# Umetco Minerals Corporation

P.O. BOX 1029
GRAND JUNCTION, COLORADO 81502
☎ (970) 245-3700

December 21, 2010

Mr. Dominic Orlando, Project Manager
U.S. Nuclear Regulatory Commission
Fuel Cycle Facilities Branch
Division of Fuel Cycle Safety and Safeguards
Office of Nuclear Material Safety and Safeguards
Mail Stop T-8-A-33
Two White Flint North, 11545 Rockville Pike
Rockville, Maryland 20852-2738

Subject: **Above Grade Tailings Impoundment and A-9 Repository Erosion Protection Enhancement Design Report**

Reference: **License SUA-648, Docket No. 40-0299**

Dear Mr. Orlando:

Attached please find two copies of the report titled Above Grade Tailings Impoundment and A-9 Repository Erosion Protection Enhancement Design Report.

As previously discussed with NRC staff, this design has been prepared to address erosion protection issues on the Above Grade Tailings Impoundment and A-9 Repository. Accordingly, Umetco is requesting approval of the design as we would like to construct the proposed erosion protection enhancements during the spring and summer of 2011.

For surety purposes, the estimated costs associated with the enhancement design is included in the design report.

If you, or your staff, have any questions, please contact me at 970-256-8889 or by e-mail at gieckte@dow.com.

Regards,

Thomas E. Gieck
Remediation Leader

TEG/jfc
Attachments: As stated

cc: Mark Moxley – WDEQ, w/attachments

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NMSS01

# GAS HILLS RECLAMATION PROJECT

# ABOVE GRADE TAILINGS IMPOUNDMENT
# AND A-9 REPOSITORY
# EROSION PROTECTION ENHANCEMENT
# DESIGN REPORT

UMETCO MINERALS CORPORATION
GAS HILLS URANIUM TAILINGS SITE SUA-648
GAS HILLS, WYOMING
DECEMBER 20, 2010

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## 1.0 Introduction

Monitoring and inspection activities performed by Umetco Minerals Corporation (Umetco) on the Above-Grade Tailings Impoundment (AGTI) and A-9 Repository (A-9) Reclamation Covers have identified isolated areas of concern associated with the erosion protection layer resulting from a design error. This issue has been previously communicated to the NRC and observed with NRC staff in the field.

While this issue has resulted in shallow incision of the underlying cover soils in isolated locations, there has been no release of tailings or degradation of the radon attenuation capacities of the completed reclamation covers.

Accordingly, this submittal provides an evaluation of the erosion protection design which identifies the design deficiency and provides an enhanced design to correct this deficiency.

### 1.1 History of Above-Grade Tailings Impoundment Plan Approval

Umetco submitted a reclamation plan for the AGTI area of the site in 1980 (D'Appolonia, 1980). During the mid-1990s, the existing reclamation plan was reevaluated to address potential erosion of the cover design, NRC's position on previously approved reclamation designs, as well as additional contamination identified adjacent to the existing cover in the area. Umetco submitted an enhanced reclamation plan for the AGTI area on October 6, 1997 that involved: (1) extending the existing radon barrier to address the additional contamination; (2) regrading areas of the impoundment; (3) installing a 137.16-cm (54-inch) frost protection layer; and (4) installing riprap erosion protection (Shepherd Miller, 1997). The NRC approved this enhanced plan in 1999. In 2000, Umetco submitted a request for approval for modification of the erosion protection design to prevent potential disturbance of cultural resources discovered during reclamation activities. The enhanced design modification was approved by NRC in April 2001. Work in this area was completed in 2002.

### 1.2 History of A-9 Repository Plan Approval

The A-9 is a former open pit uranium mine that was used for tailings disposal. The original reclamation plan was previously approved by the NRC, but the cover was never constructed. Umetco submitted a revised reclamation plan in 1998 to implement modifications to the A-9 (Shepherd Miller, 1998). The NRC approved the revised reclamation plan in 1999. This approval allowed for the North and South Evaporation Pond liners to be placed in the A-9 and for the slopes of the North and South Evaporation Ponds to be regraded. The A-9 reclamation cover includes a 45.72-cm (18-inch) thick radon barrier, 137.16-cm (54-inch) thick frost protection layer and an erosion protection layer. Work in this area was completed in 2006.

### 1.3 Construction Completion Approval

On June 29, 2007, Umetco submitted the Construction Completion Report documenting the completed construction activities at the site inclusive of the AGTI and A-9 reclamation covers. The Construction Completion Report was subsequently approved by License Amendment 60, dated September 8, 2008.

## 2.0 Erosion Protection – Areas of Concern

The areas of concern, discussed herein, were first identified by Umetco during routine field inspections. Subsequent field investigations and review of approved design documents have identified the associated cause of the sub-grade erosion as a design error. The design error is associated with utilization of inappropriate interstitial velocity for inclusion of a filter or bedding layer in the erosion protection design.

Umetco has completed a review of approved designs associated with all reclamation cover systems constructed at the site to ensure the design deficiency is confined to AGTI and A-9 and that other potential contributing factors are adequately addressed.

### 2.1 Above-Grade Tailings Impoundment

This section details the areas of concern and cause associated with erosion protection of the AGTI reclamation cover.

#### 2.1.1 AGTI Areas of Concern and Cause

The areas of concern associated with the AGTI reclamation cover are:

- Type C ($D_{50}$ = 6 inches) Erosion Protection – located on the lower portions of the northern and eastern reclamation cover slopes.
- Launched Rock – located at the bottom of the eastern slope of the reclamation cover.
- Off-Cover Erosion – occurring on the southeast corner of the repository.

Type C ($D_{50}$ = 6 inches) Erosion Protection

Umetco field inspections identified areas of soil cover erosion beneath the riprap layer on the eastern and northeastern sides of the reclamation cover on those areas with Type C erosion protection material. These locations are also located in areas which receive substantial upland flow and are susceptible to large amounts of drifting snow during the winter months. The Type C erosion protection for the AGTI consists of a single layer of riprap with a minimum layer thickness of 12 inches.

Field investigations of these areas, conducted by Umetco, concluded that cover soil erosion beneath the riprap layer are caused by concentrated interstitial flows at the interface of the erosion protection layer and cover soil sub-grade. The erosion features typically extend about 200 feet and become stable at the downstream end due to filling of the riprap void space with sediment. The geometry of the erosion features is such that the bottoms of the incisions are perpendicular to the slope for the entire length of the incision and typically about 0.5 feet in depth.

Review of the AGTI (Shepherd Miller, 1997) design indicates appropriate and conservative methods were used to determine the size of rock for the Type C erosion protection. The design error is associated with the evaluation of the filter blanket. The Design Report evaluated the need for a filter blanket by calculating interstitial flow velocity which is an acceptable and recommended procedure established in NUREG 4620. While NUREG 4620 provides guidance on calculation of interstitial velocities it does not provide an acceptable velocity at which the sub-grade layer is erosionally stable. The Design Report utilized criteria presented in NRC STP (pp A1-A20, August 1990) to determine an adjusted permissible velocity of 2.5 feet per second. Computation of the permissible interstitial velocity in this manner has resulted in unacceptable performance of the erosion protection layer at the locations noted. At about the same time as the design was approved, the NRC published draft guidance regarding adequate interstitial velocities in NUREG 1623 (Draft guidance, February 1999). This guidance states:

> *"When the computed interstitial velocity is less than 0.5 feet per second, a filter may not be needed. When velocities are between 0.5 and 1.0 feet per second, the need for a filter layer will be dependent upon the type of soil material placed at the interface. A filter should be provided when velocities are 1.0 feet per second or greater."*

The calculated interstitial velocities for the problematic Type C area of the AGTI vary between 0.6 and 0.7 feet per second. Accordingly the guidance provided by NUREG 1623 is very applicable to this site, weather conditions, and cover soils.

Another contributing factor associated with the rill formation is believed to be drifting of snow in these specific areas which tend to concentrate flows. During the winter months drifting snow fills void spaces in these areas, once the drifts begin to melt and the cover receives additional precipitation interstitial flows are diverted around and concentrated around the perimeter of the frozen drifts.

It should also be noted that there are several isolated areas within the problematic areas in which the riprap void spaces are filled with finer fraction material which is a typical artifact of the placement process. Where this condition is present there is no erosion of subsurface soils and up-slope rills are diverted around these areas, i.e., void space is filled and interstitial velocities are slowed.

There is an area within the Type C erosion protection where the slope gradient approaches 5(H) to 1(V), which is also the steepest slope on the AGTI reclamation cover. In this area a field decision was made to place a 3-inch thick layer of filter material. Inspection of this area shows no signs of sub-grade erosion which is a further indication of the design error associated with the Type C erosion protection.

<u>Launched Rock</u>

The launched rock located at the eastern toe of the AGTI repository cover was designed to address potential scour and head cut of East Canyon Creek under PMF conditions. Field inspections of the launched rock apron indicate that interstitial velocities through the Type C erosion protection immediately upgradient of the launched rock are causing sub-grade soil erosion. As with the Type C erosion protection the cause of this sub-grade soil erosion is the lack of filter material at the erosion protection sub-grade interface to slow interstitial velocities.

<u>Off-Cover Erosion</u>

An area located adjacent to the toe of the reclamation cover on the southeast corner of the cover is exhibiting incision formation caused by off-cover surface flows and drainage of the buried apron.

### 2.1.2 Evaluation of Hydrology and Erosion Protection Design

To ensure the cause of the sub-grade erosion was appropriately identified and to verify the adequacy of the erosion protection design a detailed evaluation of the designed/placed erosion protection layer was completed. This evaluation was based on current criteria found in NUREG-1623.

Evaluation of the AGTI erosion protection design was completed by identification of three critical hydraulic profiles, as shown on Drawing 2 of 8, which pass through the areas of concern associated with the Type C erosion protection. The approved PMP (one-hour thunderstorm) of 8.7 inches was used for this evaluation. Calculation of rock size was completed using the Safety Factors Method for slopes less then 10%; Stephenson Method for slopes greater then 10%; for slopes at or near 10% both Safety Factors and Stephenson Methods are shown; and for all slope segments the Abt and Johnson Method.

Results of this evaluation demonstrate that the rock size of the AGTI erosion protection layer is appropriate and conservative. The interstitial velocities for the upper slopes of the reclamation cap covered with Type A ($D_{50}$ = 0.5 inches) and Type B ($D_{50}$ = 3 inches) erosion protection are less than the 0.5 feet per second criteria established in NUREG 1623. In addition, there is no visual evidence of cover degradation or sub-grade erosion on the upper repository slopes where interstitial velocities are less then 0.5 feet per second.

The rock size for the lower portions of the AGTI slopes covered with Type C ($D_{50}$ = 6 inches) erosion protection is also conservative, however the interstitial velocities associated with this larger erosion protection material for the most part exceed the 0.5 feet per second criteria causing isolated areas of erosion at the sub-grade erosion protection layer interface.

A summary of the erosion protection evaluation is shown on Table 2.0.

## Table 2.0
## Above-Grade Tailings Impoundment Reclamation Cover - Summary of Erosion Protection Evaluation

| AGTI Profile 1 | Segment Elev. Diff. (ft) | Segment Length (ft) | Hydraulic Length (ft) | Segment Slope (ft/ft) | Intensity (in/hr) | Peak Flow (cfs/ft) | Riprap Size Calculation Method | Riprap $D_{50}$ | | Interstitial Velocity [1] (fps) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Calculated (inches) | In-Place (inches) | | |
| Segment 1 | 9 | 1,254 | 1,254 | 0.0072 | 28.15 | 0.81 | Safety Factors | 0.4 | 3.0 | 0.12 | Riprap Size ok, Interstitial Velocity ok |
| Segment 1 | 9 | 1,254 | 1,254 | 0.0072 | 28.15 | 0.81 | Abt and Johnson | 0.7 | 3.0 | 0.12 | |
| Segment 2 | 70 | 1,130 | 2,384 | 0.0619 | 23.01 | 1.26 | Safety Factors | 3.0 | 3.0 | 0.37 | Riprap Size ok, Interstitial Velocity ok |
| Segment 2 | 70 | 1,130 | 2,384 | 0.0619 | 23.01 | 1.26 | Abt and Johnson | 2.2 | 3.0 | 0.37 | |
| Segment 3 | 50 | 493 | 2,877 | 0.1014 | 21.36 | 1.41 | Safety Factors | 5.0 | 6.0 | 0.69 | Slope near 10% - Stephenson and Safety Factors Used. Riprap Size ok. Interstitial Velocity > 0.5 fps. |
| Segment 3 | 50 | 493 | 2,877 | 0.1014 | 21.36 | 1.41 | Abt and Johnson | 2.8 | 6.0 | 0.69 | |
| Segment 3 | 50 | 493 | 2,877 | 0.1014 | 21.36 | 1.41 | Stephenson | 2.9 | 6.0 | 0.69 | |

| AGTI Profile 2 | Segment Elev. Diff. (ft) | Segment Length (ft) | Hydraulic Length (ft) | Segment Slope (ft/ft) | Intensity (in/hr) | Peak Flow (cfs/ft) | Riprap Size Calculation Method | Riprap $D_{50}$ | | Interstitial Velocity [1] (fps) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Calculated (inches) | In-Place (inches) | | |
| Segment 1 | 3 | 246 | 246 | 0.0122 | 54.21 | 0.31 | Safety Factors | 0.3 | 0.5 | 0.06 | Riprap Size ok, Interstitial Velocity ok |
| Segment 1 | 3 | 246 | 246 | 0.0122 | 54.21 | 0.31 | Abt and Johnson | 0.5 | 0.5 | 0.06 | |
| Segment 2 | 42 | 545 | 791 | 0.0771 | 43.69 | 0.79 | Safety Factors | 2.7 | 3.0 | 0.41 | Riprap Size ok, Interstitial Velocity ok |
| Segment 2 | 42 | 545 | 791 | 0.0771 | 43.69 | 0.79 | Abt and Johnson | 1.8 | 3.0 | 0.41 | |
| Segment 3 | 70 | 907 | 1,698 | 0.0772 | 32.97 | 1.29 | Safety Factors | 3.6 | 6.0 | 0.59 | Riprap Size ok. Interstitial Velocity > 0.5 fps. |
| Segment 3 | 70 | 907 | 1,698 | 0.0772 | 32.97 | 1.29 | Abt and Johnson | 2.4 | 6.0 | 0.59 | |

| AGTI Profile 1 | Segment Elev. Diff. (ft) | Segment Length (ft) | Hydraulic Length (ft) | Segment Slope (ft/ft) | Intensity (in/hr) | Peak Flow (cfs/ft) | Riprap Size Calculation Method | Riprap $D_{50}$ | | Interstitial Velocity [1] (fps) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Calculated (inches) | In-Place (inches) | | |
| Segment 1 | 5 | 237 | 237 | 0.0211 | 57.42 | 0.31 | Safety Factors | 0.5 | 0.5 | 0.08 | Riprap Size ok, Interstitial Velocity ok |
| Segment 1 | 5 | 237 | 237 | 0.0211 | 57.42 | 0.31 | Abt and Johnson | 0.6 | 0.5 | 0.08 | |
| Segment 2 | 60 | 682 | 919 | 0.0880 | 45.06 | 0.95 | Safety Factors | 3.4 | 3.0 | 0.45 | Riprap Size ok, Interstitial Velocity ok |
| Segment 2 | 60 | 682 | 919 | 0.0880 | 45.06 | 0.95 | Abt and Johnson | 2.2 | 3.0 | 0.45 | |
| Segment 3 | 22 | 678 | 1,597 | 0.0324 | 32.70 | 1.20 | Safety Factors | 1.7 | 6.0 | 0.37 | Riprap Size ok, Interstitial Velocity ok, Area of Concentrated Flow -- Repair |
| Segment 3 | 22 | 678 | 1,597 | 0.0324 | 32.70 | 1.20 | Abt and Johnson | 1.6 | 6.0 | 0.37 | |
| Segment 4 | 23 | 410 | 2,007 | 0.0561 | 28.78 | 1.33 | Safety Factors | 2.8 | 6.0 | 0.50 | Riprap Size ok, Interstitial Velocity marginal -- Repair |
| Segment 4 | 23 | 410 | 2,007 | 0.0561 | 28.78 | 1.33 | Abt and Johnson | 2.1 | 6.0 | 0.50 | |

1) Interstitial Velocity based on the Placed/Specified $D_{50}$.

2) Abt and Johnson: $D_{50} = 5.23\, q^{0.56} S^{0.43} \times 1.20$

### 2.1.3 Geotechnical – Potential Settlement

The geotechnical stability with respect to settlement has been evaluated as a potential cause of sub-grade soil erosion beneath the Type C erosion protection. Several factors, enumerated below indicate that negligible settlement has occurred on the AGTI and is not a concern or contributing factor associated with the rill formation.

