | 37.31 | 55.62 |
| 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 10.35 | 7.11 | 37.47 | 54.94 |
| 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 1.04 | 9.93 | 6.69 | 37.64 | 54.25 |
| 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 9.51 | 6.26 | 37.80 | 53.57 |
| 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 1.06 | 9.09 | 5.83 | 37.96 | 52.88 |
| 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 | 8.67 | 5.40 | 36.96 | 51.03 |
| 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 8.25 | 4.97 | 35.95 | 49.17 |
| 0.37 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 7.83 | 4.61 | 34.94 | 47.38 |
| 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 1.1 | 7.41 | 4.24 | 20.97 | 32.80 |
| 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 1.11 | 6.99 | 4.24 | 20.53 | 31.75 |
| 0.4 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12 | 6.57 | 4.05 | 20.09 | 30.71 |
| 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13 | 6.15 | 3.86 | 19.65 | 29.66 |
| 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 5.73 | 3.68 | 19.21 | 28.62 |
| 0.43 | 0.00 | 0.00 | 0.00 | 0.00 | 1.15 | 5.31 | 3.49 | 18.77 | 27.57 |
| 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 1.16 | 4.89 | 3.30 | 18.33 | 26.52 |
| 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 1.17 | 4.53 | 3.12 | 17.89 | 25.54 |
| 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 1.18 | 4.34 | 2.93 | 17.45 | 24.73 |
| 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19 | 4.16 | 2.75 | 17.02 | 23.92 |
| 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 1.2 | 3.98 | 2.56 | 16.58 | 23.11 |
| 0.49 | 0.00 | 0.00 | 0.00 | 0.00 | 1.21 | 3.80 | 2.37 | 16.14 | 22.31 |
| 0.5 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 | 3.61 | 2.19 | 15.70 | 21.50 |
| 0.51 | 0.40 | 0.40 | 0.95 | 1.75 | 1.23 | 3.43 | 2.00 | 15.26 | 20.69 |
| 0.52 | 0.79 | 0.81 | 1.90 | 3.50 | 1.24 | 3.25 | 1.81 | 14.82 | 19.88 |
| 0.53 | 1.19 | 1.21 | 2.85 | 5.25 | 1.25 | 3.06 | 1.63 | 14.38 | 19.07 |
| 0.54 | 1.59 | 1.61 | 3.80 | 7.00 | 1.26 | 2.88 | 1.44 | 13.94 | 18.27 |
| 0.55 | 1.98 | 2.02 | 4.75 | 8.75 | 1.27 | 2.70 | 1.26 | 13.50 | 17.46 |
| 0.56 | 2.38 | 2.42 | 5.71 | 10.51 | 1.28 | 2.51 | 1.07 | 13.07 | 16.65 |
| 0.57 | 2.77 | 2.83 | 6.66 | 12.26 | 1.29 | 2.33 | 0.88 | 12.63 | 15.84 |
| 0.58 | 3.17 | 3.23 | 7.61 | 14.01 | 1.3 | 2.15 | 0.70 | 12.19 | 15.03 |
| 0.59 | 3.57 | 3.63 | 8.56 | 15.76 | 1.31 | 1.97 | 0.51 | 11.75 | 14.23 |
| 0.6 | 3.96 | 4.04 | 9.51 | 17.51 | 1.32 | 1.78 | 0.32 | 11.31 | 13.42 |
| 0.61 | 4.36 | 4.44 | 10.46 | 19.26 | 1.33 | 1.60 | 0.14 | 10.87 | 12.61 |
| 0.62 | 4.76 | 4.84 | 11.41 | 21.01 | 1.34 | 1.42 | 0.00 | 10.43 | 11.85 |
| 0.63 | 5.15 | 5.25 | 12.36 | 22.76 | 1.35 | 1.23 | | | 1.23 |
| 0.64 | 5.55 | 5.65 | 13.31 | 24.51 | 1.36 | 1.05 | | | 1.05 |
| 0.65 | 5.94 | 6.05 | 14.26 | 26.26 | 1.37 | 0.87 | | | 0.87 |
| 0.66 | 6.34 | 6.46 | 15.21 | 28.01 | 1.38 | 0.69 | | | 0.69 |
| 0.67 | 6.74 | 6.86 | 16.17 | 29.76 | 1.39 | 0.50 | | | 0.50 |
| 0.68 | 7.13 | 7.27 | 17.12 | 31.52 | 1.4 | 0.32 | | | 0.32 |
| 0.69 | 7.53 | 7.67 | 18.07 | 33.27 | 1.41 | 0.14 | | | 0.14 |
| 0.7 | 7.93 | 8.07 | 19.02 | 35.02 | 1.42 | 0.00 | | | 0.00 |
| 0.71 | 8.32 | 8.48 | 19.97 | 36.77 | | | | | |

Church Rock Erosion and Sedimentation
 North Upstream Diversion Channel
 10-year Peak Flow Calculation