In order to verify settlement is not a contributing factor in the formation of the erosion rill features, a minimum of one test excavation will be made on the AGTI and A-9 to expose and verify the integrity of the existing radon barrier or clay layer. Test excavations will be made in the vicinity of erosion rill features identified on both structures. Additional excavations may be required if it is determined that the radon barrier layer has experienced significant settlement or has otherwise been disturbed.

The approved AGTI reclamation plan (Shepherd Miller, 1997) evaluated settlement in two parts:

- Part 1 – from end of tailing deposition to present (i.e. 1997 being present).
- Part 2 – from present (1997) to the end of settlement.
  - Approach 1 – (Predictive Model) continued analysis from Part 1 until the pore pressures that were predicted in 1997 dissipate completely.
  - Approach 2 – (Current Field Conditions and Laboratory Results) conduct a separate settlement analysis using soil properties obtained from the field investigation conducted by Shepherd Miller and consolidation data from subsequent testing by Western Engineers, Inc. (WEI).

The following table, presented in the Design Report (Table 5-6, Shepherd Miller, 1997), provides the results of this analysis.

**Table 2.1 Settlement Analysis**

| Zone | Total Settlement Based on the Model (ft) | Future Settlement Based on Model (ft) | Future Settlement Based on Current Conditions (ft) | Percentage of Total Settlement Completed: Based on Model (%) | Percentage of Total Settlement Completed: Based on Current Conditions (%) |
|---|---|---|---|---|---|
| 1 | 9.3 | 0.79 | 0.003 | 91 | 100 |
| 2 | 4.2 | 0.08 | 0.005 | 98 | 100 |
| 3 | 2.5 | 0.53 | 0.47 | 80 | 88 |
| 4 | 6.7 | 0.58 | 0.29 | 93 | 96 |

A conservative estimate (i.e., based on Approach 1 – model) of the total anticipated Future Settlement with the addition of secondary settlement is shown on the following Table 2.2 (also shown as Table 5-7, Shepherd Miller, 1997).

**Table 2.2 Future Settlement Analysis**

| Zone | Future Primary Settlement (ft) | Secondary Settlement (ft) | Total Future Settlement (ft) |
|---|---|---|---|
| 1 | 0.79 | 0.31 | 1.1 |
| 2 | 0.08 | 0.2 | 0.28 |
| 3 | 0.53 | 0.24 | 0.77 |
| 4 | 0.58 | 0.24 | 0.82 |

Based on the results of this evaluation it was determined that a flow concentration factor of 1 was appropriate for design of riprap for the top and sideslopes of the AGTI.

To evaluate settlement as a potential cause of the gully formation a survey was performed on a 100-foot grid system in the areas of concern. The 100-foot grid system is the same as-built survey grid used at the completion of cover construction. Results of this survey clearly indicate that the Approach 2 (based on current conditions) reflect the observed settlement for AGTI to date and the Approach 1 (model) represents a very conservative evaluation of anticipated settlement. As shown on Drawing 3 of 8, the actual settlement which has occurred since cover completion is very minimal.

### 2.1.4 Radon Attenuation

While there are some isolated locations of rill formation beneath the Type C erosion protection on the AGTI reclamation cover, the geometry of the rills are shallow and perpendicular to the slope. These rills, typically, appear to develop and extend for a length of approximately 200 feet and stabilize because eroded soils are deposited within the rock voids at the downstream end thus slowing or terminating interstitial velocities. The typical rill depth is about 6 inches and in no case incisions formed greater than one foot over the radon barrier. Since radon attenuation to 20 picocuries per meter squared per second (20 $pCi/m^2/s$) occurs at a much shallower depth within the cover system, based on conservative modeling, the cover system performance with respect to radon attenuation is functioning as designed.

## 2.2 A-9 Repository

This section details the areas of concern and cause associated with erosion protection of the A-9 reclamation cover.

### 2.2.1 A-9 Areas of Concern and Cause

The areas of concern associated with the A-9 reclamation cover are:

- Type C ($D_{50}$ = 6 inches) Erosion Protection – located on the southern reclamation cover slopes.

Type C ($D_{50}$ = 6 inches) Erosion Protection

Umetco field inspections identified areas of soil cover erosion beneath the riprap layer on the southern slope of the reclamation cover on those areas with Type C erosion protection material. These locations are also located in areas which receive substantial upland flow and are susceptible to large amounts of drifting snow during the winter months. The

Type C erosion protection for the A-9 consists of a single layer of riprap with a minimum layer thickness of 12 inches.

Umetco's field investigations of these areas concluded that cover soil erosion beneath the riprap layer are caused by concentrated interstitial flows at the interface of the erosion protection layer and cover soil sub-grade. The erosion incisions typically extend about 200 feet and become stable at the downstream due to filling of the riprap void space with sediment. The incisions also terminate near the lower portions of the slope where the slope flattens, i.e., interstitial velocities are reduced. The geometry of the erosion features are such that the bottom of the incisions are perpendicular to the slope for the entire length of the incision and typically about 0.5 feet in depth.

Review of the A-9 (Shepherd Miller, 1998) design indicates appropriate and conservative methods were used to determine the size of rock for the Type C erosion protection. The design error is associated with the evaluation of the filter blanket. The Design Report evaluated the need for a filter blanket by the calculating interstitial flow velocity which is an acceptable and recommended procedure established in NUREG 4620. While NUREG 4620 provides guidance on calculation of interstitial velocities it does not provide an acceptable velocity at which the sub-grade layer is erosionally stable. The Design Report utilized criteria presented in NRC STP (pp A1-A20, August 1990) to determine an adjusted permissible velocity of 2.5 feet per second. Computation of the permissible interstitial velocity in this manner has resulted in unacceptable performance of the erosion protection layer at the locations noted. At about the same time as the design was approved, the NRC published draft guidance regarding adequate interstitial velocities in NUREG 1623 (Draft guidance, February 1999). This guidance states:

> *"When the computed interstitial velocity is less than 0.5 feet per second, a filter may not be needed. When velocities are between 0.5 and 1.0 feet per second, the need for a filter layer will be dependent upon the type of soil material placed at the interface. A filter should be provided when velocities are 1.0 feet per second or greater."*

The calculated interstitial velocities for the problematic Type C area of the A-9 vary between 0.6 and 0.8 feet per second. Accordingly the guidance provided by NUREG 1623 is very applicable to this site, weather conditions, and cover soils.

Another contributing factor associated with the rill formation is believed to be drifting of snow in these specific areas which tend to concentrate flows. During the winter months drifting snow fills void spaces in these areas, once the drifts begin to melt and the cover receives additional precipitation, interstitial flows are diverted around and concentrated around the perimeter of the frozen drifts.

It should also be noted that there are several isolated areas within the problematic areas in which the riprap void spaces are filled with finer fraction material which is a typical artifact of the placement process. Where this condition is present there is no erosion of subsurface soils and up-slope gullies are diverted around these areas, i.e., void space is filled and interstitial velocities are slowed.

The southern slope of the A-9 flattens near the toe. At this location interstitial velocities slow to 0.54 feet per second and sub-grade incisions abruptly terminate indicating that the

0.5 feet per second criteria found in NUREG 1623 is very applicable to this site and the cover soils found at the riprap cover interface.

### 2.2.2 Evaluation of Hydrology and Erosion Protection Design

To ensure the cause of the sub-grade erosion was appropriately identified and to verify the adequacy of the erosion protection design, a detailed analysis of the designed/placed erosion protection layer was performed. This evaluation is based on the current criteria found in NUREG 1623.

Evaluation of the A-9 erosion protection design was completed by identification of the critical hydraulic profile, as shown on Drawing 2 of 8, which includes the area of concern located on the southern slope of the reclamation cover. The approved PMP (one-hour thunderstorm) of 8.7 inches was used for this evaluation. Calculation of rock size was performed using the Safety Factors Method for slopes less then 10%; Stephenson Method for slopes greater then 10%; for slopes at or near 10% both Safety Factors and Stephenson were utilized; and for all slope segments the Abt and Johnson Method was used, i.e., $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$.

Results of this evaluation demonstrate that the rock size of the A-9 erosion protection is appropriate and conservative. The upper two segments of the profile are located on the Heap Leach reclamation cover which does incorporate a filter bedding layer at the interface between the riprap and soil cover.

The interstitial velocity for the top slope covered with Type B ($D_{50}$ = 3 inches) of the A-9 reclamation cover is 0.24 feet per second which is well below the 0.5 feet per second criteria established in NUREG 1623. In addition, there is no visual evidence of cover degradation or sub-grade erosion on the upper repository slopes.

The rock size for the lower (southern) portion of the A-9, covered with Type C ($D_{50}$ = 6 inches) erosion protection is also conservative, however, the interstitial velocities associated with this larger erosion protection material, for the most part, exceed the 0.5 feet per second criteria causing isolated areas of shallow incision at the interface of the erosion protection and cover soil.

A summary of the erosion protection evaluation is shown on Table 2.3.

## Table 2.3
## A-9 Repository Reclamation Cover - Summary of Erosion Protection Evaluation

| A-9 Profile | Segment Elev. Diff. (ft) | Segment Length (ft) | Hydraulic Length (ft) | Segment Slope (ft/ft) | Intensity (in/hr) | Peak Flow (cfs/ft) | Riprap Size Calculation Method | Riprap $D_{50}$ Calculated (inches) | Riprap $D_{50}$ In-Place (inches) | Interstitial Velocity [1] (fps) | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment 1 | 6 | 571 | 571 | 0.0105 | 42.08 | 0.55 | Safety Factors | 0.4 | 0.5 | 0.05 | Segment on Heap Leach Reclamation Cover |
| Segment 1 | 6 | 571 | 571 | 0.0105 | 42.18 | 0.55 | Abt and Johnson | 0.6 | 0.5 | 0.05 | |
| Segment 2 | 39 | 377 | 948 | 0.1034 | 36.52 | 0.79 | Safety Factors | 3.5 | 3.0 | 0.49 | Segment on Heap Leach Reclamation Cover, Filter Layer in Place, Stephenson and Safety Factors used – slope near 10% |
| Segment 2 | 39 | 377 | 948 | 0.1034 | 36.52 | 0.79 | Abt and Johnson | 2.1 | 3.0 | 0.49 | |
| Segment 2 | 39 | 377 | 948 | 0.1034 | 36.52 | 0.79 | Stephenson | 2.0 | 3.0 | 0.49 | |
| Segment 3 | 10 | 161 | 1,109 | 0.0621 | 34.13 | 0.87 | Safety Factors | 2.3 | 6.0 | 0.53 | Riprap Size ok, Interstitial Velocity marginal |
| Segment 3 | 10 | 161 | 1,109 | 0.0621 | 34.13 | 0.87 | Abt and Johnson | 1.8 | 6.0 | 0.53 | |
| Segment 4 | 39 | 1,354 | 2,463 | 0.0288 | 23.88 | 1.35 | Safety Factors | 1.7 | 3.0 | 0.24 | Riprap Size ok, Interstitial Velocity ok |
| Segment 4 | 39 | 1,354 | 2,463 | 0.0288 | 23.88 | 1.35 | Abt and Johnson | 1.6 | 3.0 | 0.24 | |
| Segment 5 | 15 | 120 | 2,583 | 0.125 | 23.26 | 1.38 | Stephenson | 3.3 | 6.0 | 0.77 | Riprap Size ok, Interstitial Velocity unacceptable -- Repair |
| Segment 5 | 15 | 120 | 2,583 | 0.125 | 23.26 | 1.38 | Abt and Johnson | 3.1 | 6.0 | 0.77 | |
| Segment 6 | 8 | 124 | 2,707 | 0.0645 | 22.52 | 1.40 | Safety Factors | 3.3 | 6.0 | 0.54 | Riprap Size ok, Interstitial Velocity marginal -- Repair |
| Segment 6 | 8 | 124 | 2,707 | 0.0645 | 22.52 | 1.40 | Abt and Johnson | 2.3 | 6.0 | 0.54 | |

1) Interstitial Velocity based on the Placed/Specified $D_{50}$.

2) Abt and Johnson: $D_{50} = 5.23\, q^{0.56} S^{0.43} \times 1.20$

### 2.2.3 Geotechnical – Potential Settlement

The geotechnical stability with respect to settlement has been evaluated as a potential cause of shallow sub-grade soil erosion beneath the Type C erosion protection material. Several factors as discussed below conclude that the observed settlement occurring on the A-9 is as predicted with no impact on erosion protection design.

The approved A-9 reclamation plan (Shepherd Miller, 2008) settlement analysis was performed in six stages.

- Stage 1 – deposition of tailings generated by Umetco (December 1979 to December 1984).
- Stage 2 – consolidation and drainage of Umetco tailings (December 1984 to September 1987).
- Stage 3 – placement of Susquehanna tailings and interim cover (September 1987 to December 1989).
- Stage 4 – consolidation and drainage of Susquehanna tailings and Umetco tailings (December 1989 to March 1998).
- Stage 5 – placement of additional waste and reclamation cover (March 1998 to April 1998).
- Stage 6 – consolidation and drainage subsequent to reclamation cover construction (April 1998 to end of consolidation).

For the purpose of this discussion the Stage 6 or anticipated settlement post reclamation cover construction are of interest. Results of the Stage 6 analysis predicted a maximum settlement of 1.65 feet. This settlement is anticipated subsequent to the Stage 5 immediate settlement resulting from placement of additional waste and reclamation cover loading.

Long-Term settlement (maximum creep) was predicted to be 0.87 feet. The total settlement is the sum of the immediate, consolidation, and creep settlements, however, for this evaluation the Stage 5 immediate settlement of 0.2 feet is neglected because the as-built (100-foot grid) survey was performed at the conclusion of completion of the reclamation cover, i.e., immediate settlement had occurred. Accordingly, the maximum predicted post reclamation cover loading settlement is the consolidation settlement of 1.65 feet plus long-term creep of 0.87 feet or 2.52 feet.

As part of this evaluation, Umetco performed a survey on the same 100-foot grid system to ensure settlement is occurring as predicted without differential settlement which could impact the radon barrier or concentrate surface flows. Results of the survey are shown on Drawing 4 of 8 along with comparison contours to identify any differential settlement. As shown on the drawing, settlement of about 1 foot has occurred at the maximum waste thickness section located at the southern end of the repository and diminishing near the northern end. Settlement is occurring in a uniform manner and well within the predicted limits of settlement, i.e., no strain on radon barrier or concentrated flows.

As stated above, the maximum settlement is occurring at the southern end of the repository which increases the slope across the top of the repository, however, the size of the riprap placed on the top slope of the repository (Segment 4) is such that it is oversized by almost a factor of 2 at the southern (critical) end of the slope. To ensure the Type B ($D_{50}$ = 3 inches) is adequate based on worst case settlement conditions, the required rock size was calculated assuming an additional 3 feet of settlement at the southern end of the repository resulting in a top slope of 0.0318 feet/foot. This scenario would result in an increase required $D_{50}$ of 1.8 inches using the Safety Factors Method and 1.70 inches using the Abt and Johnson Method. The interstitial velocity would increase to only 0.26 feet per second which is well below the 0.5 feet per second criteria established in NUREG 1623.

Because of the uniform bottom configuration of the A-9 and waste placement, there is no reason to anticipate that settlement will occur in a non-uniform manner.

### 2.2.4 Radon Attenuation

While there are some isolated locations of rill formation beneath the Type C erosion protection on the A-9 reclamation cover, the geometry of the rills are shallow and perpendicular to the slope. These rills, typically, appear to develop and extend for a length of approximately 200 feet and stabilize because eroded soils are deposited within the rock voids thus slowing or terminating interstitial velocities. The typical rill depth is about 6 inches and in no case incisions formed greater than one foot over the radon barrier. Since radon attenuation to 20 $pCi/m^2/s$ occurs at a much shallower depth within the cover system, based on conservative modeling, the cover system performance with respect to radon attenuation is functioning as designed.

## 2.3 Evaluation of Heap Leach and GHP No. 2 Reclamation Covers

Umetco has evaluated the Heap Leach and GHP No. 2 Reclamation Covers to ensure the situation found with the AGTI and A-9 does not exist. The designs for both of these cover systems were prepared by Umetco, in-house, approved by the NRC, and contain filter layers beneath all Type B and Type C erosion protection which are placed on the 5(H) to 1(V) cover outslopes. Reclamation covers have been inspected in the field with no indication of cover degradation.

## 3.0 Enhancement of Erosion Protection Design

In order to correct the erosion features on the AGTI and A-9 structures, repair methodologies have been devised to provide adequate bedding material beneath/within the Type C erosion protection placed on the lower portions of the outslopes. A multi-layer filter system will be provided at the upstream and downstream sides of the launch rock structure located on the east side of the AGTI to reduce erosion. The off-cover erosion occurring on the southeast corner of the AGTI will be corrected by the installation of a riprap armored apron channel.