| Time Step (hrs) | Basin A1 Flow (cfs) | Basin A2 Flow (cfs) | Basin B Flow (cfs) | Total Flow (cfs) | Time Step (hrs) | Basin A1 Flow (cfs) | Basin A2 Flow (cfs) | Basin B Flow (cfs) | Total Flow (cfs) |
|-----------------|---------------------|---------------------|--------------------|------------------|-----------------|---------------------|---------------------|--------------------|------------------|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 21.55 | 21.95 | 51.70 | 95.19 |
| 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 | 22.53 | 21.35 | 54.05 | 97.93 |
| 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 | 23.51 | 20.75 | 56.40 | 100.66 |
| 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.75 | 24.48 | 20.15 | 58.75 | 103.39 |
| 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.76 | 24.43 | 20.10 | 62.39 | 106.93 |
| 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 24.38 | 20.05 | 66.02 | 110.46 |
| 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.78 | 24.33 | 20.00 | 69.66 | 113.99 |
| 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.79 | 24.28 | 19.95 | 73.30 | 117.53 |
| 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.8 | 24.23 | 19.90 | 76.93 | 121.06 |
| 0.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.81 | 24.18 | 19.84 | 80.57 | 124.59 |
| 0.1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 24.13 | 19.79 | 80.45 | 124.37 |
| 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 24.08 | 19.74 | 80.33 | 124.15 |
| 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.84 | 24.03 | 19.69 | 80.20 | 123.92 |
| 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 | 23.98 | 19.64 | 80.08 | 123.70 |
| 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 | 23.93 | 19.59 | 79.96 | 123.48 |
| 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.87 | 23.88 | 19.54 | 79.84 | 123.25 |
| 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 | 23.83 | 19.48 | 79.72 | 123.03 |
| 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.89 | 23.78 | 19.43 | 79.60 | 122.81 |
| 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.9 | 23.73 | 19.38 | 79.48 | 122.58 |
| 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 23.68 | 19.33 | 79.35 | 122.36 |
| 0.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 | 23.62 | 19.28 | 79.23 | 122.14 |
| 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 23.57 | 19.23 | 79.11 | 121.91 |
| 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 23.52 | 19.18 | 78.99 | 121.69 |
| 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 23.47 | 19.12 | 78.87 | 121.47 |
| 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 23.42 | 19.07 | 78.75 | 121.24 |
| 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.97 | 23.37 | 19.02 | 78.63 | 121.02 |
| 0.26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.98 | 23.32 | 18.10 | 78.51 | 119.92 |
| 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 23.27 | 17.17 | 78.38 | 118.83 |
| 0.28 | 0.00 | 0.00 | 0.00 | 0.00 | 1 | 23.22 | 16.25 | 78.26 | 117.73 |
| 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 | 22.31 | 15.32 | 78.14 | 115.78 |
| 0.3 | 0.00 | 0.00 | 0.00 | 0.00 | 1.02 | 21.41 | 14.40 | 78.02 | 113.82 |
| 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03 | 20.50 | 13.48 | 77.90 | 111.87 |
| 0.32 | 0.00 | 0.00 | 0.00 | 0.00 | 1.04 | 19.59 | 12.55 | 77.78 | 109.92 |
| 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 18.68 | 11.63 | 77.66 | 107.97 |
| 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 1.06 | 17.78 | 10.70 | 77.53 | 106.01 |
| 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 | 16.87 | 9.78 | 75.36 | 102.00 |
| 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 15.96 | 8.85 | 73.18 | 98.00 |
| 0.37 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 15.05 | 8.09 | 71.00 | 94.14 |
| 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 1.1 | 14.15 | 7.76 | 66.78 | 88.69 |
| 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 1.11 | 13.24 | 7.43 | 66.01 | 86.68 |
| 0.4 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12 | 12.33 | 7.11 | 65.24 | 84.68 |
| 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13 | 11.42 | 6.78 | 64.47 | 82.68 |
| 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 10.52 | 6.45 | 63.70 | 80.67 |
| 0.43 | 0.00 | 0.00 | 0.00 | 0.00 | 1.15 | 9.61 | 6.12 | 62.93 | 78.67 |
| 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 1.16 | 8.70 | 5.80 | 62.16 | 76.66 |
| 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 1.17 | 7.94 | 5.47 | 61.39 | 74.65 |
| 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 1.18 | 7.22 | 5.14 | 60.62 | 72.64 |
| 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19 | 6.50 | 4.82 | 59.85 | 70.63 |
| 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 1.2 | 5.88 | 4.49 | 59.08 | 68.62 |
| 0.49 | 0.00 | 0.00 | 0.00 | 0.00 | 1.21 | 5.36 | 4.16 | 58.31 | 66.61 |
| 0.5 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 | 4.94 | 3.84 | 57.54 | 64.60 |
| 0.51 | 0.98 | 1.00 | 2.35 | 4.33 | 1.23 | 4.62 | 3.51 | 56.77 | 62.59 |
| 0.52 | 1.96 | 2.00 | 4.70 | 8.65 | 1.24 | 4.30 | 3.18 | 56.00 | 60.58 |
| 0.53 | 2.94 | 2.99 | 7.05 | 12.98 | 1.25 | 4.07 | 2.86 | 55.23 | 58.57 |
| 0.54 | 3.92 | 3.99 | 9.40 | 17.31 | 1.26 | 3.84 | 2.53 | 54.46 | 56.56 |
| 0.55 | 4.90 | 4.99 | 11.75 | 21.64 | 1.27 | 3.61 | 2.20 | 53.69 | 54.55 |
| 0.56 | 5.88 | 5.99 | 14.10 | 25.96 | 1.28 | 3.38 | 1.88 | 52.92 | 52.54 |
| 0.57 | 6.86 | 6.98 | 16.45 | 30.29 | 1.29 | 3.15 | 1.55 | 52.15 | 50.53 |
| 0.58 | 7.84 | 7.98 | 18.80 | 34.62 | 1.3 | 2.92 | 1.22 | 51.38 | 48.52 |
| 0.59 | 8.81 | 8.98 | 21.15 | 38.94 | 1.31 | 2.69 | 0.90 | 50.61 | 46.51 |
| 0.6 | 9.79 | 9.98 | 23.50 | 43.27 | 1.32 | 2.46 | 0.57 | 49.84 | 44.50 |
| 0.61 | 10.77 | 10.97 | 25.85 | 47.60 | 1.33 | 2.23 | 0.24 | 49.07 | 42.49 |
| 0.62 | 11.75 | 11.97 | 28.20 | 51.92 | 1.34 | 2.00 | 0.00 | 48.30 | 40.48 |
| 0.63 | 12.73 | 12.97 | 30.55 | 56.25 | 1.35 | 1.77 | | 47.53 | 38.47 |
| 0.64 | 13.71 | 13.97 | 32.90 | 60.58 | 1.36 | 1.54 | | 46.76 | 36.46 |
| 0.65 | 14.69 | 14.96 | 35.25 | 64.91 | 1.37 | 1.31 | | 45.99 | 34.45 |
| 0.66 | 15.67 | 15.96 | 37.60 | 69.23 | 1.38 | 1.08 | | 45.22 | 32.44 |
| 0.67 | 16.65 | 16.96 | 39.95 | 73.56 | 1.39 | 0.85 | | 44.45 | 30.43 |
| 0.68 | 17.63 | 17.96 | 42.30 | 77.89 | 1.4 | 0.62 | | 43.68 | 28.42 |
| 0.69 | 18.61 | 18.95 | 44.65 | 82.21 | 1.41 | 0.39 | | 42.91 | 26.41 |
| 0.7 | 19.59 | 19.95 | 47.00 | 86.54 | 1.42 | 0.16 | | 42.14 | 24.40 |
| 0.71 | 20.57 | 20.95 | 49.35 | 90.87 | | 0.00 | | 41.37 | 22.39 |

**BERM RIPRAP DESIGN
INFORMATION**



MONTGOMERY WATSON
Mining Group

Project Name: _____
Project Number: _____ Sheet: _____ of _____
Prepared By: _____ Date: _____
Checked By: _____ Date: _____

Riprap for Berm / Road Embankment

- use Abt / Johnson method presented in NUREG-1623:

$$D_{50}(\text{in}) = 5.23 (\text{slope})^{0.43} (q_{\text{des}})^{0.56}$$

$$q_{\text{des}} = \text{design unit discharge (cfs/ft)} = q * C_f$$

q = calculated discharge (cfs/ft)

C_f = concentration factor (ranges from 1.0 to 3.0)

From hydrologic analysis (see attached):

$$Q = 3.20 \text{ cfs}$$

$$\text{flow width} = 100 \text{ ft} \rightarrow q = \frac{3.20 \text{ cfs}}{100 \text{ ft}} = 0.032 \text{ cfs/ft}$$

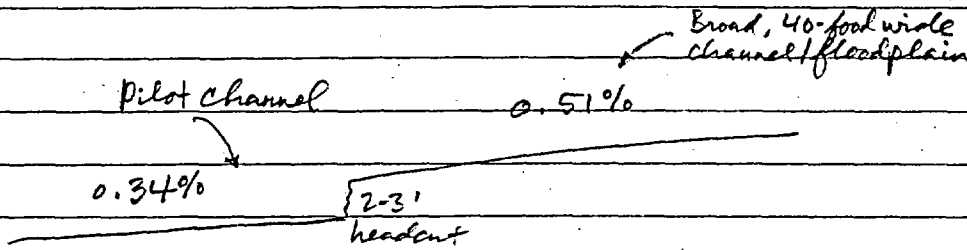
$$\text{use } C_f = 3.0$$

$$q_{\text{des}} = 0.032 \text{ cfs/ft} * 3.0 \rightarrow q_{\text{des}} = 0.096 \text{ cfs/ft}$$

$$\text{steepest sideslope} = 0.67 \text{ ft/ft}$$

$$D_{50}(\text{in}) = 5.23 (0.67)^{0.43} (0.096)^{0.56} \rightarrow \underline{\underline{D_{50} = 1.20 \text{ in}}}$$

N. channel @ berm Hydraulic Hydrologic Analysis



Pilot below headcut:

$Q @ 3.5' \text{ depth} = \underline{76 \text{ cfs}}$ (storm on 9/10)

$\tau = \gamma d S = (62.4)(3.5)(0.0034) = 0.74 \text{ psf}$

$V = 3 \text{ ft/sec}$

$\tau_{crit} = 0.075$ (Randy loam, non-colloidal)

$N_{per} = 2.5 \text{ ft/s}$

Broad channel above headcut:

Width = 40', 1:1 sides, slope = 0.0051 ft/ft
(normal depth):

$d = 0.76 \text{ ft}$

$V = 2.5 \text{ ft/s}$

$\tau = (62.4)(0.76)(0.0051) = 0.24 \text{ psf}$

Hydrologic analysis using SCS Triangular UH

From NOAA Atlas 14:

5yr - 1 hour = 0.92 in

10yr - 1 hour = 1.14 in

100 year, 1-hour = 1.81 in (from Rec Plan)

| January 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| February 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| March 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| April 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |
| May 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |
| June 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | | | | |
| July 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |
| August 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | | |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |
| September 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |
| October 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | | |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |
| November 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |
| December 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

N. channel Hydraulic Analysis (cont)
Hydrologic Analysis (cont)

SCS Triangular UH spreadsheet output:

$$Q_{5\text{-yr}} = 58 \text{ cfs}$$

$$Q_{10\text{-yr}} = 125 \text{ cfs}$$

$$Q_{100\text{-yr}} = 296 \text{ cfs (from Rec Plan Appx E)}$$

 \Rightarrow 9/10/03 storm < 10-yr event

Hydraulic Summary

pilot:

| Event | Q (cfs) | w (f/s) | depth (ft) | $\tau = \gamma d^2$ (psf) |
|---------|---------|---------|------------|---------------------------|
| 5-yr | 58 | 2.58 | 3.36 | 0.71 |
| 10-yr | 125 | 3.06 | 4.17 | 0.88 |
| 100-yr | 296 | 4.15 | 5.14 | 1.09 |
| 9/10/03 | 76 | 3.03 | 3.50 | 0.74 |

wide chan.

| Event | Q (cfs) | w (f/s) | depth (f/s) | $\tau = \gamma d^2$ (psf) |
|---------|---------|---------|-------------|---------------------------|
| 5-yr | 58 | 2.23 | 0.65 | 0.21 |
| 10-yr | 125 | 3.01 | 1.04 | 0.33 |
| 100-yr | 296 | 4.19 | 1.76 | 0.56 |
| 9/10/03 | 76 | 2.48 | 0.77 | 0.25 |

| January 2003 | | | | | | |
|----------------|----|----|----|----|----|----|
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | |
| 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| February 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| March 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | 31 | | | | |
| April 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |
| May 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | | |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | | | | | | |
| June 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | |
| 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | | | | |
| July 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |
| August 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |
| September 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | | |
| October 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | 31 | | | | | |
| November 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 29 | 30 | | | | | |
| December 2003 | | | | | | |
| S | S | M | T | W | Th | F |
| | | | 1 | 2 | 3 | 4 |
| 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | |

NORMAL DEPTH CALCULATION

PROJECT: UNC Erosion and Sedimentation Evaluation

LOCATION: North Upstream Diversion above the pilot channel/headcut

Channel Hydraulic properties (input):

| | |
|------------------------|--------|
| Flow (cfs): | 76 |
| Manning's n: | 0.035 |
| Bottom Width (ft): | 40 |
| Right Side Slope, z:1 | 1 |
| Left Side Slope, z:1 | 1 |
| Channel Slope (ft/ft): | 0.0051 |

Solve

Solve: ctrl-s

| <u>Depth</u> | <u>Formula</u> |
|--------------|----------------|
| 0.756 | 0 |

Channel Hydraulic Results:

| | |
|---|-----------|
| Depth (ft) = | 0.756 |
| Hydraulic Radius (ft) = | 0.731 |
| Cross-sectional Area (ft ²) = | 30.80 |
| Average Velocity (ft ² /s) = | 2.47 |
| Topwidth (ft) = | 41.51 |
| Froude Number = | 0.51 |
| Flow condition: | SUBCRITIC |

Pilot at North Diversion, 9/10/03 storm
Worksheet for Irregular Channel

| Project Description | |
|---------------------|---|
| Project File | c:\haestad\fmw\project1.fm2 |
| Worksheet | Pilot at North Diversion, 9/10/03 event |
| Flow Element | Irregular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