## 3.1 Above Grade Tailings Impoundment

This section details the design of repairs in areas of concern associated with erosion protection of the AGTI reclamation cover.

### 3.1.1 AGTI Areas of Concern and Repair

The areas of concern associated with the AGTI reclamation cover are:

- Type C ($D_{50}$ = 6 inches) Erosion Protection Bedding – located on the lower portions of the northern and eastern reclamation cover slopes.
- Launched Rock Filter– located at the bottom of the eastern slope of the reclamation cover.

- Off-Cover Erosion Control Apron Channel– occurring on the southeast corner of the repository.

### 3.1.2 Type C Erosion Protection, Bedding Repair

Field investigations indicated that the rills in the existing erosion protection are generally confined to the eastern or lee side of the AGTI with some minor rills occurring on the north face. Two bedding repair methods have been devised for the AGTI.

The first method (repair method one) involves removal of the existing Type C erosion protection layer, placement of a minimum 3-inch thick layer of Type A bedding material (Design $D_{50} = 0.5$ inch, actual $D_{50} = 1.0$ inch, average from field gradations) and replacement of the Type C riprap to a minimum depth of 1 foot. The areas to receive this treatment method total approximately 19.5 acres and are shown on Drawings 5 of 8 and 6 of 8.

The second repair method (repair method two) involves spreading a blended bedding material ($D_{50} \approx 0.64$ inch) over the surface of the existing Type C riprap and vibrating/working the material into the bottom portion of the 1-foot thick layer of erosion protection. Section 3.3 of this report discusses field tests conducted to verify the constructability of this method. A minimum 4-inch layer of blended bedding material will be provided and 25-foot wide staging bands will be provided on 10-foot elevation centers to access the slope. The existing Type C riprap will be removed from the access band areas and a minimum 3-inch layer of Type A bedding material will be placed to plate the existing frost barrier and act as a bedding layer. When the access/staging bands are no longer required, the Type C riprap previously removed will be replaced and blended/transitioned into the surrounding undisturbed erosion material to a minimum depth of 1 foot. The area to receive this treatment method totals 42.8 acres and encompasses the majority of the north outslope of the AGTI as shown on Drawings 5 of 8 and 6 of 8.

#### 3.1.2.1 Repair Method One Compatibility Calculations:

An adequate quantity of Type A bedding material is stockpiled at the Rattlesnake Quarry to complete the repairs on the AGTI.

**Bedding Filter Criteria:**

Criterion 1*: $D_{15}$ (Riprap) / $D_{85}$ (Bedding Material) < 5, prevents migration of the bedding material into the riprap.

Criterion 2*: $D_{15}$ (Bedding Material) / $D_{85}$ Frost Barrier Material) < 10, prevents erosion of soil below the bedding material.

* NRC, NUREG/CR-4620 (USNRC 1986)

**Material Gradation Data:**

Frost Barrier Material* – $D_{85} = 0.066$ inch

Type A Bedding Material* – $D_{15} = 0.52$ inch, $D_{85} = 1.95$ inches

Type C Riprap Material* – $D_{15} = 4.48$ inches

*$D_{15}$ and $D_{85}$ sizes from averages of field gradations performed during construction.

Criterion 1 – 4.48/1.95 = 2.3 < 5, Check

Criterion 2 – 0.52/0.066 = 7.9 < 10, Check

**Interstitial Velocity Criteria:**

$Vv = W\ m^{0.5}\ I^{0.54}$, NUREG-1623 (USNRC, Draft Guidance 1999)

Recommended interstitial <0.5 feet per second (ft/s)

Where:
Vv = Interstitial velocity, inches per second (in/s)
W = Constant, 11.316
m = $D_{50}$ of bedding material, inches, and
I = Hydraulic gradient, feet per foot (ft/ft)

**Input Data:**

$D_{50}$ Type A Bedding = 1.0 inch, average from field gradations during construction

Assume worst case – 5H:1V slope, hydraulic gradient = 0.2 ft/ft

$Vv = 11.316 * 1^{0.5} * 0.2^{0.54} = 4.75$ in/s

4.75 in/s = 0.39 ft/s < 0.5 ft/s, Check

**3.1.2.2 Repair Method Two Compatibility Calculations:**

Repair method two will require the crushing of existing rock material stockpiled at the Rattlesnake Quarry. The crushed rock will be blended with existing quarry fines to produce the desired bedding material gradation (30 percent quarry fines / 70 percent 2-inch minus crushed rock). The proposed individual material gradations and target bedding material gradations are as follows (blend calculations and a gradation graph are presented in Appendix A):

Crushed Rock Gradation:

**Table 3.0, Crushed Rock Gradation**

| Size | Percent Passing |
|---|---|
| 2-inch | 100 |
| 1 ½-inch | 80 - 100 |
| 1-inch | 50 - 70 |
| ¾-inch | 30 – 50 |
| 3/8-inch | 0 - 5 |

Average Existing Quarry Fines Gradation:

**Table 3.1, Existing Quarry Fines Gradation**

| Sieve Size | Percent Passing |
|---|---|
| ¾-inch | 100 |
| 3/8-inch | 98 |
| No. 4 | 77 |
| No. 8 | 63 |
| No. 16 | 55 |
| No. 30 | 51 |
| No. 50 | 47 |
| No. 100 | 30 |
| No. 200 | 5.4 |

Target 30/70 Bedding Blend Gradation:

**Table 3.2, 30/70 Bedding Gradation Band**

| Sieve Size | Percent Passing |
|---|---|
| 2-inch | 100 |
| 1 ½-inch | 80 – 100 |
| ¾-inch | 40 – 70 |
| 3/8-inch | 20 – 50 |
| No. 4 | 10 – 40 |
| No. 200 | 0 - 10 |

**Bedding Filter Criteria:**

Criterion 1*: $D_{15}$ (Riprap) / $D_{85}$ (Bedding Material) < 5, prevents migration of the bedding material into the riprap.

Criterion 2*: $D_{15}$ (Bedding Material) / $D_{85}$ Frost Barrier Material) < 10, prevents erosion of soil below the bedding material.

* NRC, NUREG/CR-4620 (USNRC 1986)

**Material Gradation Data:**

Frost Barrier Material[1] – $D_{85}$ = 0.066 inch

30/70 Bedding Material[2] – $D_{15}$ = minimum 0.006 inch, maximum 0.27 inch

$D_{85}$ = minimum 1.05 inches, maximum 1.56 inches

Type C Riprap Material[1] – $D_{15}$ = 4.48 inches

[1]$D_{15}$ and $D_{85}$ sizes averaged from field gradations performed during construction

[2]Minimum and maximum sizes from gradation band

Criterion 1 – Minimum bedding band - 4.48/1.05 = 4.27 < 5, Check

Criterion 1 – Maximum bedding band - 4.48/1.56 = 2.87 < 5, Check

Criterion 2 – Minimum bedding band – 0.006/0.066 = 0.09 < 10, Check

Criterion 2 – Maximum bedding band - 0.27/0.066 = 4.09 < 10, Check

**Interstitial Velocity Criteria:**

$Vv = W\ m^{0.5}\ I^{0.54}$, NUREG-1623 (USNRC, Draft Guidance 1999)

Recommended interstitial velocity <0.5 feet per second (ft/s)

Where:
Vv = Interstitial velocity, inches per second (in/s)
W = Constant, 11.316,
m = $D_{50}$ of bedding material, inches, and
I = Hydraulic gradient, feet per foot (ft/ft)

**Input Data:**

$D_{50}$ 30/70 Bedding Blend = minimum 0.38 inch, maximum 0.88 inch

Assume worst case – 5H:1V slope, hydraulic gradient = 0.2 f ft/ft

Minimum gradation band:

$Vv = 11.316 * 0.38^{0.5} * 0.2^{0.54} = 2.88$ in/s

2.88 in/s = 0.24 ft/s < 0.5 ft/s, Check

Maximum gradation band:

$Vv = 11.316 * 0.88^{0.5} * 0.2^{0.54} = 4.44$ in/s

4.44 in/s = 0.37 ft/s < 0.5 ft/s, Check

### 3.1.3 Launch Rock Structure Filter Installation

Multi-layer filter zones will be installed on both the upstream and downstream sides of the existing launch rock structure to reduce erosion and repair erosion sink holes that have developed upstream of the structure. The filter zone on the upstream side of the structure will consist of three filter material layers. The existing upstream face of the launch rock structure will be exposed (approximate 6-foot deep excavation) and a minimum 1-foot thick layer of Type C riprap will be placed next to the existing Type E launch rock material. A minimum 1-foot thick layer of Type A bedding will be placed next to the Type C rock followed by a minimum 1-foot thick layer of 30/70 blended bedding material. The filter zone will be backfilled with the frost barrier material previously removed and the filter zone will extend the full length of the launch rock structure. The required excavation is located well beyond the limits of the radon barrier on the east side of the AGTI and the radon barrier and waste materials will not be exposed. It is expected that the excavation required to facilitate installation of the filter zone will include and encompass all indentified sink hole features. Any sink hole features which may fall outside of the required excavation will be repaired by the placement of additional frost barrier material.

The downstream side of the launch rock structure will receive a similar filter zone treatment. After a shallow trench has been excavated at the toe of the structure and filled with Type A bedding, Type C rock will be placed next to the existing Type E launch rock followed by minimum 1-foot layers each of Type A bedding, 30/70 blended bedding, another layer of Type A bedding which will be covered with a final layer of Type C rock. Details of both the upstream and downstream filter installation are shown on Drawing 6 of 8.

### 3.1.3.1 Launch Rock Filter Compatibility Calculations

Adequate quantities of Type A bedding material and Type C rock are stockpiled at the Rattlesnake Quarry to complete the filter zones on the AGTI launch rock structure. The quantity of 30/70 bedding material will have to be processed in the quarry as specified previously.

**Piping Filter Criteria:**

Criterion 1* - $5 < D_{15}$ (Filter) / $D_{15}$ (Base) $< 40$,

Criterion 2* - $D_{50}$ (Filter) / $D_{85}$ (Base) $\leq 5$, and

Criterion 3* - $D_{50}$ (Filter) / $D_{50}$ (Base) $< 40$

*US Bureau of Reclamation, Design of Small Dams, pg. 235, 1977

**Filter Material Gradation Data:**

**Table 3.4, Filter Material Gradations**

| Material Type | $D_{15}$ (in.) | $D_{50}$ (in.) | $D_{85}$ (in). |
|---|---|---|---|
| Frost Barrier[1] | 0.0011 | .02 | .066 |
| 30/70 Bedding Blend[2] | 0.02 | 0.64 | 1.31 |
| Type A Bedding[1] | 0.52 | 1.0 | 1.95 |
| Type C Rock[1] | 4.48 | 6.32 | 7.86 |
| Type E Rock[1] | 21 | 31 | 45.1 |

[1]Average gradation from field tests
[2]Calculated values of 30/70 blended material (See Figure 2 of Appendix A)

**Compatibility Calculations:**

<u>30/70 Blend / Frost Barrier</u>
Criterion 1, $5 < 0.02/0.0011 < 40$, $5 < 20 < 40$, Check
Criterion 2, $0.02/0.066 \leq 5$, $0.03 \leq 5$, Check
Criterion 3, $0.64/.02 < 40$, $32 < 40$, Check

<u>Type A Bedding / 30/70 Blend</u>
Criterion 1, $5 < 0.52/0.02 < 40$, $5 < 26 < 40$, Check
Criterion 2, $0.52/1.31 \leq 5$, $0.4 \leq 5$, Check
Criterion 3, $1.0/0.64 < 40$, $1.5 < 40$, Check

<u>Type C Rock / Type A Bedding</u>
Criterion 1, $5 < 4.48/0.52 < 40$, $5 < 9 < 40$, Check
Criterion 2, $4.48/1.95 \leq 5$, $2.3 \leq 5$, Check
Criterion 3, $6.32/1.0 < 40$, $6.3 < 40$, Check

Type E Rock / Type C Rock
Criterion 1, $5 < 21/4.48 < 40$, $5 < 4.7 < 40$, Check
Criterion 2, $21/7.86 \leq 5$, $2.7 \leq 5$, Check
Criterion 3, $31/6.32 < 40$, $4.9 < 40$, Check

### 3.1.4 Off-Cover Erosion Control Apron Channel

A slope area located adjacent to the toe of the impoundment cover on the southeast corner of the AGTI has experienced some erosion caused by off-cover surface runoff and drainage exiting the downstream end of the existing buried apron. This slope area will be stabilized by placement of a riprap armored apron channel. The erosion damage will be repaired by placing compacted random sub-grade material obtained from grading activities required to shape the slope area. After sub-grade preparation and shaping, the apron channel will receive a minimum 6-inch layer of Type A bedding material overlain by an 18-inch thick layer of Type C riprap. Near the downstream end of the apron channel the Type C riprap will be tied into the existing buried apron material to provide drainage of the buried apron. The entire length of the apron channel will match the existing surface of the impoundment cover erosion protection material (maximum slope 0.17 feet per foot.). The apron channel will vary in width from 141.0 feet to 78.0 feet. Details of the apron channel design are shown on Drawing 8 of 8.

#### 3.1.4.1 Apron Channel Design Calculations

The erosion protection required for the apron channel was evaluated considering the approved PMP (one-hour thunderstorm) of 8.7 inches, using both the Stephenson Method for slopes greater than 10% and the Abt and Johnson Method.

The Stephenson Method returned a required $D_{50}$ of 4.06 inches and the Abt and Johnson method also indicates that a minimum $D_{50}$ of 4.06 inches is required. The $D_{50}$ of the Type C riprap stockpiled in the Rattlesnake Quarry averages 6.34 inches with a $D_{100}$ of 9 inches. Due to frequent wetting/concentrated flow, an 18-inch thick layer of Type C riprap will be placed on a 6-inch layer of Type A bedding material. It has been previously demonstrated, in this report, that the Type A bedding material will provide adequate bedding for a 0.2 feet per foot (5H:1V) slope. The Stephenson Method calculation sheets are presented in Appendix A and the Abt and Johnson Method calculation follows:

Abt and Johnson Rock Sizing Method:

$D_{50} = 5.23 * q^{0.56} * S^{0.43} * 1.20$, NRC NUREG-1623 (USNRC, Draft Guidance 1999)

Where,
$D_{50}$ - Minimum median stone size, inches
q - Unit Flow Rate, feet per second (fps), (1.78 fps from Rational Formula for unit width analysis),
S - Slope, feet per foot (ft/ft), (0.17 ft/ft. from design Drawing)

$D_{50} = 5.23 * 1.79^{0.56} * 0.17^{0.43} * 1.20 = 4.06$ inches, $D_{50}$ Type C riprap = 6.34 inches, Check

### 3.2 A-9 Repository

This section details the design of repairs in areas of concern associated with erosion protection of the A-9 reclamation cover.

### 3.2.1 A-9 Areas of Concern and Repair

The areas of concern associated with the A-9 reclamation cover are:

- Type C ($D_{50}$ = 6 inches) Erosion Protection Bedding – located on the southern reclamation cover slopes.
- Type C Erosion Protection Bedding – located at the toe of the Heap Leach Repository (northeast edge of the A-9 Repository).

### 3.2.2 Type C Erosion Protection, Bedding Repair

Field investigations indicated that the rills in the existing erosion protection are generally confined to the southern crest area and outslope. Based on the erosion protection evaluation presented in Table 2.3 of this report, it appears that the interstitial velocity at the end of flow segment 3 is slightly higher than recommended. While no evidence of rill formation has been detected in this area, bedding material will be added here as well as repairs to the A-9 crest and southern slope. Two bedding repair methods have been devised for the AGTI.

The first method (repair method one) involves removal of the existing Type C erosion protection layer, placement of a minimum 3-inch thick layer of Type A bedding material (Design $D_{50}$ = 0.5 inch, actual $D_{50}$ = 1.0 inch from average of field gradations) and replacement of the Type C riprap to a minimum depth of 1 foot. A 30-foot wide zone of type B riprap at the southern crest will be removed, the sub-grade will be repaired with a minimum 3-inch layer of Type A bedding material (or greater depth as required to reestablish grade). The repaired/prepared sub-grade in this zone will be covered with the Type B riprap previously removed. In all cases the repaired erosion protection materials will be replaced at the originally required depths in a manner that will provide a smooth transition from the existing (undisturbed) material to the repair areas. The A-9 crest area and southern outslope will receive these treatments and the area totals approximately 5.9 acres as shown on Drawing 7 of 8.