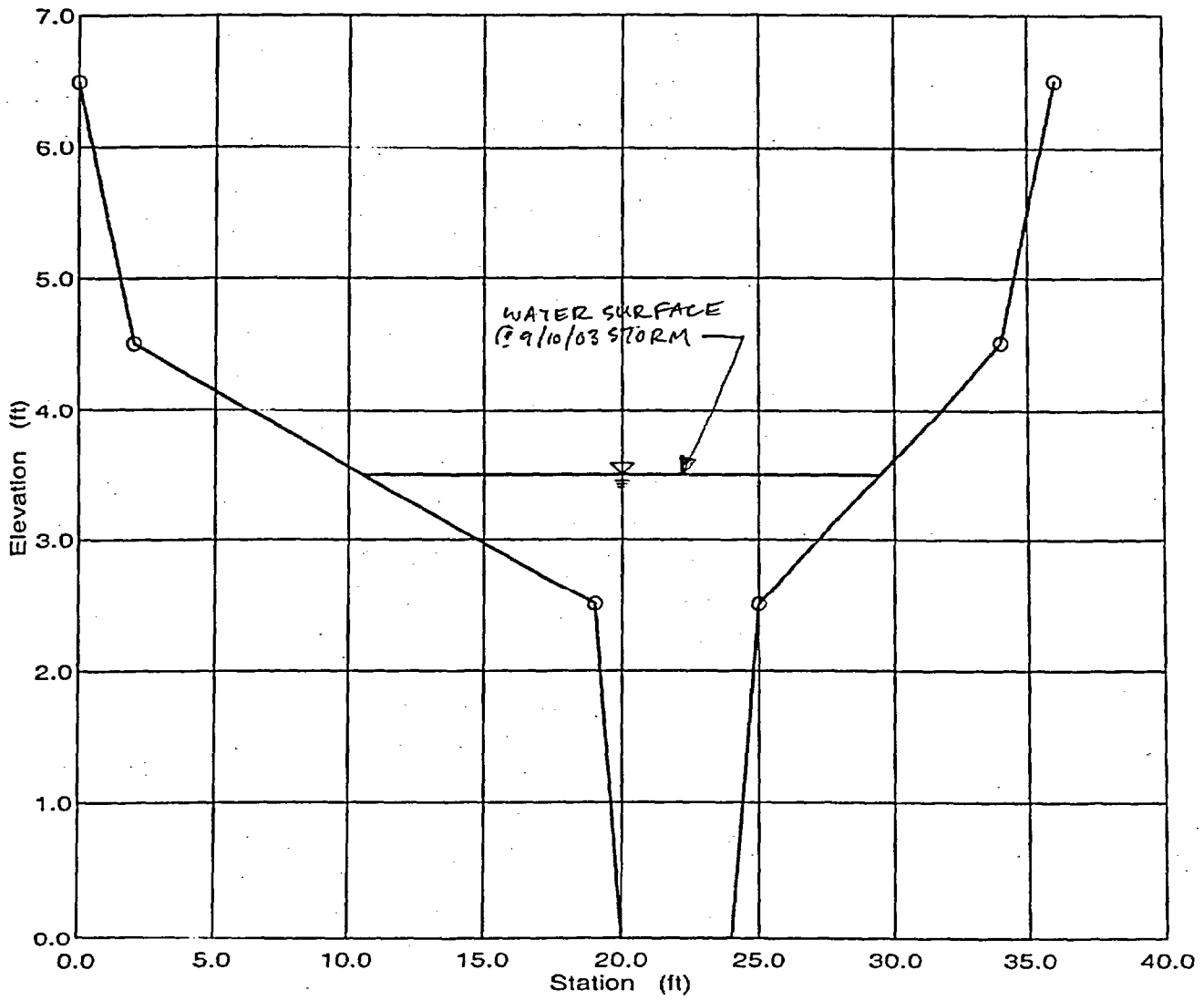
| Input Data | | | | |
|--------------------------------------|----------------|---------------|-------------|-----------|
| Channel Slope | 0.003400 ft/ft | | | |
| Water Surface Elevation | 3.50 ft | | | |
| Elevation range: 0.00 ft to 6.50 ft. | | | | |
| Station (ft) | Elevation (ft) | Start Station | End Station | Roughness |
| 0.00 | 6.50 | 0.00 | 2.00 | 0.030 |
| 2.00 | 4.50 | 2.00 | 19.00 | 0.040 |
| 19.00 | 2.50 | 19.00 | 25.00 | 0.030 |
| 20.00 | 0.00 | 25.00 | 34.00 | 0.040 |
| 24.00 | 0.00 | 34.00 | 36.00 | 0.030 |
| 25.00 | 2.50 | | | |
| 34.00 | 4.50 | | | |
| 36.00 | 6.50 | | | |

| Results | |
|---------------------------|-----------------------|
| Wtd. Mannings Coefficient | 0.031 |
| Discharge | 75.64 cfs |
| Flow Area | 25.00 ft ² |
| Wetted Perimeter | 22.55 ft |
| Top Width | 19.00 ft |
| Height | 3.50 ft |
| Critical Depth | 2.07 ft |
| Critical Slope | 0.018554 ft/ft |
| Velocity | 3.03 ft/s |
| Velocity Head | 0.14 ft |
| Specific Energy | 3.64 ft |
| Froude Number | 0.47 |
| Flow is subcritical. | |

Pilot at North Diversion, 9/10/03 storm
 Cross Section for Irregular Channel

| Project Description | |
|---------------------|---|
| Project File | c:\haestad\fmw\project1.fm2 |
| Worksheet | Pilot at North Diversion, 9/10/03 cvcnt |
| Flow Element | Irregular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

| Section Data | |
|---------------------------|----------------|
| Wtd. Mannings Coefficient | 0.031 |
| Channel Slope | 0.003400 ft/ft |
| Water Surface Elevation | 3.50 ft |
| Discharge | 75.64 cfs |



An alternative approach to designing stable, unlined channels is to use regime relationships. These relationships define equilibrium conditions between flow and the channel boundaries. Chapter 10 discusses this approach.

Example Problem 4.10 Erodible channel design

Design a channel to carry 20 cfs down a 0.5% slope. The channel material is to be an ordinary firm loam. The water will be transporting colloidal silts. The channel is to be trapezoidal with 3:1 side slopes. Use (a) the limiting velocity approach and (b) the limiting tractive force approach.