The second repair method (repair method two) involves spreading a blended bedding material ($D_{50} \approx$ 0.64 inch) over the surface of the existing Type C riprap and vibrating/working the material into the bottom portion of the 1-foot thick layer of erosion protection. Section 3.3 of this report discusses field tests conducted to verify the constructability of this method. A minimum 4-inch layer of blended bedding material will be provided and 25-foot wide staging/access corridors will be provided around the perimeter of the existing Type B erosion protection material on the top of the A-9. A minimum 3-inch layer of Type A bedding material will be placed on the existing Type B riprap to provide access and act as a staging area for the placement of bedding material on the adjacent Type C armored slopes. The Type A material will remain on the Type B riprap after repairs to the slopes are complete. The areas to receive this treatment method total 7.1 acres as shown on Drawing 7 of 8.

Bedding compatibility calculations for repair methods one and two presented in Sections 3.1.2.1 and 3.1.2.2 of this report also apply to the repair methods proposed for the A-9.

## 3.3 Constructability Verification Field Tests

The constructability of filling the void space of the existing Type C riprap (repair method two) was verified by field testing in the Rattlesnake Quarry. During the fall of 2010, an approximate 100-foot wide by 100-foot long test bed of Type C riprap was constructed in the Rattlesnake Quarry. The test bed was constructed on a sloping surface in the quarry which varied from

7(H):1(V) to 4(H):1(V) and simulates the existing slopes found on the AGTI and A-9. The test bed sub-grade was shaped and compacted and a minimum 12-inch thick layer of Type C erosion protection material was placed and compacted in accordance with the placement and compaction techniques incorporated on the completed AGTI and A-9.

Two bedding material types were spread over the riprap test bed in order to evaluate placement techniques and the feasibility of working bedding material into the void spaces in the riprap. The first bedding material type considered was a 30/70 blend of quarry fines and imported 1-inch minus crushed rock. This material readily penetrated the Type C rock material with dozer track walking and mechanical vibration. The second bedding material type considered was the existing Type A bedding material (3-inch minus material) stockpiled in the quarry. This material also penetrated the Type C material though not as readily and slightly more energy was required to work the coarser material into the riprap. Both material types were successfully worked into the bottom portion of the 12-inch thick Type C riprap layer.

Placement methods evaluated included conventional dumping of bedding material on the surface and spreading with a dozer tractor and sprinkling or spreading bedding materials on the surface of the riprap with loader type equipment. Again, both methods were successfully worked into the riprap layer, however, the more conventional dumping and dozer spreading of the material resulted in the waste of material, required significantly more vibratory effort and left bedding material visible on the surface. The second placement method (sprinkling bedding material with a loader) resulted in a more uniform distribution of bedding material, less vibratory effort and no wasted material. It was noted during the testing that point contact on the surface between the vibratory equipment and the Type C rock resulted in more effective penetration of the bedding materials.

In conclusion, the results of field testing indicate that bedding materials up to and including 3-inch minus material can effectively be worked into the existing Type C erosion material layer. Loader spreading of the material is the most desirable and economical bedding placement method. Therefore, a bedding material comprised of 70 percent 2-inch minus crushed rock and 30 percent quarry fines and spreading with loader type equipment is proposed as a viable method to introduce bedding material into the existing Type C erosion protection material where no rill damage has occurred on the AGTI and A-9. Photographs of the testing process and a gradation plot of bedding materials introduced into the erosion protection layer during testing are presented in Appendix B.

## 4.0 Technical Construction Specifications

### 4.1 Use of Site

All repair work, new construction and Contractor operations, including staging shall be conducted within the established Gas Hills site transfer boundary shown on the Drawings. No work or construction activities will be allowed outside such boundary without the Owner's approval.

### 4.2 Required Excavation

Prior to initiation of repair activities, test excavations shall be made to verify the integrity of the existing radon barrier or clay layer in the vicinity of existing rill features. A minimum of one excavation shall be made on the AGTI and A-9, additional excavations may be required if it is determined that the radon barrier layer has been disturbed or excessive settlement has occurred. All soil material (frost barrier material) and erosion protection material shall be carefully removed and stockpiled for re-use. Material removed from required excavations shall be replaced in accordance with these Specifications.

## 4.3 Radon Barrier

This section discusses placement of the radon barrier layer of the reclamation cover should it become necessary to place radon barrier material during erosion protection repair activities or test pit examination of the radon barrier. It is anticipated that no radon barrier material will be disturbed or require placement.

### 4.3.1 Materials

Clayey soils for constructing the radon barrier layer have been obtained from a permitted borrow source and stockpiled on site. Should it become necessary to place radon barrier material, the in-place material removed from required excavations will be stockpiled for re-use. The Cody shale (claystone) material contained in the stockpile shall be conditioned prior to re-use placement in the radon barrier. The moisture content of the stockpiled material shall be within 2 percent of the specified moisture prior to placement.

Conditioning of this material shall (at a minimum) require application of water, disking and desiccation to the extent necessary to provide a homogeneous borrow material prior to excavation and placement. Soils used in constructing the radon barrier shall conform to the following physical requirements:

- At least 50 percent passing the No. 200 sieve.
- Maximum particle size of 1 inch.
- Liquid limit of the material shall be at least 25 percent with a minimum plasticity index of 10.
- Maximum hydraulic conductivity of 1E-7 cm/sec when compacted to 95 percent of maximum standard Proctor density (ASTM D 698).

### 4.3.2 Placement

Radon barrier (clayey soil) shall be placed in equal continuous layers not exceeding 6 inches compacted thickness and shall be compacted to a minimum of 95 percent of the maximum standard Proctor density (ASTM D 698), at a moisture content of between optimum moisture content and 4 percent above optimum moisture content.

The placement areas and thickness for the radon barrier layer are shown on the drawings or shall match the depth removed from required excavations. Distribution and gradation of materials in each layer will be, as far as practicable, free of lenses, pockets, streaks, or layers of material differing substantially in texture, gradation or moisture content from surrounding materials.

Compacting radon barrier soils shall be accomplished using tamping foot (sheepsfoot) roller or mechanical hand tamping equipment. In placing the first lift of radon barrier material, care shall be taken to avoid mixing of underlying radiologically contaminated soils. The top surface of the compacted final lift of the radon barrier shall be bladed to the uniform and smooth grades established on the drawings or as modified by the engineer in the field.

If the compacted surface of any layer or fill is too dry or smooth to bond properly with the layer of material to be placed thereon, it will be moistened and/or reworked with a harrow, scarifier, or suitable equipment, to a sufficient depth to provide relatively uniform moisture content and a satisfactory bonding surface before the next layer of fill is placed. If the compacted surface of any layer of the placed material is too wet to obtain the specified compaction of the fill material to be placed thereon, the material shall be allowed to dry out, reworked, or scarified to reduce the moisture content and recompacted to the specified density.

Fill soils shall not be placed when the sub-grade is frozen, or when ambient temperatures do not permit placement or compaction of fill material to the specified density without developing frost lenses in the fill.

Construction surfaces, including lift surfaces, shall be protected from desiccation prior to placing subsequent lifts or frost protection materials.

The top of the radon barrier layer shall be graded to within +0.1 foot of the design grade shown on the drawings or as modified by the engineer in the field. The in-place thickness of the radon barrier layer shall be equal to or greater than 100 percent of the design thickness shown.

## 4.4 Frost Protection Layer/Random Fill

This section discusses placement of the frost protection layer of the reclamation cover where test pits are excavated to examine the condition of the radon barrier or where rill repairs are required to reestablish grade. Random fill material shall be placed to establish sub-grade for the apron channel and shall be obtained from required excavations and/or grading activities in the vicinity of the apron channel.

In general, repairs to the existing frost barrier layer will be made with Type A bedding material.

### 4.4.1 Materials

Random fill and the frost protection layer of the cover shall be constructed with soils obtained from local mine spoil borrow sources, required excavations or the Rattlesnake Quarry. Suitable materials obtained from the borrow sources, Rattlesnake Quarry or required excavations shall consist of processed Type A rock bedding material, or clayey and/or silty sand, classified as SC, SM and/or SC-SM, in accordance with the Unified Soil Classification System. Soils used for random fill and construction of the frost protection layer shall be free of brush, roots, sod, lumps or rocks larger than one-half of the lift thickness, or other perishable or unsuitable materials.

A significant volume of soils obtained from mine spoil borrow sources at the site have radiological characteristics which are naturally occurring but unsuitable for cover construction. Umetco will continuously monitor borrow excavations in the field. If additional material is required to affect repairs or fill test pits, the radiological and characteristic suitability of borrow materials will be determined on a load-by-load basis. For the most part, radiologically elevated (naturally occurring) materials, which are present in borrow areas, occur in isolated ponds and at times small clusters of loosely cemented rock. Upon initial scanning of this material it may appear that radiologically elevated materials are wide spread and unsuitable for cover construction while post-handling measurements may indicate that the radiological characteristics of the material are suitable.

### 4.4.2 Placement

Random fill and frost protection soils shall be placed in equal continuous layers not exceeding 12 inches compacted depth and compacted to a minimum of 95 percent of maximum standard Proctor density (ASTM D 698), at a moisture content above minus 2 percent of optimum.

The placement areas and thickness for the frost protection layer are shown on the drawings or shall match existing depths removed from test pit excavations. Distribution and gradations of materials in each layer will be, as far as practicable, free of lenses, pockets, streaks, or layers of material differing substantially in texture, gradation, or moisture content from surrounding materials.

If the compacted surface of any layer of fill is too dry or smooth to bond properly with the layer of material to be placed thereon, it will be moistened and/or reworked with a harrow, scarifier, or other suitable equipment to a sufficient depth to provide a relatively uniform moisture content and a satisfactory bonding surface before the next layer of earthfill is placed.

No material will be placed in the fill layer when sub-grade soils are frozen or when ambient temperatures do not permit placement or compaction of soils to the specified density without developing frost lenses in the fill.

The top of the frost protection layer shall be graded to within +0.1 foot of the design grade shown on the drawings or as modified by the engineer in the field. The in-place thickness of the frost protection layer shall be equal to or greater than 100 percent of the design thickness shown.

## 4.5 Erosion Protection and Bedding Materials

Erosion protection materials shall be obtained from existing stockpiles in Umetco's Rattlesnake Quarry located approximately 6 miles east of the Gas Hills site. Erosion protection materials from this quarry site have been approved for use as erosion protection for repositories at the Gas Hills site, i.e., AGTI and A-9. Umetco has performed and documented quality control testing of erosion protection material to verify that processed materials meet durability requirements previously specified and gradation requirements specified herein. Gradation tests will be performed on the processed materials used as Type A bedding, the 30/70 blended bedding material and component materials used to create the blended bedding material. Type C riprap stockpiled in the quarry, to be used in the construction of the apron channel and launch rock filters has previously been verified to meet durability and gradation requirements and will not required further testing.

Erosion protection materials used as bedding material will initially be tested when each type of material is produced, blended or placed. Thereafter, the testing shall be performed at a minimum frequency of one test for each 10,000 cubic yards or fraction thereof produced and placed. No durability testing will be required. The 30/70 blended bedding material shall be blended by weight and suitable mixing and/or blending hoppers equipped with a weighing devise shall be provided to ensure a consistent blend or mix is produced.

In-place bedding material gradations and depth checks will be performed at a frequency of one set of tests (depth and gradation) for every 500 square feet of Type A bedding material placed or blended bedding material introduced into the existing erosion protection material. A minimum 3-foot square test pit will be excavated to perform gradation/depth check tests.

### 4.5.1 Gradation Requirements

Erosion protection (riprap) materials shall be reasonably well graded within the limits presented in Tables 4.0 and 4.1. The sizes are specified in terms of square opening of U. S. Standard Sieves or by the nominal sizes of the materials.

**Table 4.0 Erosion Protection Gradation Requirements**

| Type A ($D_{50}$ = 0.5") | | Type B ($D_{50}$ = 3") | | Type C ($D_{50}$ = 6") | |
|---|---|---|---|---|---|
| **Sieve Size** | **Percent Passing** | **Sieve Size** | **Percent Passing** | **Sieve Size** | **Percent Passing** |
| 3" | 100 | 6" | 100 | 10" | 100 |
| 1.5" | 60 - 100 | 5" | 50 - 100 | 9" | 50 - 100 |
| 1" | 40 - 100 | 4" | 30 - 100 | 8" | 20 - 100 |
| 3/4" | 20 - 100 | 3" | 0 - 50 | 6" | 0 - 50 |
| 1/2" | 5 - 50 | 2" | 0 - 15 | 4" | 0 - 15 |
| 3/8" | 0 - 25 | | | | |
| No. 4 | 0 - 5 | | | | |

**Table 4.1 30/70 Blended Bedding Gradation Requirements**

| Crushed Rock | | Quarry Fines (Average of existing material) | | 30/70 Bedding Blend ($D_{50}$ = 0.64") | |
|---|---|---|---|---|---|
| **Sieve Size** | **Percent Passing** | **Sieve Size** | **Percent Passing** | **Sieve Size** | **Percent Passing** |
| 2" | 100 | ¾" | 100 | 2" | 100 |
| 1.5" | 80 - 100 | 3/8" | 98 | 1.5" | 80 - 100 |
| 1" | 50 - 70 | No. 4 | 77 | ¾"" | 40 - 70 |
| 3/4" | 30 – 50 | No. 8 | 63 | 3/8" | 20 - 50 |
| 3/8" | 0 - 5 | No. 16 | 55 | No. 4 | 10 - 40 |
| | | No. 30 | 51 | No. 200 | 0 - 10 |
| | | No. 50 | 47 | | |
| | | No. 100 | 30 | | |
| | | No. 200 | 5.4 | | |

## 4.6 Erosion Protection Placement

This section discusses construction (placement) of the erosion protection layer(s), erosion protection bedding and filters on the reclamation covers and associated hydraulic structures, e.g., toe aprons, apron channel, etc.

### 4.6.1 Sub-grade Preparation

In areas designated for existing riprap removal and replacement (repair method one), the existing riprap material shall be carefully removed in panels no wider than 50 feet and temporarily stockpiled on the adjoining/completed panel. Removed riprap shall be replaced as soon as is practicable after the minimum 3-inch thick Type A bedding layer has been placed and approved by the Owner's representative. In general, the removal panels will be oriented perpendicular to the slope and the actual width of panels will be determined in the field dependent on the capabilities of the Contractor's equipment. All riprap and bedding materials shall be placed in accordance with these Specifications.

In areas designated to receive bedding material vibrated into the existing riprap (repair method two), the 30/70 blended bedding material shall be spread uniformly, with loader type equipment, over the slope between the access route bands (shown on the Drawings). Test panels will be prepared on the existing slope to determine the most acceptable method and amount of bedding material required (to be applied on the slope) to ensure that a minimum of 4-inches of bedding material is vibrated or worked into the bottom portion of the existing 12-inch layer of Type C riprap. The number of passes and size of vibratory equipment shall also be determined on the test panels and the acceptable result shall be duplicated throughout the placement of subsequent bedding material. The access route/staging bands shall be plated with a minimum 3-inch thick layer of Type A bedding material (after the existing erosion protection material has been removed) which will act as a running or wear surface and a bedding layer for the riprap removed to construct the access band. Access/staging bands shall be provided as shown on the Drawings.

Surfaces to be prepared for placing erosion protection shall be cleared of rubbish and any deleterious material. Prior to placing erosion protection materials, the subsurface shall be graded to within +0.1 foot of the final design grade established on the drawings or as modified by the engineer in the field. All surfaces prepared to receive erosion protection materials and/or bedding material shall be proof rolled with a smooth drum roller or approved equivalent. A designated representative of the QC staff shall witness proof rolling. Damage to the prepared sub-grade by construction activities or erosional forces, i.e., storm runoff, etc., shall be repaired in accordance with these specifications prior to placing erosion protection materials.

Frozen or unsuitable materials shall not be used for sub-grade preparation. Preparing the sub-grade surface shall occur when ambient temperatures permit adequate grading and proof rolling of the sub-grade. Placing erosion protection materials shall not be allowed when snow is present on the sub-grade.

### 4.6.2 Placement and Compaction

Erosion protection materials shall be placed to the lines and grades established on the Drawings described in these Specifications or as established by the engineer in the field.

Erosion protection materials shall be handled, loaded, transported, stockpiled, and placed in a manner that avoids nonconformance with the specifications due to segregation and degradation, including materials moved to and from stockpiles. Various placement methods used by the contractor that tend to segregate particle sizes within the layer will not be permitted.

Erosion protection material, up to a maximum nominal size of 12 inches, may be placed by end dumping and spread by bulldozer, hydraulic excavator, or approved equivalent. Dumped riprap shall be placed to its full course thickness in one operation and in such a manner as to avoid displacing the bedding material or sub-grade. The finished erosion protection layer shall be free from pockets of small stones and clusters of larger stones. Placing stone by dumping into chutes or by similar methods will likely cause segregation of the various sizes and will not be permitted. The desired distribution of the various sizes of stones throughout the mass shall be obtained by selective loading of the material at the quarry, by controlled dumping of successive loads during final placement, or by other methods of placement that produce the specified results. Rearranging of individual stones by mechanical equipment or by hand may be required to the extent necessary to obtain a well-keyed and reasonably well graded distribution of stone sizes as specified above. Larger pieces of riprap may require individual placement. Hand arrangement will be required only to the extent necessary to secure acceptable results. Stones shall be selected and positioned so as to produce an essentially solid, densely placed face of rock with all stones firmly wedged in place. Any stones that are not firmly wedged shall be adjusted and additional selected stones inserted or existing stones replaced to achieve solid interlock.

Each layer of erosion protection materials shall be track-walked by two passes of Caterpillar D6 bulldozer, smooth drum roller, or approved equivalent. Erosion protection materials shall be spread in a manner that will achieve full coverage and a uniformly distributed well-keyed, densely placed layer.

Construction equipment other than spreading and compaction equipment shall not be allowed to move over the placed erosion protection and bedding layers except at equipment crossovers as designated by the QC representative.

### 4.6.3 Tolerances

The erosion protection (riprap) layers shall be placed to the limits and thickness shown on the drawings and within the following tolerances.

1) The top of the frost protection or sub-grade shall be within $\pm$ 0.1 foot of the design elevation or grade established on the drawing or as modified by the engineer in the field.
2) The thickness of erosion protection and bedding layers shall be no less than 90 percent of the design thickness shown on the drawings.
3) Local irregularities not exceeding the tolerances above will be permitted, provided that such irregularities do not form mounds, ridges, swales, or depressions that in the opinion of the QC Officer could cause concentrations of surface runoff.

## 5.0 Quality Control Plan

This section details the quality control and quality assurance activities to be performed.

The objectives of the quality control plan are to effectively control the quality of work performed, to verify that construction activities are performed in accordance with the approved plans and specifications, and provide adequate checks and audits to assure proper implementation of the quality control activities. Proper implementation of these activities will provide detailed documentation of the project and assure construction reclamation activities have been performed in accordance with the approved plans and specifications.

### 5.1 Quality Control/Quality Assurance Personnel

Quality control activities shall be implemented and managed by the QC Officer. These activities include field sampling, construction inspection, field testing, and laboratory testing. The QC Officer, appointed by the engineer, shall supervise field and laboratory QC technicians and control documentation of construction and quality control activities. The QC Officer shall have the specific authority and responsibility to reject work or material, to stop work, to require removal or placement, to specify and require appropriate corrective actions if it is determined work is not in conformance with the approved plans and specifications.

Quality assurance activities shall be implemented by the QA Officer who is an independent consultant and/or Umetco technical staff member with expertise in a specific aspect of reclamation work being performed. Quality assurance functions include pre-qualification of QC personnel, verification of test procedures and results, equipment checks, and review of calculations and associated documentation.

## 5.2 Test Procedures and Documentation

QC procedures and report forms have been developed, approved, and utilized for reclamation activities associated with Gas Hills disposal cells, i.e., AGTI and A-9. These procedures and report forms (summarized below) will be used in the QC activities. Table 5.0 summarizes previously approved test procedures. Table 5.1 provides a summary of QC forms to be used in documenting QC sampling, testing, and inspection activities. Modification to these procedures and forms (from those previously reviewed and accepted) will be made only to the extent that reflects modification of ASTM standards or enhances/clarifies documentation associated with construction inspection and testing activities.

## 5.3 Environmental Quality, Health and Radiation Protection

Work will be performed in compliance with statutes, rules and regulations, licenses and permits rendered applicable under Source Material License No. SUA-648. Work will be monitored by the Owner in accordance with the site's Radiation Monitoring Procedures. Applicable procedures will be provided to the successful bidder. Procedures are available for review at Owner's Grand Junction offices prior to bidding.

Reclamation activities at the Gas Hills site are conducted in accordance with Radioactive Materials License SUA-648. This license requires that all equipment, vehicles and materials meet the established release criteria for fixed and removable surface contamination prior to leaving the site restricted area. These release criteria are intended to control the spread of radioactive materials off-site and keep personal exposure to radioactive materials as low as reasonably achievable (ALARA). Radiological scanning procedures are established for this site and will be utilized in execution of project work. These procedures are summarized as follows:

### 5.3.1 Surveys for Unrestricted Release

All equipment, vehicles and parts leaving the designated site restricted area or other areas identified as containing 11e.(2) materials will be surveyed to confirm the presence or absence of surface contamination. All light vehicles, equipment and parts leaving the designated restricted area or area where 11e.(2) materials are present will be washed to remove all visible soils and materials. The survey will be an alpha, beta/gamma survey, and a removable smear counted for alpha and beta/gamma activity. If surface activities exceed the established release limits, further decontamination will be required until the release limits can be achieved. These surveys will be conducted by the Umetco's Radiation Safety Officer (RSO) or designated individuals. The surface activity levels for each piece of equipment released for unrestricted use will be documented and signed by the RSO and maintained on file. A copy of the equipment release will accompany all parts, equipment and vehicles not routinely leaving the site.

### 5.3.2 Surveys for Conditional Release

#### 5.3.2.1 Heavy Equipment Surveys

All heavy equipment leaving the designated restricted area or identified 11e.(2) areas will be washed to remove visible soils and materials from tires, treads and/or wheel wells. Heavy equipment will be permitted to leave the site after removal of loose soils and materials. To verify that materials are not being tracked from the restricted area, 10 percent of the equipment will be subject to survey for fixed and removable contamination. Any equipment being transferred from the site for unrestricted release will have to meet all applicable release limits described above for unrestricted release.

#### 5.3.2.2 Pre-Entry Surveys

All of the Contractor's equipment used at the Gas Hills site will be subject to being surveyed for beta/gamma and alpha surface contamination prior to entry onto the site. The results of these surveys will be documented and may be reviewed at the Gas Hills site. If the equipment does not pass the established surface contamination criteria limits, the Owner may require the equipment to be decontaminated before allowing entry onto the site.

Any decontamination for entry onto the site will be at the Contractor's expense.

Storage and handling of hazardous materials, including flammable or combustible liquids, shall be in accordance with applicable County, State, Federal Regulations and Owner polices.

Construction activities will be performed using methods that will prevent entrance or accidental spillage of hazardous or contaminated liquids into nearby gullies or washes.

During construction, care shall be taken by the Contractor to preserve the natural landscape and prevent any unnecessary destruction, scarring or defacing of the natural surroundings in the vicinity of the work.

Best Management Practices (BMPs) will be used to prevent sediment from being transported off-site due to storm water runoff. BMPs include, but are not limited to, such sediment control practices as interceptor dikes/ditches, filter fences, straw bales, temporary sediment basins, check dams or methods approved by the Owner's project representative.

Reasonable and practical efforts will be made to operate construction equipment in a manner that minimizes emissions of air contaminates. Fugitive dust from unpaved haul roads, construction activities and other areas of heavy vehicle use will be controlled by watering, vehicle speed and/or dust suppression agents approved by Owner. If, during times of dry conditions and/or high wind, the release of fugitive dust becomes uncontrollable, Owner or Owner's representative may request that the Contractor temporarily suspend construction activities until dust releases can be controlled or atmospheric conditions improve. No compensation for the suspension of Work to comply with air quality requirements due to atmospheric conditions or excessive dust releases will be made.

**Table 5.0 Summary of QC Test Procedures**

| Procedure No. | QC Procedure Title |
|---|---|
| QC GHP - 1 | Field Inspections |
| QC GHP - 2 | Sampling of Aggregates and Soils |
| QC GHP - 3 | Field Description of Soils |
| QC GHP - 4 | Particle Size Analysis |
| QC GHP - 5 | Size Analysis of Soil Finer Than No. 200 Sieve |
| QC GHP - 6 | Moisture Content of Soils |
| QC GHP - 7 | Atterberg Tests |
| QC GHP - 8 | Soil Classification for Engineering Purposes |
| QC GHP - 9 | Laboratory Compaction Test |
| QC GHP - 10 | In-Place Density Tests |
| QC GHP - 11 | Compacted Soil Layer Thickness |
| QC GHP - 12 | Particle Size Analysis of Natural and Man-Made Riprap Materials |
| QC GHP - 13 | Rock Protection Layer Thickness |

**Table 5.1 Summary of QC Test and Inspection Forms**

| Form No. | QC Form Title |
|---|---|
| F-1 | Construction Activities Report |
| F-2 | Soil Sampling Log |
| F-3 | Gradation Analysis Worksheet |
| F-4 | Gradation Analysis with Hydrometer Worksheet |
| F-5 | Gradation Test Results |
| F-6 | Moisture & Density Worksheet |
| F-7 | Atterberg Limits 1-Point Worksheet |
| F-8 | Atterberg, -200, Moisture Density Worksheet |
| F-9 | Atterberg Limits 3-Point Worksheet |
| F-10 | Summary of Laboratory Tests |
| F-11 | Field Density (Sand Cone, Balloon) |
| F-12 | Laboratory Compaction Test |
| F-13 | Rock and Moisture Correction Calculations |
| F-14 | Moisture-Density Relationships - 1 |
| F-15 | Moisture-Density Relationships - 2 |
| F-16 | Nuclear Test Data |
| F-17 | Grouting Logs |
| F-18 | Compliance Report |
| F-19 | Field Change Order |
| F-20 | Design Change Order |

## 5.4 Test Frequencies

The minimum test frequencies performed as part of the QC program are detailed below in Table 5.2.

## Table 5.2 Minimum Test Frequencies

| Test | Procedure | Standard | Frequency |
|---|---|---|---|
| **Radon Barrier, Frost Protection Layer and Erosion Protection** | | | |
| Field Moisture and Density | QC GHP - 10 | ASTM D2922<br>ASTM D3017 | 1 test per 500 CY |
| Sand Cone Correlation | QC GHP - 10 | ASTM D1556<br>ASTM D2216 | 1 test for every 10 nuclear gauge tests |
| Laboratory Compaction | QC GHP - 9 | ASTM D698 | 1 test for every 10 field tests depending on variability of soils. |
| Soil Classification<br>• Particle Size Analysis<br>• Atterberg Limits | QC GHP - 7<br>QC GHP - 8<br>QC GHP - 12 | ASTM D2487<br>ASTM D4318<br>ASTM D1140<br>ASTM D422 | 1 test per 1000 CY |
| Erosion Protection/Bedding Materials<br>• Gradation (Quarry Production)<br>• In-Place Bedding Depth Check and Gradation | QC GHP - 12 | ASTM C117,C136<br>ASTM C117,C136 | 1 test per 10,000 CY<br>1 set of tests per 500 SF of bedding material placed. |
| **Sub-grade, Random Fill, Grading** | | | |
| Field Moisture and Density | QC GHP - 10 | ASTM D2922<br>ASTM D3017 | 1 test per 1000 CY |
| Sand Cone Correlation | QC GHP - 10 | ASTM D1556<br>ASTM D2216 | 1 test for every 10 nuclear gauge tests |
| Laboratory Compaction | QC GHP - 9 | ASTM D698 | 1 test for every 10 field tests depending on variability of soils. |
| Soil Classification<br>• Particle Size Analysis<br>• Atterberg Limits | QC GHP - 7<br>QC GHP - 8<br>QC GHP - 12 | ASTM D2487<br>ASTM D4318<br>ASTM D1140<br>ASTM D422 | 1 test per 2000 CY |

# Appendix A
# Design Calculations and Gradation Plots

## A-1 – Erosion Protection Calculations

Above Grade Tailings Impoundment, Profile 1, Segments 1 through 3,
Above Grade Tailings Impoundment, Profile 2, Segments 1 through 3,
Above Grade Tailings Impoundment, Profile 3, Segments 1 through 3, and
A-9 Repository, Profile 1, Segments 1 through 6

## A-2 – 30/70 Blended Bedding Material Design

30/70 Bedding Blend Calculations, and
30/70 Bedding Blend Gradation Plot

## A-3 – Launch Rock Filter Design

Launch Rock Filter Material Gradation Plots

## A-4 – Apron Channel Erosion Protection Design

Stephenson Method Erosion Protection Calculation, and
Stephenson Method Worksheet used for Rational
Formula determination of Unit Width Flow

# Appendix A-1 – Erosion Protection Calculations

Above Grade Tailings Impoundment, Profile 1, Segments 1 through 3,
Above Grade Tailings Impoundment, Profile 2, Segments 1 through 3,
Above Grade Tailings Impoundment, Profile 3, Segments 1 through 3, and
A-9 Repository, Profile 1, Segments 1 through 6

***Erosion Protection Calculation:***
***Safety Factors Method for Slopes Less than 10%***

Project: **Gas Hills - AGTI Profile 1**
Item: **Segment 1**
Date: **11/30/2010**

Comment:

| (min) | Rainfall Duration of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 68.48 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 68.48 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 1254 | feet | |
| Elevation Difference (H) | 9 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | *Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1)* | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| Slope (S) | 0.007 | ft/ft | |
| Slope; angle from horizontal ($\alpha$) | 0.41 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.21 | hours | *(SCS Triangular Hydrograph Theory)* |
| | 12.70 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 68.48 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.96 | inches | PMP x % of 1-hour PMP |
| Rainfall Intensity (i), see Note 1 | 28.15 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.81 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 32 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* | |
| $D_{50}$ of Riprap ($D_{50}$) | 0.38 | inches (Input Trial Riprap $D_{50}$) | |
| Cover Slope ($\alpha$) | 0.41 | degrees | |
| Mannings Coefficient (n) | 0.0222 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.3113 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.1394 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9748 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0139** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 0.56 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

0.67 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 1.38 inches/second | $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.12 feet/second | |

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

*Erosion Protection*
***Safety Factors Method - two gradient slope***

Project: **Gas Hills - AGTI Profile 1**
Item: **Segment 2**
Date: **11/30/2010**

Comment:

Rainfall Duration

| (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 78.50 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 78.50 |

**Hydrology:**

*Upper Top Slope:*

| | | | |
|---|---|---|---|
| Length of Slope (L) | 1254 | feet | |
| Elevation Difference (H) | 9 | feet | |

*Lower Top Slope:*

| | | | |
|---|---|---|---|
| Length of Slope (L) | 1130 | feet | |
| Elevation Difference (H) | 70 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |

*Upper Top Slope:*

| | | | |
|---|---|---|---|
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.41 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.21 | hours | (SCS Triangular Hydrograph Theory) |
| | 12.70 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |

*Lower Top Slope:*

| | | | |
|---|---|---|---|
| Slope (S) | 0.0619 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.54 | degrees | |
| Area; unit-width basis (Aw) | 0.05 | acres | |
| Time of Concentration (tc) | 0.09 | hours | (Kirpich Method) |
| | 5.11 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 17.81 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 78.50 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 6.83 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 23.01 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.26 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 35 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 3.0 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 3.54 | degrees | |
| Mannings Coefficient (n) | 0.0313 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2612 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.0097 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8942 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0159** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 1.80 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$ |
| $D_{50}$ (inches) = | 2.16 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 4.43 inches/second | $Vv = Wm^{0.5}\, i^{\,0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.37 feet/second | |

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

***Erosion Protection Calculation***
***<u>Safety Factors Method</u>***

Project: **Gas Hills - AGTI Profile 1**
Item: **Segment 3**
Date: **11/30/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 82.03 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 82.03 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Length of Slope (L) | 1254 | feet | |
| Elevation Difference (H) | 9 | feet | |
| *Segment 2* | | | |
| Length of Slope (L) | 1130 | feet | |
| Elevation Difference (H) | 70 | feet | |
| Segment 3 | | | |
| Length of Slope (L) | 493 | feet | |
| Elevation Difference (H) | 50 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.41 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.21 | hours | (SCS Triangular Hydrograph Theory) |
| | 12.70 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.54 | degrees | |
| Area; unit-width basis (Aw) | 0.05 | acres | |
| Time of Concentration (tc) | 0.09 | hours | (Kirpich Method) |
| | 5.11 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 3* | | | |
| Slope (S) | 0.1014 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.79 | degrees | |
| Area; unit-width basis (Aw) | 0.07 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (Kirpich Method) |
| | 2.23 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 20.04 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 82.03 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 7.14 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 21.36 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.41 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 38 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 5.0 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 5.79 | degrees | |
| Mannings Coefficient (n) | 0.0341 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2539 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.6067 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8537 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0122** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 2.37 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$ |
| $D_{50}$ (inches) = | 2.84 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 8.24 inches/second | $Vv = Wm^{0.5}\, i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.69 feet/second | |