Solution:

(a) Limiting velocity approach. From Table 4.2, $v_p = 3.5$ fps, $n = 0.020$,

$$v_p = \frac{1.49}{n} R^{2/3} S^{1/2}$$

$$R = \left[\frac{v_p n}{1.49 S^{1/2}} \right]^{3/2} = \left[\frac{3.5(0.020)}{1.49(0.005)^{1/2}} \right]^{3/2} = 0.54$$

$$A = \frac{Q}{v_p} = \frac{20.00}{3.5} = 5.71$$

$$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = \frac{bd + 3d^2}{b + 6.32d} = 0.54 \quad (a)$$

$$A = bd + zd^2 = bd + 3d^2 = 5.71. \quad (b)$$

Substituting Eq. (b) into Eq. (a) yields

$$\frac{5.71}{b + 6.32d} = 0.54$$

or

$$b = 10.58 - 6.32d. \quad (c)$$

Substituting this into Eq. (b) yields

$$(10.58 - 6.32d)d + 3d^2 = 5.71$$

$$-3.32d^2 + 10.58d - 5.71 = 0.00.$$

This is a quadratic equation of the form

$$ax^2 + bx + c = 0,$$

which has as a solution

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Therefore

$$d = \frac{-10.58 \pm \sqrt{10.58^2 - 4(-3.32)(-5.71)}}{2(-3.32)}$$

$$d = \frac{-10.58 + 6.00}{-6.64} = 2.50; 0.69.$$

Table 4.2 Limiting Velocities and Tractive Forces for Open Channels (Straight after Aging)^a

| Material | n | Water transporting colloidal silts | | | |
|--|-------|------------------------------------|----------------------|----------------|----------------------|
| | | For Clear Water | Tractive force (psf) | Velocity (fps) | Tractive force (psf) |
| Fine sand colloidal | 0.020 | 1.50 | 0.027 | 2.50 | 0.075 |
| Sandy loam noncolloidal | 0.020 | 1.75 | 0.037 | 2.50 | 0.075 |
| Silt loam noncolloidal | 0.020 | 2.00 | 0.048 | 3.00 | 0.110 |
| Alluvial silts noncolloidal | 0.020 | 2.00 | 0.048 | 3.50 | 0.150 |
| Ordinary firm loam | 0.020 | 2.50 | 0.075 | 3.50 | 0.150 |
| Volcanic ash | 0.020 | 2.50 | 0.075 | 3.50 | 0.150 |
| Stiff clay very colloidal | 0.025 | 3.75 | 0.260 | 5.00 | 0.460 |
| Alluvial silts colloidal | 0.025 | 3.75 | 0.260 | 5.00 | 0.460 |
| Shales and hardpans | 0.025 | 6.00 | 0.670 | 6.00 | 0.670 |
| Fine gravel | 0.020 | 2.50 | 0.075 | 5.00 | 0.320 |
| Graded loam to cobbles when noncolloidal | 0.030 | 3.75 | 0.380 | 5.00 | 0.660 |
| Graded silts to cobbles when colloidal | 0.030 | 4.00 | 0.430 | 5.50 | 0.800 |
| Coarse gravel noncolloidal | 0.025 | 4.00 | 0.300 | 6.00 | 0.670 |
| Cobbles and shingles | 0.035 | 5.00 | 0.910 | 5.50 | 1.100 |

^aFrom Lane (1955).

If $d = 2.50$, then from Eq. (c) we get

$$b = 10.58 - 6.32(2.50) = -5.22,$$

which is clearly not possible. If $d = 0.69$, we get

$$b = 10.58 - 6.32(0.69) = 6.22.$$

Therefore the channel dimensions must be

$$b = 6.22 \text{ ft}, \quad d = 0.69 \text{ ft}, \quad z = 3.0.$$

Check:

$$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = \frac{6.22(0.69) + 3(0.69)^2}{6.22 + 2(0.69)\sqrt{10}} = 0.54$$

$$v = \frac{1.49}{n} R^{2/3} S^{1/2} = \frac{1.49}{0.02} (0.54)^{2/3} (0.005)^{1/2} = 3.5.$$

The velocity is OK.

$$A = bd + zd^2 = 6.22(0.69) + 3(0.69)^2 = 5.72$$

$$Q = vA = 3.50(5.72) = 20.00.$$

The capacity is OK.

Church Rock Erosion and Sedimentation
 North Channel Berm, PMF Flow Calculation for Riprap Sizing

Duration (hrs) 0.25
 Flow Length (mi) 0.01159
 Basin Area (sq. mi) 0.00022
 Basin Vertical (ft) 15.7
 Curve Number 80
 1-hr rainfall (in) 8.42
 tc (hr) 0.01
 Adjusted tc 0.01
 tl (hrs) 0.0031
 tp 0.13
 base 0.34
 qp 0.8310