***Erosion Protection Calculation***
***Stephenson Method for Slopes Greater than 10%***

Project: **Gas Hills - AGTI Profile 1**
Item: **Segment 3**
Date: **11/30/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 82.03 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 82.03 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *First Top Slope:* | | | |
| Length of Slope (L) | 1254 | feet | |
| Elevation Difference (H) | 9 | feet | |
| *Side Slope:* | | | |
| Length of Slope (L) | 1130 | feet | |
| Elevation Difference (H) | 70 | feet | |
| *Buried Toe Apron:* | | | |
| Length of Slope (L) | 493 | feet | |
| Elevation Difference (H) | 50 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *First Top Slope:* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.41 | degrees | |
| Area; unit-width basis (Aw) | 0.0288 | acres | |
| Time of Concentration (tc) | 0.2116 | hours | (Kirpich Method) |
| | 12.70 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Second Top Slope:* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal | 3.54 | degrees | |
| Area; unit-width basis (Aw) | 0.0259 | acres | |
| Time of Concentration (tc) | 0.0852 | hours | (Kirpich Method) |
| | 5.11 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Buried Toe Apron:* | | | |
| Slope (S) | 0.1014 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.79 | degrees | |
| Area; unit-width basis (Aw) | 0.0660 | acres | |
| Time of Concentration (tc) | 0.0372 | hours | (Kirpich Method) |
| | 2.23 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 20.04 | minutes | (tc top) + (Tc slope) |
| % of 1-hour PMP | 82.03 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 7.14 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 21.36 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.41 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design:**

| | | |
|---|---|---|
| Rockfill Porosity (n) | 0.4 | |
| Relative Density of Rock (s) | 2.52 | |
| Angle of Friction ($\phi$) | 40 | degrees |
| Empirical Factor (C) | 0.25 | (varies from 0.22 for gravel and pebbles to 0.27 for crushed granite) |

**$D_{50}$ = 0.24 feet**
**2.85 inches**

$D_{50} = q(\tan\theta)^{7/6}\, n^{1/6} / C\, g^{1/2}\, ((1-n)(s-1)\cos\theta\,(\tan\phi - \tan\theta))^{5/3})^{2/3}$ *Eq 4.28; 4620*

*acceleration of gravity (g) = 32.174 feet/second$^2$*

TYPICAL VALUES:

| | |
|---|---|
| Porosity of Rock Layer (n) | 0.39 to 0.46 |
| Angle of Friction | 37 to 42 |
| Relative Density of Rock (s): | |
| Limestone - | 2.42 to 2.74 |
| Limy Sandstone - | 2.14 to 2.67 |
| Sandstone - | 2.20 to 2.50 |
| Quartzite - | 2.66 |
| Basalt - | 2.58 |
| Granite - | 2.41 |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 2.37 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

$D_{50}$ (inches) = 2.84 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

Interstitial Flow Velocity = 8.24 inches/second $V_v = W m^{0.5}\, i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.69 feet/second

*Erosion Protection Calculation:*
***Safety Factors Method for Slopes Less than 10%***

Project: **Gas Hills - AGTI Profile 2**
Item: **Segment 1**
Date: **12/1/2010**

Comment:

| (min) | Rainfall Duration of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 30.68 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 30.68 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 246 | feet | |
| Elevation Difference (H) | 3 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | *Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1)* | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| Slope (S) | 0.012 | ft/ft | |
| Slope; angle from horizontal ($\alpha$) | 0.70 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.05 | hours | *(SCS Triangular Hydrograph Theory)* |
| | 2.95 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 30.68 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 2.67 | inches | PMP x % of 1-hour PMP |
| Rainfall Intensity (i), see Note 1 | 54.21 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.31 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 32 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* | |
| $D_{50}$ of Riprap ($D_{50}$) | 0.3 | inches (Input Trial Riprap $D_{50}$) | |
| Cover Slope ($\alpha$) | 0.70 | degrees | |
| Mannings Coefficient (n) | 0.0214 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.1446 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.1100 | lbs/sq. ft. | $\tau_o = \gamma\ \delta\ \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9746 | | $\eta = 21\ \tau_o / (\Sigma\sigma - 1)\ \gamma\ \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0058** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 0.41 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43}$ |
| | 0.49 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 0.5 inches

| | | | |
|---|---|---|---|
| Interstitial Flow Velocity = | 0.73 | inches/second | $V_v = W m^{0.5} i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.06 | feet/second | |

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

*Erosion Protection*
***Safety Factors Method - two gradient slope***

Project: **Gas Hills - AGTI Profile 2**
Item: **Segment 2**
Date: **12/1/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 47.16 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 47.16 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Upper Top Slope:* | | | |
| Length of Slope (L) | 246 | feet | |
| Elevation Difference (H) | 3 | feet | |
| *Lower Top Slope:* | | | |
| Length of Slope (L) | 545 | feet | |
| Elevation Difference (H) | 42 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *Upper Top Slope:* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.70 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.05 | hours | (SCS Triangular Hydrograph Theory) |
| | 2.95 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Lower Top Slope:* | | | |
| Slope (S) | 0.0771 | ft/ft | |
| Slope; angle from horizontal (θ) | 4.41 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (Kirpich Method) |
| | 2.68 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 5.63 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 47.16 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 4.10 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 43.69 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.79 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 35 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* | |
| $D_{50}$ of Riprap ($D_{50}$) | 2.7 | inches (Input Trial Riprap $D_{50}$) | |
| Cover Slope ($\alpha$) | 4.41 | degrees | |
| Mannings Coefficient (n) | 0.0308 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.1835 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.8823 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8682 | | $\eta = 21\,\tau_o\,/\,(\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0195** | | SF = $\cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 1.53 inches $D_{50} = 5.23\,q^{0.56}\,S^{0.43}$

$D_{50}$ (inches) = 1.83 inches $D_{50} = 5.23\,q^{0.56}\,S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

Interstitial Flow Velocity = 4.98 inches/second $V_v = W m^{0.5}\, i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.41 feet/second

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

***Erosion Protection Calculation***
***Safety Factors Method***

Project: **Gas Hills - AGTI Profile 2**
Item: **Segment 3**
Date: **12/1/2010**

Comment:

Rainfall Duration

| (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 60.64 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 60.64 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Length of Slope (L) | 246 | feet | |
| Elevation Difference (H) | 3 | feet | |
| *Segment 2* | | | |
| Length of Slope (L) | 545 | feet | |
| Elevation Difference (H) | 42 | feet | |
| Segment 3 | | | |
| Length of Slope (L) | 907 | feet | |
| Elevation Difference (H) | 70 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *Segment 1* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.70 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.05 | hours | (SCS Triangular Hydrograph Theory) |
| | 2.95 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.08 | ft/ft | |
| Slope; angle from horizontal (θ) | 4.41 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (Kirpich Method) |
| | 2.68 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 3* | | | |
| Slope (S) | 0.0772 | ft/ft | |
| Slope; angle from horizontal (θ) | 4.41 | degrees | |
| Area; unit-width basis (Aw) | 0.04 | acres | |
| Time of Concentration (tc) | 0.07 | hours | (Kirpich Method) |
| | 3.97 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 9.60 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 60.64 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.28 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 32.97 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.29 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 38 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 3.6 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 4.41 | degrees | |
| Mannings Coefficient (n) | 0.0323 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2521 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.2142 | lbs/sq. ft. | $\tau_o = \gamma\ \delta\ \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8961 | | $\eta = 21\ \tau_o\ /\ (\Sigma\sigma - 1)\ \gamma\ \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0025** | | SF = cos $\alpha$ tan $\phi$ / $\eta$ tan $\phi$ + sin $\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 2.00 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43}$ |
| $D_{50}$ (inches) = | 2.40 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 7.11 inches/second | $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.59 feet/second | |

*Erosion Protection Calculation:*
***Safety Factors Method for Slopes Less than 10%***

Project: **Gas Hills - AGTI Profile 3**
Item: **Segment 1**
Date: **12/1/2010**

Comment:

| (min) | Rainfall Duration % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 27.50 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 27.50 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 237 | feet | |
| Elevation Difference (H) | 5 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | *Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1)* | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| Slope (S) | 0.021 | ft/ft | |
| Slope; angle from horizontal ($\alpha$) | 1.21 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.04 | hours | *(SCS Triangular Hydrograph Theory)* |
| | 2.32 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 27.50 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 2.39 | inches | PMP x % of 1-hour PMP |
| Rainfall Intensity (i), see Note 1 | 57.42 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.31 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 32 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* | |
| $D_{50}$ of Riprap ($D_{50}$) | 0.48 | inches (Input Trial Riprap $D_{50}$) | |
| Cover Slope ($\alpha$) | 1.21 | degrees | |
| Mannings Coefficient (n) | 0.0231 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.1302 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.1714 | lbs/sq. ft. | $\tau_o = \gamma\ \delta\ \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9485 | | $\eta = 21\ \tau_o / (\Sigma\sigma - 1)\ \gamma\ \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0179** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 0.52 inches $D_{50} = 5.23\ q^{0.56}\ S^{0.43}$

0.62 inches $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 0.5 inches

| | | | |
|---|---|---|---|
| Interstitial Flow Velocity = | 0.99 | inches/second | $Vv = Wm^{0.5}\, i^{\,0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.08 | feet/second | |

*Erosion Protection*
*Safety Factors Method - two gradient slope*

Project: **Gas Hills - AGTI Profile 3**
Item: **Segment 2**
Date: **12/1/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 46.20 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 46.20 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Upper Top Slope:* | | | |
| Length of Slope (L) | 237 | feet | |
| Elevation Difference (H) | 5 | feet | |
| *Lower Top Slope:* | | | |
| Length of Slope (L) | 682 | feet | |
| Elevation Difference (H) | 60 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |
| *Upper Top Slope:* | | | |
| Slope (S) | 0.02 | ft/ft | |
| Slope; angle from horizontal | 1.21 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (SCS Triangular Hydrograph Theory) |
| | 2.32 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Lower Top Slope:* | | | |
| Slope (S) | 0.0880 | ft/ft | |
| Slope; angle from horizontal ($\theta$) | 5.03 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.05 | hours | (Kirpich Method) |
| | 3.03 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 5.35 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 46.20 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 4.02 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 45.06 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.95 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 35 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 3.37 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 5.03 | degrees | |
| Mannings Coefficient (n) | 0.0320 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2009 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.1031 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8697 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0013** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 1.79 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$ |
| $D_{50}$ (inches) = | 2.15 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 5.35 inches/second | $Vv = Wm^{0.5}\, i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.45 feet/second | |

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

*Erosion Protection Calculation*
***Safety Factors Method***

Project: **Gas Hills - AGTI Profile 3**
Item: **Segment 3**
Date: **12/1/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 61.24 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 61.24 |

**Hydrology:**

*Segment 1*

| | | |
|---|---|---|
| Length of Slope (L) | 237 | feet |
| Elevation Difference (H) | 5 | feet |

*Segment 2*

| | | |
|---|---|---|
| Length of Slope (L) | 682 | feet |
| Elevation Difference (H) | 60 | feet |

Segment 3

| | | |
|---|---|---|
| Length of Slope (L) | 678 | feet |
| Elevation Difference (H) | 22 | feet |

| | | |
|---|---|---|
| PMP | 8.7 | inches |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |

*Segment 1*

| | | | |
|---|---|---|---|
| Slope (S) | 0.02 | ft/ft | |
| Slope; angle from horizontal | 1.21 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (SCS Triangular Hydrograph Theory) |
| | 2.32 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |

*Segment 2*

| | | | |
|---|---|---|---|
| Slope (S) | 0.09 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.03 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.05 | hours | (Kirpich Method) |
| | 3.03 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

*Segment 3*

| | | | |
|---|---|---|---|
| Slope (S) | 0.0324 | ft/ft | |
| Slope; angle from horizontal (θ) | 1.86 | degrees | |
| Area; unit-width basis (Aw) | 0.04 | acres | |
| Time of Concentration (tc) | 0.07 | hours | (Kirpich Method) |
| | 4.42 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 9.78 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 61.24 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.33 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 32.70 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.20 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 38 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 1.7 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 1.86 | degrees | |
| Mannings Coefficient (n) | 0.0285 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2909 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.5890 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9206 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0389** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 1.33 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

$D_{50}$ (inches) = 1.59 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

Interstitial Flow Velocity = 4.45 inches/second $Vv = Wm^{0.5}\, i^{\,0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.37 feet/second

***Erosion Protection Calculation:***
***<u>Safety Factors Method</u>***

Project: **Gas Hills - AGTI Profile 3**
Item: **Segment 4**
Date: **12/1/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 67.30 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 67.30 |

**Hydrology:**

| | | |
|---|---|---|
| *Segment 1* | | |
| Length of Slope (L) | 237 | feet |
| Elevation Difference (H) | 5 | feet |
| *Segment 2* | | |
| Length of Slope (L) | 682 | feet |
| Elevation Difference (H) | 60 | feet |
| Segment 3 | | |
| Length of Slope (L) | 678 | feet |
| Elevation Difference (H) | 22 | feet |
| *Segment 4* | | |
| Length of Slope (L) | 410 | feet |
| Elevation Difference (H) | 23 | feet |
| PMP | 8.7 | inches |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Slope (S) | 0.02 | ft/ft | |
| Slope; angle from horizontal | 1.21 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (SCS Triangular Hydrograph Theory) |
| | 2.32 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.09 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.03 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.05 | hours | (Kirpich Method) |
| | 3.03 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 3* | | | |
| Slope (S) | 0.03 | ft/ft | |
| Slope; angle from horizontal (θ) | 1.86 | degrees | |
| Area; unit-width basis (Aw) | 0.04 | acres | |
| Time of Concentration (tc) | 0.07 | hours | (Kirpich Method) |
| | 4.42 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 4* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.21 | degrees | |
| Area; unit-width basis (Aw) | 0.05 | acres | |
| Time of Concentration (tc) | 0.04 | hours | (Kirpich Method) |
| | 2.43 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 12.21 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 67.30 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.86 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 28.78 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.33 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design:**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 36 | | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 2.8 | inches | (Input Trial Riprap $D_{50}$) |
| Cover Slope ($\alpha$) | 3.21 | degrees | |
| Mannings Coefficient (n) | 0.0310 | | $n = 0.0395\,(D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2756 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.9649 | lbs/sq. ft. | $\tau_o = \gamma\,\delta\,\Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9156 | | $\eta = 21\,\tau_o / (\Sigma\sigma - 1)\,\gamma\,\Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0058** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 1.77 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

$D_{50}$ (inches) = 2.13 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

Interstitial Flow Velocity = 5.99 inches/second $V_v = W m^{0.5}\, i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.50 feet/second

*Erosion Protection Calculation:*
***Safety Factors Method for Slopes Less than 10%***

Project: **Gas Hills - A-9**
Item: **Segment 1**
Date: **11/29/2010**

Comment:

| (min) | Rainfall Duration % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 48.34 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 48.34 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 571 | feet | |
| Elevation Difference (H) | 6 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | *Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1)* | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| Slope (S) | 0.011 | ft/ft | |
| Slope; angle from horizontal ($\alpha$) | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | *(SCS Triangular Hydrograph Theory)* |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 48.34 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 4.21 | inches | PMP x % of 1-hour PMP |
| Rainfall Intensity (i), see Note 1 | 42.18 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.55 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | | |
|---|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | | |
| Specific Weight of Rock (Ss) | 2.52 | | |
| Angle of Repose of Riprap ($\phi$) | 33 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* | |
| $D_{50}$ of Riprap ($D_{50}$) | 0.4 | inches (Input Trial Riprap $D_{50}$) | |
| Cover Slope ($\alpha$) | 0.60 | degrees | |
| Mannings Coefficient (n) | 0.0224 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2219 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.1455 | lbs/sq. ft. | $\tau_o = \gamma\ \delta\ \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9664 | | $\eta = 21\ \tau_o / (\Sigma\sigma - 1)\ \gamma\ \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0177** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 0.53 inches $D_{50} = 5.23\ q^{0.56}\ S^{0.43}$

0.64 inches $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on SF Design D50:**

Interstitial Flow Velocity = 0.60 inches/second $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.05 feet/second

***Erosion Protection***
***Safety Factors Method - two gradient slope***

Project: **Gas Hills - A-9**
Item: **Segment 2**
Date: **11/29/2010**

Comment:

Rainfall Duration

| (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 54.47 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 54.47 |

**Hydrology:**

*Upper Top Slope:*

| | | | |
|---|---|---|---|
| Length of Slope (L) | 571 | feet | |
| Elevation Difference (H) | 6 | feet | |

*Lower Top Slope:*

| | | | |
|---|---|---|---|
| Length of Slope (L) | 377 | feet | |
| Elevation Difference (H) | 39 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |

*Upper Top Slope:*

| | | | |
|---|---|---|---|
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | (SCS Triangular Hydrograph Theory) |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |

*Lower Top Slope:*

| | | | |
|---|---|---|---|
| Slope (S) | 0.1034 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.03 | hours | (Kirpich Method) |
| | 1.80 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 7.78 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 54.47 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 4.74 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 36.52 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.79 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 36 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 3.5 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 5.91 | degrees | |
| Mannings Coefficient (n) | 0.0322 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.1726 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.1140 | lbs/sq. ft. | $\tau_o = \gamma\, \delta\, \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.8457 | | $\eta = 21\ \tau_o / (\Sigma\sigma - 1)\ \gamma\, \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0075** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 1.73 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

$D_{50}$ (inches) = 2.08 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

Interstitial Flow Velocity = 5.84 inches/second $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.49 feet/second

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

***Erosion Protection Calculation***

***Stephenson Method for Slopes Greater than 10%***

*For Analysis of Top discharge to Sideslope*

Project: **Gas Hills - A-9**
Item: **Segment 2**
Date: **11/30/2010**

Comment:

Rainfall Duration

| (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 54.47 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 54.47 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Top Slope:* | | | |
| Length of Slope (L) | 571 | feet | |
| Elevation Difference (H) | 6 | feet | |
| *Side Slope:* | | | |
| Length of Slope (L) | 377 | feet | |
| Elevation Difference (H) | 39 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *Top Slope:* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | (Kirpich Method) |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Side Slope:* | | | |
| Slope (S) | 0.10 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.03 | hours | (SCS Triangular Hydrograph Theory) |
| | 1.80 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 7.78 | minutes | (tc top) + (Tc slope) |
| % of 1-hour PMP | 54.47 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 4.74 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 36.52 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.79 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Stephenson**

| | | |
|---|---|---|
| Rockfill Porosity (n) | 0.4 | |
| Relative Density of Rock (s) | 2.52 | |
| Angle of Friction ($\phi$) | 40 | degrees |
| Empirical Factor (C) | 0.25 | (varies from 0.22 for gravel and pebbles to 0.27 for crushed granite) |

**$D_{50}$ = 0.16 feet**
**1.98 inches**

$D_{50} = q(\tan\theta)^{7/6} n^{1/6} / C g^{1/2} ((1-n)(s-1) \cos\theta (\tan\phi - \tan\theta))^{5/3})^{2/3}$ *Eq 4.28; 4620*

*acceleration of gravity (g) = 32.174 feet/second$^2$*

TYPICAL VALUES:

| | |
|---|---|
| Porosity of Rock Layer (n) | 0.39 to 0.46 |
| Angle of Friction | 37 to 42 |
| Relative Density of Rock (s): | |
| Limestone - | 2.42 to 2.74 |
| Limy Sandstone - | 2.14 to 2.67 |
| Sandstone - | 2.20 to 2.50 |
| Quartzite - | 2.66 |
| Basalt - | 2.58 |
| Granite - | 2.41 |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 1.73 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$

$D_{50}$ (inches) = 2.08 inches $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

Interstitial Flow Velocity = 5.84 inches/second $V_v = W m^{0.5}\, i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.49 feet/second

1) Bedding Layer Placed (Heap Leach Design)
2) Because segment 2 slope is very close to 10%, segment will also be evaluated using Stephenson Method.

***Erosion Protection Calculation***
***<u>Safety Factors Method</u>***

Project: **Gas Hills - A-9**
Item: **Segment 3**
Date: **11/30/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 58.34 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 58.34 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Length of Slope (L) | 571 | feet | |
| Elevation Difference (H) | 6 | feet | |
| *Segment 2* | | | |
| Length of Slope (L) | 377 | feet | |
| Elevation Difference (H) | 39 | feet | |
| Segment 3 | | | |
| Length of Slope (L) | 161 | feet | |
| Elevation Difference (H) | 10 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *Segment 1* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | (SCS Triangular Hydrograph Theory) |
| | 5.98 | minutes | $tc = (11.9 L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.10 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.03 | hours | (Kirpich Method) |
| | 1.80 | minutes | $tc = (11.9 L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 3* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.55 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.02 | hours | (Kirpich Method) |
| | 1.14 | minutes | $tc = (11.9 L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 8.92 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 58.34 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.08 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 34.13 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 0.87 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 38 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 2.3 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 3.55 | degrees | |
| Mannings Coefficient (n) | 0.0300 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2034 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.7884 | lbs/sq. ft. | $\tau_o = \gamma\, \delta\, \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9108 | | $\eta = 21\, \tau_o / (\Sigma\sigma - 1)\, \gamma\, \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0081** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 1.46 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$ |
| $D_{50}$ (inches) = | 1.76 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 6.32 inches/second | $Vv = Wm^{0.5}\, i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.53 feet/second | |

***Erosion Protection Calculation:***
***Safety Factors Method***

Project: Gas Hills - A-9
Item: Segment 4
Date: 11/30/2010

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 76.90 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 76.90 |

**Hydrology:**

| | | |
|---|---|---|
| *Segment 1* | | |
| Length of Slope (L) | 571 | feet |
| Elevation Difference (H) | 6 | feet |
| *Segment 2* | | |
| Length of Slope (L) | 377 | feet |
| Elevation Difference (H) | 39 | feet |
| Segment 3 | | |
| Length of Slope (L) | 161 | feet |
| Elevation Difference (H) | 10 | feet |
| *Segment 4* | | |
| Length of Slope (L) | 1354 | feet |
| Elevation Difference (H) | 39 | feet |
| PMP | 8.7 | inches |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | (SCS Triangular Hydrograph Theory) |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.10 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.03 | hours | (Kirpich Method) |
| | 1.80 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 3* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.55 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.02 | hours | (Kirpich Method) |
| | 1.14 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 4* | | | |
| Slope (S) | 0.03 | ft/ft | |
| Slope; angle from horizontal (θ) | 1.65 | degrees | |
| Area; unit-width basis (Aw) | 0.06 | acres | |
| Time of Concentration (tc) | 0.13 | hours | (Kirpich Method) |
| | 7.89 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 16.81 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 76.90 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 6.69 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 23.88 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.35 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design:**

| | | |
|---|---|---|
| Specific Weight of Liquid ($\gamma$) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap ($\phi$) | 36 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 1.7 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope ($\alpha$) | 1.65 | degrees | |
| Mannings Coefficient (n) | 0.0285 | | $n = 0.0395 (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.3238 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 0.5819 | lbs/sq. ft. | $\tau_o = \gamma \delta \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number ($\eta$) | 0.9094 | | $\eta = 21 \tau_o / (\Sigma\sigma - 1) \gamma \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0532** | | SF = $\cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 1.35 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43}$ |
| $D_{50}$ (inches) = | 1.62 inches | $D_{50} = 5.23\, q^{0.56}\, S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 3 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 2.93 inches/second | $Vv = Wm^{0.5}\, i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.24 feet/second | |

***RIPRAP DESIGN:***
***<u>Stephenson Method for Slopes Greater than 10%</u>***

Project: **Gas Hills A-9**
Item: **Segment 5**
Date: **11/30/2010**

Comment: Segment 5

Rainfall Duration

| (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 78.01 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 78.01 |

**Hydrology:**

| | | | |
|---|---|---|---|
| *Segment 1* | | | |
| Length of Slope (L) | 571 | feet | |
| Elevation Difference (H) | 6 | feet | |
| *Segment 2* | | | |
| Length of Slope (L) | 377 | feet | |
| Elevation Difference (H) | 39 | feet | |
| *Segment 3* | | | |
| Length of Slope (L) | 161 | feet | |
| Elevation Difference (H) | 10 | feet | |
| *Segment 4* | | | |
| Length of Slope (L) | 1354 | feet | |
| Elevation Difference (H) | 39 | feet | |
| *Segment 5* | | | |
| Length of Slope (L) | 120 | feet | |
| Elevation Difference (H) | 15 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) | |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* | |
| *Segment 1* | | | |
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.0131 | acres | |
| Time of Concentration (tc) | 0.0997 | hours | (Kirpich Method) |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 2* | | | |
| Slope (S) | 0.10 | ft/ft | |
| Slope; angle from horizontal | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.0087 | acres | |
| Time of Concentration (tc) | 0.0300 | hours | (Kirpich Method) |
| | 1.80 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| *Segment 3* | | | |
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.55 | degrees | |
| Area; unit-width basis (Aw) | 0.0255 | acres | |
| Time of Concentration (tc) | 0.0190 | hours | (Kirpich Method) |
| | 1.14 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| *Segment 4* | | | |
| Slope (S) | 0.03 | ft/ft | |
| Slope; angle from horizontal (θ) | 1.65 | degrees | |
| Area; unit-width basis (Aw) | 0.0565 | acres | |
| Time of Concentration (tc) | 0.1315 | hours | (Kirpich Method) |
| | 7.89 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| *Segment 5* | | | |
| Slope (S) | 0.13 | ft/ft | |
| Slope; angle from horizontal (θ) | 7.13 | degrees | |
| Area; unit-width basis (Aw) | 0.0593 | acres | |
| Time of Concentration (tc) | 0.0116 | hours | (Kirpich Method) |
| | 0.69 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |
| Total tc for sideslopes (tc) | 17.51 | minutes | (tc top) + (Tc slope) |
| % of 1-hour PMP | 78.01 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 6.79 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 23.26 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.38 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Stephenson**

| | | |
|---|---|---|
| Rockfill Porosity (n) | 0.4 | |
| Relative Density of Rock (s) | 2.52 | |
| Angle of Friction (ϕ) | 40 | degrees |
| Empirical Factor (C) | 0.26 | (varies from 0.22 for gravel and pebbles to 0.27 for crushed granite) |

**$D_{50}$ = 0.28 feet**
**3.34 inches**

$D_{50} = q(\tan\theta)^{7/6}\ n^{1/6} / C\ g^{1/2}\ ((1-n)(s-1)\cos\theta\ (\tan\phi - \tan\theta))^{5/3})^{2/3}$ *Eq 4.28; 4620*

*acceleration of gravity (g) = 32.174 feet/second²*

TYPICAL VALUES:

| | |
|---|---|
| Porosity of Rock Layer (n) | 0.39 to 0.46 |
| Angle of Friction | 37 to 42 |
| Relative Density of Rock (s): | |
| Limestone - | 2.42 to 2.74 |
| Limy Sandstone - | 2.14 to 2.67 |
| Sandstone - | 2.20 to 2.50 |
| Quartzite - | 2.66 |
| Basalt - | 2.58 |
| Granite - | 2.41 |

**Riprap Design: Abt and Johnson**

$D_{50}$ (inches) = 2.56 inches *$D_{50} = 5.23\ q^{0.56}\ S^{0.43}$*

$D_{50}$ (inches) = 3.07 inches *$D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$*

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

Interstitial Flow Velocity = 9.23 inches/second $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973)

Interstitial Flow Velocity = 0.77 feet/second

***RIPRAP DESIGN:***
***Safety Factors Method for three Gradient Top Slope***

Project: **Gas Hills - A-9**
Item: **Segment 6**
Date: **11/30/2010**

Comment:

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 0.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 79.48 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 79.48 |

**Hydrology:**

*Segment 1*

| | | |
|---|---|---|
| Length of Slope (L) | 571 | feet |
| Elevation Difference (H) | 6 | feet |

*Segment 2*

| | | |
|---|---|---|
| Length of Slope (L) | 377 | feet |
| Elevation Difference (H) | 39 | feet |

Segment 3

| | | |
|---|---|---|
| Length of Slope (L) | 161 | feet |
| Elevation Difference (H) | 10 | feet |

*Segment 4*

| | | |
|---|---|---|
| Length of Slope (L) | 1354 | feet |
| Elevation Difference (H) | 39 | feet |

*Segment 5*

| | | |
|---|---|---|
| Length of Slope (L) | 120 | feet |
| Elevation Difference (H) | 15 | feet |

*Segment 6*

| | | |
|---|---|---|
| Length of Slope (L) | 124 | feet |
| Elevation Difference (H) | 8 | feet |

| | | |
|---|---|---|
| PMP | 8.7 | inches |
| Runoff Coefficient (C) | 1 | Runoff Coefficient of 1 is recommended for PMP applications. (refer to NUREG/CR-4620, section 4.8.1) |
| Flow Concentration Factor (CF) | 1 | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor.* |

*Segment 1*

| | | | |
|---|---|---|---|
| Slope (S) | 0.01 | ft/ft | |
| Slope; angle from horizontal | 0.60 | degrees | |
| Area; unit-width basis (Aw) | 0.01 | acres | |
| Time of Concentration (tc) | 0.10 | hours | (SCS Triangular Hydrograph Theory) |
| | 5.98 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |

*Segment 2*

| | | | |
|---|---|---|---|
| Slope (S) | 0.10 | ft/ft | |
| Slope; angle from horizontal (θ) | 5.91 | degrees | |
| Area; unit-width basis (Aw) | 0.02 | acres | |
| Time of Concentration (tc) | 0.03 | hours | (Kirpich Method) |
| | 1.80 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

*Segment 3*

| | | | |
|---|---|---|---|
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.55 | degrees | |
| Area; unit-width basis (Aw) | 0.03 | acres | |
| Time of Concentration (tc) | 0.02 | hours | (Kirpich Method) |
| | 1.14 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

*Segment 4*

| | | | |
|---|---|---|---|
| Slope (S) | 0.03 | ft/ft | |
| Slope; angle from horizontal (θ) | 1.65 | degrees | |
| Area; unit-width basis (Aw) | 0.06 | acres | |
| Time of Concentration (tc) | 0.13 | hours | (Kirpich Method) |
| | 7.89 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

*Segment 5*

| | | | |
|---|---|---|---|
| Slope (S) | 0.13 | ft/ft | |
| Slope; angle from horizontal (θ) | 7.13 | degrees | |
| Area; unit-width basis (Aw) | 0.06 | acres | |
| Time of Concentration (tc) | 0.01 | hours | (Kirpich Method) |
| | 0.69 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

*Segment 6*

| | | | |
|---|---|---|---|
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.69 | degrees | |
| Area; unit-width basis (Aw) | 0.06 | acres | |
| Time of Concentration (tc) | 0.02 | hours | (Kirpich Method) |
| | 0.92 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ *page D-3; STP* |

| | | | |
|---|---|---|---|
| Total tc for sideslopes (tc) | 18.43 | minutes | (tc top) + (tc slope) |
| % of 1-hour PMP | 79.48 | % | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 6.91 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 22.52 | in/hr | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.40 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

**Riprap Design: Safety Factors**

| | | |
|---|---|---|
| Specific Weight of Liquid (γ) | 62.4 | |
| Specific Weight of Rock (Ss) | 2.52 | |
| Angle of Repose of Riprap (φ) | 40 | *(Refer to Fig. 4.8; Page 46; NUREG/CR-4620)* |
| $D_{50}$ of Riprap ($D_{50}$) | 3.3 | inches (Input Trial Riprap $D_{50}$) |

| | | | |
|---|---|---|---|
| Cover Slope (α) | 3.69 | degrees | |
| Mannings Coefficient (n) | 0.0319 | | $n = 0.0395\ (D_{50})^{1/6}$ *Eq. 4.41; 4620* |
| Depth of Flow (d) | 0.2775 | feet | $((q \times n)/1.486(S)^{1/2})^{3/5}$ *Eq. 4.55; 4620* |
| Bed Shear Stress ($\tau_o$) | 1.1173 | lbs/sq. ft. | $\tau_o = \gamma\ \delta\ \Sigma$ *Eθ. 4.21; 4620* |
| Stability Number (η) | 0.8996 | | $\eta = 21\ \tau_o / (\Sigma\sigma - 1)\ \gamma\ \Delta_{50}$ *Eθ. 4.20; 4620* |
| **Safety Factor =** | **1.0222** | | $SF = \cos\alpha \tan\phi / \eta \tan\phi + \sin\alpha$ *Eq. 4.27; 4620* |

**Riprap Design: Abt and Johnson**

| | | |
|---|---|---|
| $D_{50}$ (inches) = | 1.94 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43}$ |
| $D_{50}$ (inches) = | 2.33 inches | $D_{50} = 5.23\ q^{0.56}\ S^{0.43} \times 1.20$ |

**Interstitial Flow Velocity based on Design (Placed $D_{50}$)**

Design/Placed $D_{50}$ = 6 inches

| | | |
|---|---|---|
| Interstitial Flow Velocity = | 6.45 inches/second | $Vv = Wm^{0.5}\ i^{0.54}$ (Leps (1973) |
| Interstitial Flow Velocity = | 0.54 feet/second | |