| t (hrs) | V/tp | q/qp | Incremental Rainfall (inches) | | | Total |
|---------|-------|------|-------------------------------|----------|----------|-------|
| | | | 0.2528 | 1.279493 | 3.794322 | |
| 0 | 0 | 0.00 | 0.00 | | | 0.00 |
| 0.01 | 0.078 | 0.06 | 0.02 | | | 0.02 |
| 0.02 | 0.156 | 0.13 | 0.03 | | | 0.03 |
| 0.03 | 0.234 | 0.19 | 0.05 | | | 0.05 |
| 0.04 | 0.312 | 0.26 | 0.07 | | | 0.07 |
| 0.05 | 0.390 | 0.32 | 0.08 | | | 0.08 |
| 0.06 | 0.468 | 0.39 | 0.10 | | | 0.10 |
| 0.07 | 0.546 | 0.45 | 0.11 | | | 0.11 |
| 0.08 | 0.624 | 0.52 | 0.13 | | | 0.13 |
| 0.09 | 0.702 | 0.58 | 0.15 | | | 0.15 |
| 0.1 | 0.780 | 0.65 | 0.16 | | | 0.16 |
| 0.11 | 0.859 | 0.71 | 0.18 | | | 0.18 |
| 0.12 | 0.937 | 0.78 | 0.20 | | | 0.20 |
| 0.13 | 1.015 | 0.84 | 0.21 | | | 0.21 |
| 0.14 | 1.093 | 0.80 | 0.20 | | | 0.20 |
| 0.15 | 1.171 | 0.77 | 0.19 | | | 0.19 |
| 0.16 | 1.249 | 0.73 | 0.18 | | | 0.18 |
| 0.17 | 1.327 | 0.69 | 0.17 | | | 0.17 |
| 0.18 | 1.405 | 0.65 | 0.16 | | | 0.16 |
| 0.19 | 1.483 | 0.61 | 0.15 | | | 0.15 |
| 0.2 | 1.561 | 0.57 | 0.14 | | | 0.14 |
| 0.21 | 1.639 | 0.53 | 0.13 | | | 0.13 |
| 0.22 | 1.717 | 0.49 | 0.12 | | | 0.12 |
| 0.23 | 1.795 | 0.45 | 0.11 | | | 0.11 |
| 0.24 | 1.873 | 0.42 | 0.11 | | | 0.11 |
| 0.25 | 1.951 | 0.38 | 0.10 | 0.00 | | 0.10 |
| 0.26 | 2.029 | 0.34 | 0.09 | 0.08 | | 0.17 |
| 0.27 | 2.107 | 0.30 | 0.08 | 0.17 | | 0.24 |
| 0.28 | 2.185 | 0.26 | 0.07 | 0.25 | | 0.31 |
| 0.29 | 2.263 | 0.22 | 0.06 | 0.33 | | 0.39 |
| 0.3 | 2.341 | 0.18 | 0.05 | 0.41 | | 0.46 |
| 0.31 | 2.419 | 0.14 | 0.04 | 0.50 | | 0.53 |
| 0.32 | 2.497 | 0.11 | 0.03 | 0.58 | | 0.61 |
| 0.33 | 2.576 | 0.07 | 0.02 | 0.66 | | 0.68 |
| 0.34 | 2.654 | 0.03 | 0.01 | 0.75 | | 0.75 |
| 0.35 | 2.732 | | 0.00 | 0.83 | | 0.83 |
| 0.36 | 2.810 | | 0.00 | 0.91 | | 0.91 |
| 0.37 | 2.888 | | 0.00 | 1.00 | | 1.00 |
| 0.38 | 2.966 | | 0.00 | 1.08 | | 1.08 |
| 0.39 | 3.044 | | 0.00 | 1.03 | | 1.03 |
| 0.4 | 3.122 | | 0.00 | 0.98 | | 0.98 |
| 0.41 | 3.200 | | 0.00 | 0.93 | | 0.93 |
| 0.42 | 3.278 | | 0.00 | 0.88 | | 0.88 |
| 0.43 | 3.356 | | 0.00 | 0.83 | | 0.83 |
| 0.44 | 3.434 | | 0.00 | 0.78 | | 0.78 |
| 0.45 | 3.512 | | 0.00 | 0.73 | | 0.73 |
| 0.46 | 3.590 | | 0.00 | 0.68 | | 0.68 |
| 0.47 | 3.668 | | 0.00 | 0.63 | | 0.63 |
| 0.48 | 3.746 | | 0.00 | 0.58 | | 0.58 |
| 0.49 | 3.824 | | 0.00 | 0.53 | | 0.53 |
| 0.5 | 3.902 | | 0.00 | 0.48 | 0.00 | 0.48 |
| 0.51 | 3.980 | | 0.00 | 0.43 | 0.25 | 0.68 |
| 0.52 | 4.058 | | 0.00 | 0.38 | 0.49 | 0.88 |
| 0.53 | 4.136 | | 0.00 | 0.33 | 0.74 | 1.07 |
| 0.54 | 4.215 | | 0.00 | 0.28 | 0.98 | 1.27 |
| 0.55 | 4.293 | | 0.00 | 0.23 | 1.23 | 1.46 |
| 0.56 | 4.371 | | 0.00 | 0.18 | 1.48 | 1.66 |
| 0.57 | 4.449 | | 0.00 | 0.13 | 1.72 | 1.86 |
| 0.58 | 4.527 | | 0.00 | 0.08 | 1.97 | 2.05 |
| 0.59 | 4.605 | | 0.00 | 0.04 | 2.21 | 2.25 |
| 0.6 | 4.683 | | 0.00 | 0.00 | 2.46 | 2.46 |
| 0.61 | 4.761 | | 0.00 | 0.00 | 2.71 | 2.71 |
| 0.62 | 4.839 | | 0.00 | 0.00 | 2.95 | 2.95 |

| | | | | | | |
|------|-------|------|------|------|------|------|
| 0.63 | 4.917 | 0.00 | 0.00 | 3.20 | 3.20 | 3.05 |
| 0.64 | 4.995 | 0.00 | 0.00 | 3.05 | 3.05 | 2.90 |
| 0.65 | 5.073 | 0.00 | 0.00 | 2.90 | 2.90 | 2.76 |
| 0.66 | 5.151 | 0.00 | 0.00 | 2.76 | 2.76 | 2.61 |
| 0.67 | 5.229 | 0.00 | 0.00 | 2.61 | 2.61 | 2.46 |
| 0.68 | | 0.00 | 0.00 | 2.46 | 2.46 | 2.32 |
| 0.69 | | 0.00 | 0.00 | 2.32 | 2.32 | 2.17 |
| 0.7 | | 0.00 | 0.00 | 2.17 | 2.17 | 2.02 |
| 0.71 | | 0.00 | 0.00 | 2.02 | 2.02 | 1.87 |
| 0.72 | | 0.00 | 0.00 | 1.87 | 1.87 | 1.73 |
| 0.73 | | 0.00 | 0.00 | 1.73 | 1.73 | 1.58 |
| 0.74 | | 0.00 | 0.00 | 1.58 | 1.58 | 1.43 |
| 0.75 | | 0.00 | 0.00 | 1.43 | 0.00 | 1.43 |
| 0.76 | | 0.00 | 0.00 | 1.28 | 0.14 | 1.43 |
| 0.77 | | 0.00 | 0.00 | 1.14 | 0.29 | 1.42 |
| 0.78 | | 0.00 | 0.00 | 0.99 | 0.43 | 1.42 |
| 0.79 | | 0.00 | 0.00 | 0.84 | 0.58 | 1.42 |
| 0.8 | | 0.00 | 0.00 | 0.69 | 0.72 | 1.42 |
| 0.81 | | 0.00 | 0.00 | 0.55 | 0.87 | 1.41 |
| 0.82 | | 0.00 | 0.00 | 0.40 | 1.01 | 1.41 |
| 0.83 | | 0.00 | 0.00 | 0.25 | 1.15 | 1.41 |
| 0.84 | | 0.00 | 0.00 | 0.10 | 1.30 | 1.40 |
| 0.85 | | 0.00 | 0.00 | 0.00 | 1.44 | 1.44 |
| 0.86 | | 0.00 | 0.00 | 0.00 | 1.59 | 1.59 |
| 0.87 | | 0.00 | 0.00 | 0.00 | 1.73 | 1.73 |
| 0.88 | | 0.00 | 0.00 | 0.00 | 1.88 | 1.88 |
| 0.89 | | 0.00 | 0.00 | 0.00 | 1.79 | 1.79 |
| 0.9 | | 0.00 | 0.00 | 0.00 | 1.70 | 1.70 |
| 0.91 | | 0.00 | 0.00 | 0.00 | 1.62 | 1.62 |
| 0.92 | | 0.00 | 0.00 | 0.00 | 1.53 | 1.53 |
| 0.93 | | 0.00 | 0.00 | 0.00 | 1.44 | 1.44 |
| 0.94 | | 0.00 | 0.00 | 0.00 | 1.36 | 1.36 |
| 0.95 | | 0.00 | 0.00 | 0.00 | 1.27 | 1.27 |
| 0.96 | | 0.00 | 0.00 | 0.00 | 1.19 | 1.19 |
| 0.97 | | 0.00 | 0.00 | 0.00 | 1.10 | 1.10 |
| 0.98 | | 0.00 | 0.00 | 0.00 | 1.01 | 1.01 |
| 0.99 | | 0.00 | 0.00 | 0.00 | 0.93 | 0.93 |
| 1 | | 0.00 | 0.00 | 0.00 | 0.84 | 0.84 |
| 1.01 | | 0.00 | 0.00 | 0.00 | 0.75 | 0.75 |
| 1.02 | | 0.00 | 0.00 | 0.00 | 0.67 | 0.67 |
| 1.03 | | 0.00 | 0.00 | 0.00 | 0.58 | 0.58 |
| 1.04 | | 0.00 | 0.00 | 0.00 | 0.49 | 0.49 |
| 1.05 | | 0.00 | 0.00 | 0.00 | 0.41 | 0.41 |
| 1.06 | | 0.00 | 0.00 | 0.00 | 0.32 | 0.32 |
| 1.07 | | 0.00 | 0.00 | 0.00 | 0.23 | 0.23 |
| 1.08 | | 0.00 | 0.00 | 0.00 | 0.15 | 0.15 |
| 1.09 | | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 |
| 1.1 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.11 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.12 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.13 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.14 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.15 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.16 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.17 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.18 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.19 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.2 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.21 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.22 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.23 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.24 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.25 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.26 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.27 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.28 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.29 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.3 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.31 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.32 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.33 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.34 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.35 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.36 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.37 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.38 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.39 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.4 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.41 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.42 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Appendix C



MWH

APPENDIX C

COST CALCULATIONS

MWH

Project: UNC Church Rock, Erosion and Sedimentation
 Description: Berm Sizing Calculations
 Prepared By: J. Thompson
 Date: 11 Oct 2004

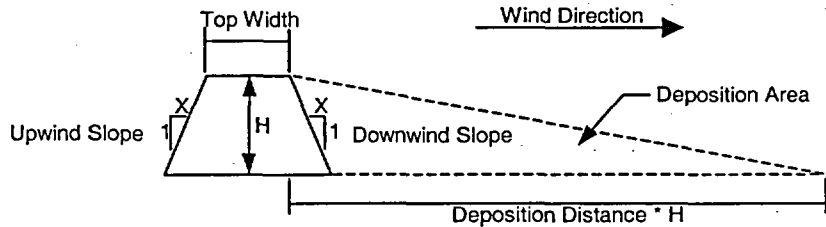
Description: Design a berm to form a sediment trap for wind blown particulates to prevent eolian deposition in the diversion channels on the Church Rock Tailings Impoundment. Size berm for varying numbers of years between cleanout for bonding calculation comparison of costs.

Sources of Data: Eolian erosion deposition rate based on field survey conducted by M. Ross. Deposition geometry based on USACOE Coastal Engineering Manual - Part III, Chapter 4 (EM 1110-2-1100 ,2002)

Assumptions: Effective deposition area has a triangular shape and extends to a distance 5 times the height downwind of the berm. Maximum deposition distance is 10 times the berm height in the downwind direction. Approximate locations of swales are shown in the attached figure.

Calculations:

Berm Geometry
 Top Width 0 ft
 Upwind Slope 1 :1
 Downwind Slope 1 :1
 Deposition Distance: 5 ft
 Berm Offset: 10 ft from downwind toe to crest of swale
 Deposition Rates: Length:
 Swale C 0.46 ft³/ft 600 ft
 Swale D 0.27 ft³/ft 500 ft
 Swale E 1.78 ft³/ft 1000 ft



| STORAGE VOLUMES AND MAINTENANCE FREQUENCY | | | | | | |
|---|---------------------------------|---------------------------------------|------------------|----------------------------|---------|---------|
| Berm Height (ft) | Berm Vol. (ft ³ /ft) | Deposition Vol. (ft ³ /ft) | Berm Offset (ft) | Maintenance Period (years) | | |
| | | | | Swale C | Swale D | Swale E |
| 1.0 | 1 | 2 | 10 | 4.4 | 36.7 | 2.5 |
| 1.5 | 2 | 5 | 15 | 9.9 | 55.1 | 5.6 |
| 2.0 | 4 | 8 | 20 | 17.6 | 73.5 | 9.9 |
| 2.5 | 6 | 13 | 25 | 27.4 | 91.8 | 15.4 |
| 3.0 | 9 | 18 | 30 | 39.5 | 110.2 | 22.2 |
| 3.5 | 12 | 25 | 35 | 53.8 | 128.6 | 30.3 |
| 4.0 | 16 | 32 | 40 | 70.2 | 146.9 | 39.5 |
| 4.5 | 20 | 41 | 45 | 88.9 | 165.3 | 50.0 |
| 5.0 | 25 | 50 | 50 | 109.8 | 183.7 | 61.7 |
| 5.5 | 30 | 61 | 55 | 132.8 | 202.0 | 74.7 |
| 6.0 | 36 | 72 | 60 | 158.0 | 220.4 | 88.9 |
| 6.5 | 42 | 85 | 65 | 185.5 | 238.8 | 104.3 |
| 7.0 | 49 | 98 | 70 | 215.1 | 257.1 | 121.0 |

MWH

Project: UNC Church Rock, Erosion and Sedimentation

Description: Berm Sizing Calculations

Prepared By: J. Thompson

Date: 11 Oct 2004

| BERM CONSTRUCTION COST | | | |
|------------------------|---------|-------|-------------------------|
| Item | Cost | Units | Source |
| Rock Delivered to Site | \$20 | cy | Estimated |
| Spread Material | \$1.52 | cy | Bulldozer, Means pg. 57 |
| Total Cost per CY | \$21.52 | cy | Calculated |

| ESTIMATED BERM MATERIAL COST | | | | |
|------------------------------|-----------------------|----------------|----------|----------|
| Berm Height (ft) | Berm Vol. (ft3/ft) | Materials Cost | | |
| | | Swale C | Swale D | Swale E |
| 1.0 | 1 | \$478 | \$399 | \$797 |
| 1.5 | 2 | \$1,076 | \$897 | \$1,793 |
| 2.0 | 4 | \$1,913 | \$1,594 | \$3,188 |
| 2.5 | 6 | \$2,989 | \$2,491 | \$4,981 |
| 3.0 | 9 | \$4,304 | \$3,587 | \$7,173 |
| 3.5 | 12 | \$5,858 | \$4,882 | \$9,764 |
| 4.0 | 16 | \$7,652 | \$6,376 | \$12,753 |
| 4.5 | 20 | \$9,684 | \$8,070 | \$16,140 |
| 5.0 | 25 | \$11,956 | \$9,963 | \$19,926 |
| 5.5 | 30 | \$14,466 | \$12,055 | \$24,110 |
| 6.0 | 36 | \$17,216 | \$14,347 | \$28,693 |
| 6.5 | 42 | \$20,205 | \$16,837 | \$33,675 |
| 7.0 | 49 | \$23,433 | \$19,527 | \$39,055 |

MWH

Project: UNC Church Rock, Erosion and Sedimentation
 Description: Bonding Calculations
 Prepared By: J. Thompson
 Date: 11 Oct 2004

| BONDING CALCULATIONS | | | | | | | | | | |
|--|-----------|-----------|--------------|-----------|-----------|-----------|----------|----------|----------|----------|
| SEDIMENT REMOVAL UNIT RATE | | | | | | | | | | |
| Load truck 3CY Bucket | \$8.40 | per C.Y. | Means pg. 49 | | | | | | | |
| Haul, using a 6CY truck, 1 Mile | 5.25 | per C.Y. | Means pg. 56 | | | | | | | |
| Unit weight of sediment | 110 | pcf | | | | | | | | |
| Load truck 3CY Bucket | \$5.66 | per ton | Calculated | | | | | | | |
| Haul, using a 6CY truck, 1 Mile | \$3.54 | per ton | Calculated | | | | | | | |
| Total Unit Rate per Ton | \$9.19 | per ton | Calculated | | | | | | | |
| BOND COST | | | | | | | | | | |
| Sediment Accumulation | | | | | | | | | | |
| Swale C | 15 | tons/yr | | | | | | | | |
| Swale D | 7 | tons/yr | | | | | | | | |
| Swale E | 98 | tons/yr | | | | | | | | |
| Sediment Removal Unit Rate | \$9.19 | /ton | | | | | | | | |
| Mob/demob | \$1,000 | ea | | | | | | | | |
| Maintenance Report Preparation | \$2,000 | ea | | | | | | | | |
| Design Period | 1000 | yrs | | | | | | | | |
| Real rate of return (i) | 1 | % | | | | | | | | |
| Maintenance Frequency (yrs, n) | 5 | 10 | 15 | 20 | 25 | 30 | 40 | 45 | 50 | 60 |
| Number of Maintenance Events | 200 | 100 | 67 | 50 | 40 | 34 | 25 | 23 | 20 | 17 |
| $(1/(1+i)^n)$ Factor | 0.951 | 0.905 | 0.861 | 0.820 | 0.780 | 0.742 | 0.672 | 0.639 | 0.608 | 0.550 |
| Tons of Sediment to be Removed | | | | | | | | | | |
| Swale C | 75 | 150 | 226 | 301 | 376 | 451 | 601 | 677 | 752 | 902 |
| Swale D | 37 | 75 | 112 | 150 | 187 | 225 | 299 | 337 | 374 | 449 |
| Swale E | 489 | 978 | 1467 | 1956 | 2444 | 2933 | 3911 | 4400 | 4889 | 5867 |
| Maintenance Cost/Event (current value) | | | | | | | | | | |
| Swale C | \$691 | \$1,382 | \$2,073 | \$2,764 | \$3,455 | \$4,146 | \$5,527 | \$6,218 | \$6,909 | \$8,291 |
| Swale D | \$344 | \$688 | \$1,032 | \$1,376 | \$1,720 | \$2,064 | \$2,752 | \$3,097 | \$3,441 | \$4,129 |
| Swale E | \$4,494 | \$8,988 | \$13,481 | \$17,975 | \$22,469 | \$26,963 | \$35,951 | \$40,444 | \$44,938 | \$53,926 |
| Mobilization and Reporting | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 | \$3,000 |
| Bond Cost | | | | | | | | | | |
| Swale C | \$13,545 | \$13,208 | \$12,877 | \$12,551 | \$12,232 | \$11,918 | \$11,307 | \$11,010 | \$10,718 | \$10,152 |
| Swale D | \$6,745 | \$6,577 | \$6,412 | \$6,250 | \$6,091 | \$5,935 | \$5,630 | \$5,482 | \$5,337 | \$5,055 |
| Swale E | \$88,097 | \$85,906 | \$83,752 | \$81,635 | \$79,556 | \$77,513 | \$73,539 | \$71,607 | \$69,712 | \$66,029 |
| Mobilization and Reporting | \$58,812 | \$28,675 | \$18,637 | \$13,625 | \$10,622 | \$8,624 | \$6,137 | \$5,312 | \$4,654 | \$3,673 |
| Total Bond Cost | \$167,199 | \$134,366 | \$121,678 | \$114,062 | \$108,501 | \$103,990 | \$96,613 | \$93,411 | \$90,421 | \$84,910 |

MWH

Project: UNC Church Rock, Erosion and Sedimentation

Description: Bonding Calculations

Prepared By: J. Thompson

Date: 11 Oct 2004

| BONDING COST WITH VARYING MAINTENANCE FREQUENCY BY SWALE | | | | | | | | | | |
|--|-----------------------------|----------|----------|--------------|-----------|---------|----------|----------|-----------|------------|
| Optimization Alternatives | Maintenance Freq./ Berm Ht. | | | Capital Cost | Bond Cost | | | | | Total Cost |
| | Swale C | Swale D | Swale E | | Swale C | Swale D | Swale E | Mob/Rept | Total | |
| Preferred Maintenance Freq./Berm Ht. | 30 / 3.0 | 45 / 1.5 | 15 / 2.5 | \$10,182 | \$11,918 | \$5,482 | \$83,752 | \$18,637 | \$119,789 | \$129,971 |
| Notes: Maintenance frequency is in years and berm height is in feet | | | | | | | | | | |

MWH

Project: UNC Church Rock, Erosion and Sedimentation

Description: Berm Sizing Calculations

Prepared By: B. Adams

Date 19 Jul 2004

| JETTY MAINTENANCE BOND CALCULATION | | | |
|---|------------|----------|---------------------|
| Berm Maintenance Cost¹ | | | |
| Hrs per Day | 8 | | Assumed |
| Work Duration | 1 | days | Assumed |
| Skidsteer Crew Cost | \$73.67 | per hr. | Means pg. 547 |
| 2 Laborers Unit Rate | \$52.00 | per hr. | Means pg. 547 |
| Total Unit Rate | \$125.67 | per hr. | Calculated |
| Herbicide Application | \$400.00 | ea. | Assumed |
| Jetty Repair Total | \$1,405.36 | per year | |
| Required Bond Investment | | | |
| Design Period (yrs) | | | 1000 |
| Maintenance Period (yrs) | | | 1 |
| Number of Maintenance Episodes | | | 1000 |
| Real rate of return (percent) | | | 1 |
| (1+i) ⁿ Factor | | | 20,959.16 |
| Bond Cost | | | \$140,529.29 |
| Notes: | | | |
| 1) Assumes work is done using 1 skidsteer and 2 laborers, in an 8 hr days | | | |