## Appendix A-2 – 30/70 Blended Bedding Material Design

30/70 Bedding Blend Calculations, and
30/70 Bedding Blend Gradation Plot

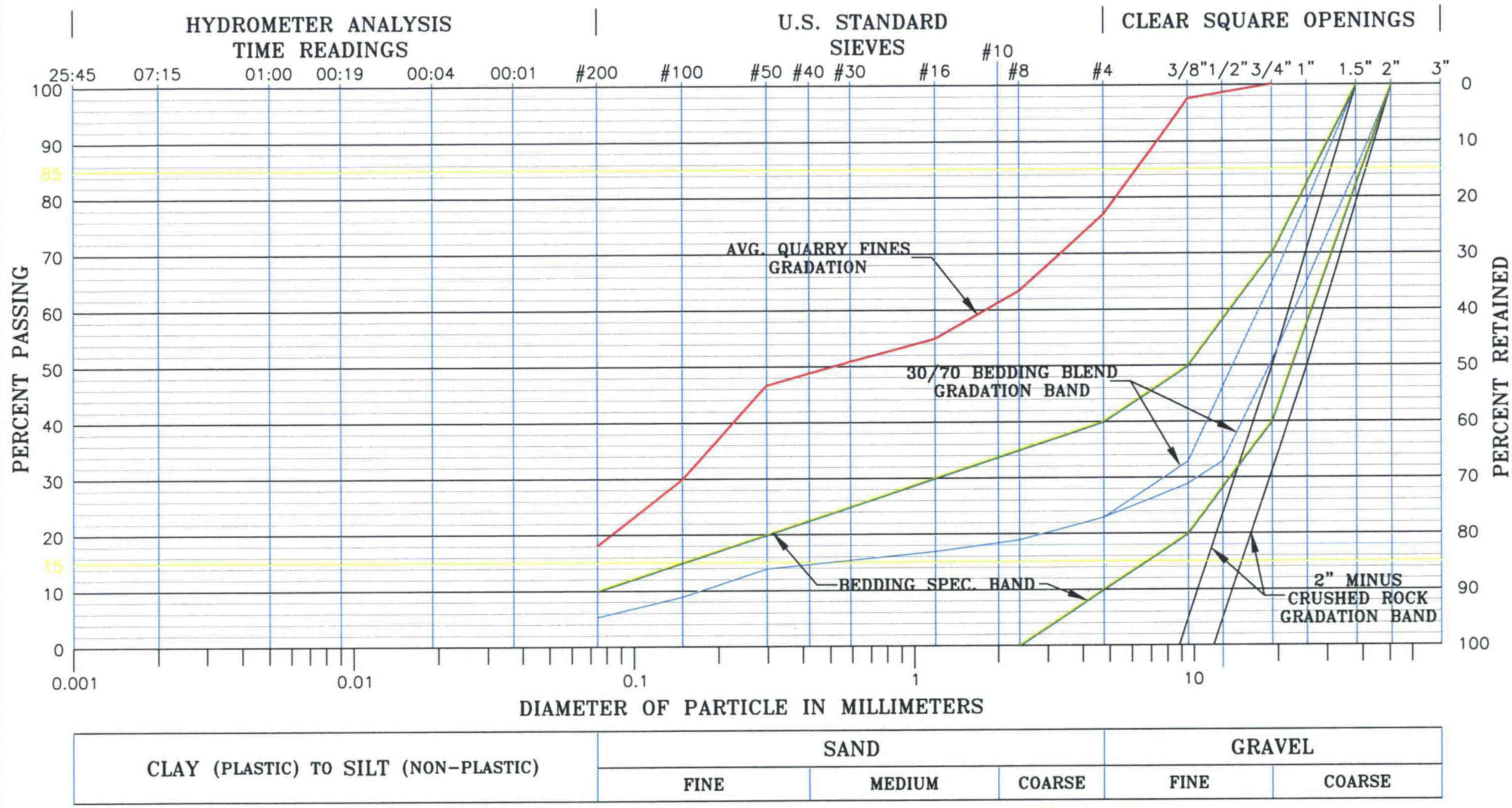
**Gas Hills Bedding Blend Calculations (11-10-2010):**
30% (fines) / 70% Crushed Rock (High Band Crushed Rock Gradation)

| Material | Aggregate 1 (Fines)* | | Aggregate 2 (2" Max) | | Aggregate 3 (N/A) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % used | | 30 | | 70 | | | | | |
| | | | | | | | | | |
| Sieve | % Pass | % Blend | % Pass | % Blend | % Pass | % Blend | Total Blend | Target Value | Design Range |
| 2 | 100 | 30 | 100 | 70 | | | 100 | 100 | 100 |
| 1 1/2 | 100 | 30 | 79 | 55 | | | 85 | | 80 -100 |
| 1 | 100 | 30 | 50 | 35 | | | 65 | <72 | |
| 0.75 (3/4) | 100 | 30 | 30 | 21 | | | 51 | | 40 - 70 |
| 0.5 (1/2) | 99 | 30 | 5 | 3.5 | | | 33 | | |
| 0.375 (3/8) | 98 | 29 | | 0 | | | 29 | | 20 - 50 |
| No. 4 | 77 | 23 | | | | | 23 | | 10 - 60 |
| No. 8 | 63 | 19 | | | | | 19 | | |
| No.16 | 55 | 17 | | | | | 17 | | |
| No. 30 | 51 | 15 | | | | | 15 | | |
| No. 50 | 47 | 14 | | | | | 14 | | |
| No. 100 | 30 | 9 | | | | | 9 | | |
| No. 200 | 18.0 | 5.4 | | | | | 5.4 | | 0 - 10 |

**Gas Hills 30/70 Bedding Blend Calculations (11-10-2010):**
30% (fines) / 70% 2-inch Minus Crushed Rock (Low Band Crushed Rock Gradation)

| Material | Aggregate 1 (Fines)* | | Aggregate 2 (2" Max) | | Aggregate 3 (N/A) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % used | | 30 | | 70 | | | | | |
| | | | | | | | | | |
| Sieve | % Pass | % Blend | % Pass | % Blend | % Pass | % Blend | Total Blend | Target Value | Design Range |
| 2 | 100 | 30 | 100 | 70 | | | 100 | 100 | 100 |
| 1 1/2 | 100 | 30 | 100 | 70 | | | 100 | | 80 -100 |
| 1 | 100 | 30 | 70 | 49 | | | 79 | <72 | |
| 0.75 (3/4) | 100 | 30 | 50 | 35 | | | 65 | | 40 - 70 |
| 0.375 (3/8) | 98 | 29 | 5 | 3.5 | | | 33 | | 20 - 50 |
| No. 4 | 77 | 23 | | | | | 23 | | 10 - 40 |
| No. 8 | 63 | 19 | | | | | 19 | | |
| No.16 | 55 | 17 | | | | | 17 | | |
| No. 30 | 51 | 15 | | | | | 15 | | |
| No. 50 | 47 | 14 | | | | | 14 | | |
| No. 100 | 30 | 9 | | | | | 9 | | |
| No. 200 | 18.0 | 5.4 | | | | | 5.4 | | 0 - 10 |

* Average of Quarry Fine Gradations Tested During Quarry Processing




NOTES:

D85 (30/70 BLEND HIGH SPEC. BAND) = 1.56"
D85 (30/70 BLEND LOW SPEC. BAND) = 1.05"

D50 (30/70 BLEND HIGH SPEC. BAND) = 0.88"
D50 (30/70 BLEND LOW SPEC. BAND) = 0.38"

D15 (30/70 BLEND HIGH SPEC. BAND) = 0.27"
D15 (30/70 BLEND LOW SPEC. BAND) = 0.006"

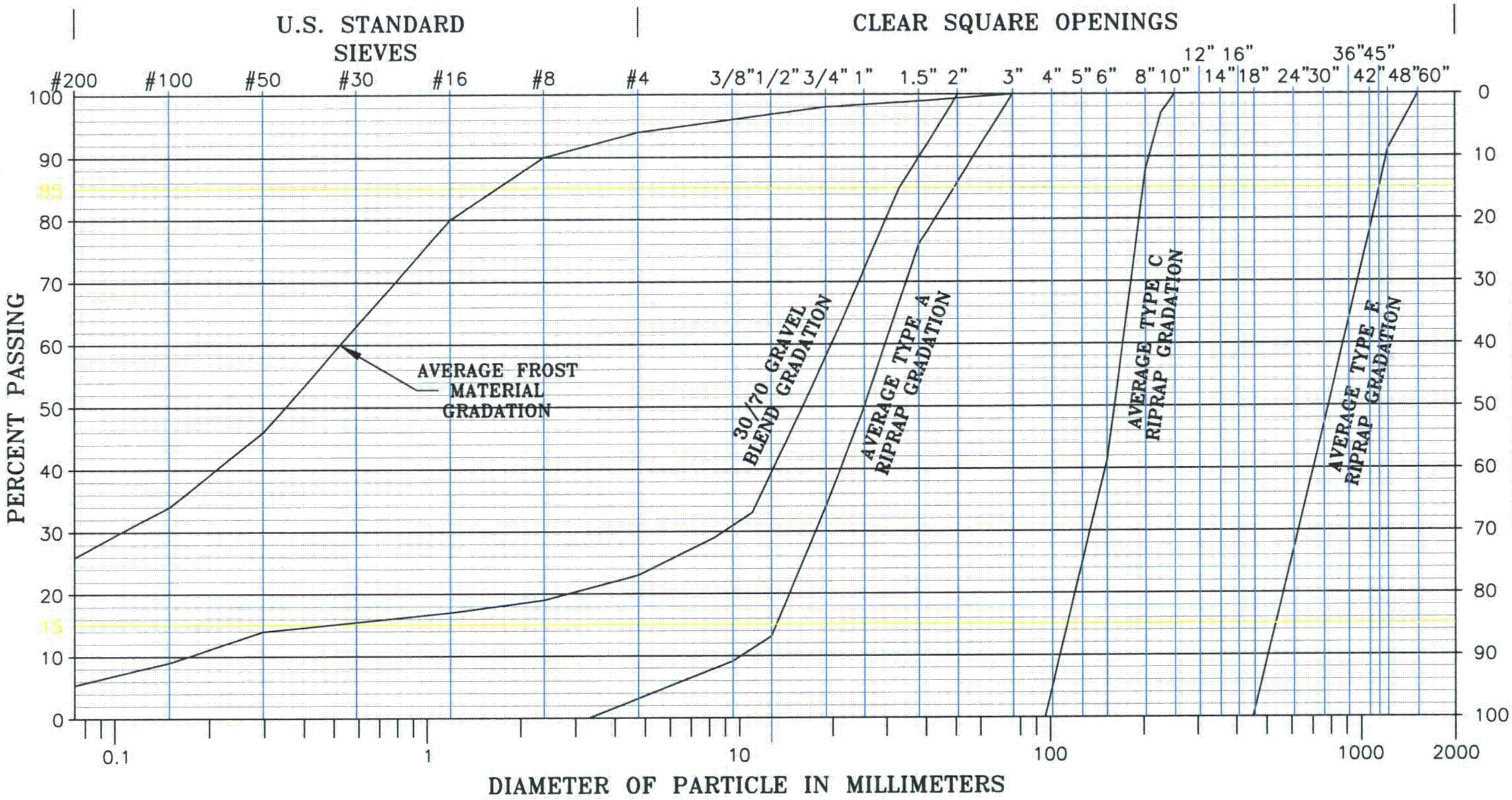
DESIGNATION: TYPE C BEDDING BLEND SAMPLE No: BLEND CALCULATIONS DATE: 11/10/2010

Umetco Minerals Corp.
Remedial Activities
GAS HILLS
30/70 BEDDING BLEND

NOVEMBER 10, 2010 Figure 1

# Appendix A-3 – Launch Rock Filter Design

Launch Rock Filter Material Gradation Plots




NOTES:

D15 (FROST MATERIAL) = 0.0011"
D50 (FROST MATERIAL) = 0.02"
D85 (FROST MATERIAL) = 0.066"

D15 (30/70 BLEND) = 0.02"
D50 (30/70 BLEND) = 0.64"
D85 (30/70 BLEND) = 1.31"

D15 (TYPE A RIPRAP) = 0.52"
D50 (TYPE A RIPRAP) = 1.00"
D85 (TYPE A RIPRAP) = 1.95"

D15 (TYPE C RIPRAP) = 4.48"
D50 (TYPE C RIPRAP) = 6.32"
D85 (TYPE C RIPRAP) = 7.86"

D15 (TYPE E RIPRAP) = 21.0"
D50 (TYPE E RIPRAP) = 31.0"
D85 (TYPE E RIPRAP) = 45.1"

Umetco Minerals Corp.
Remedial Activities
GAS HILLS LAUNCH ROCK FILTER DESIGN

November, 2010 Figure 2

## Appendix A-4 – Apron Channel Erosion Protection Design

Stephenson Method Erosion Protection Calculation, and
Stephenson Method Worksheet used for Rational
Formula determination of Unit Width Flow.

***RIPRAP DESIGN:***
***Stephenson Method for Slopes Greater than 10%***

Project: **Gas Hills**
Item: **Discharge Apron**
Date: **8/4/2010**

Comment: **Apron channel on Above Grade TI. Southwest of Wetlands**
**100 yr., 24 hr precip. = 3.2"**
**PMP = 8.7 in/hr**

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 59.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 59.00 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 2310.13 | feet | |
| Elevation Difference (H) | 133 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | | *Recommended runoff coefficient of 1 be used for PMF applications. (refer to NUREG CR-4620, section 4.8.1)* |
| Flow Concentration Factor (CF) | 3 | | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor* (enter 0 if not PMP application) |

| | | | |
|---|---|---|---|
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.30 | degrees | |
| Area; unit-width basis (Aw) | 0.05 | acres | |
| Time of Concentration (tc) | 0.15 | hours | *(Kirich Method)* |
| | 9.12 | minutes | $tc = (11.9\ L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 59.00 | | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.13 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (i), see Note 1 | 33.78 | inches/hour | i = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 5.37 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

**Riprap Design:**

| | | | |
|---|---|---|---|
| Rockfill Porosity (n) | 0.4 | | |
| Relative Density of Rock (s) | 2.56 | | |
| Angle of Friction (ϕ) | 40 | degrees | |
| Empirical Factor (C) | 0.25 | | *(varies from 0.22 for gravel and pebbles to 0.27 for crushed granite; NUREG/CR-4620 page 48)* |

**$D_{50}$ = 0.33795 feet**
**4.06 inches**

$D_{50} = (q(\tan\theta)^{7/6} n^{1/6} / C g^{1/2} ((1-n)(s-1) \cos\theta (\tan\phi - \tan\theta))^{5/3})^{2/3}$ *Eq 4.28; 4620*
*acceleration of gravity (g) = 32.174 feet/second²*

Note 1 : If Tc <= 2.5 min then: i = PMP rainfall depth x (60/2.5 min)

TYPICAL VALUES:

Porosity of Rock Layer (n) 0.39 to 0.46
Angle of Friction 37 to 42
Relative Density of Rock (s):
Limestone - 2.42 to 2.74
Limy Sandstone - 2.14 to 2.67
Sandstone - 2.20 to 2.50
Quartzite - 2.66
Basalt - 2.58
Granite - 2.41

*Flow Concentration Factor:*

*The Flow Concentration Factor is multiplied by the peak flow rate. Flow Concentration Factor is incorporated into the design process to account for cover modifications resulting from differential settlement, collapsing soils, marginal quality control in cover placement, erosion, major hydraulic events and monitoring disturbance. It is reasonable to assume that values between 2 and 3 are attainable with only a slight evolutionary chage in the cover. Flow Concentration Factor is not utilized in NRC/STP or DOE/TAD design procedures.*

***RIPRAP DESIGN:***
***Stephenson Method for Slopes Greater than 10%***

Project: **Gas Hills**
Item: **Discharge Apron**
Date: **8/4/2010**

Comment: **Determine unit flow for Abt/Johnson sizing calculation. Use flow concentration of 1, to obtain unit flow. PMP = 8.7 in/hr**

| Rainfall Duration (min) | % of 1-hour PMP | |
|---|---|---|
| 2.5 | 27.5 | 0.00 |
| 5 | 45 | 0.00 |
| 10 | 62 | 59.00 |
| 15 | 74 | 0.00 |
| 20 | 82 | 0.00 |
| 30 | 89 | 0.00 |
| 45 | 95 | 0.00 |
| 60 | 100 | 0.00 |
| | | 59.00 |

**Hydrology:**

| | | | |
|---|---|---|---|
| Length of Slope (L) | 2310.13 | feet | |
| Elevation Difference (H) | 133 | feet | |
| PMP | 8.7 | inches | |
| Runoff Coefficient (C) | 1 | | *Recommended runoff coefficient of 1 be used for PMF applications. (refer to NUREG CR-4620, section 4.8.1)* |
| Flow Concentration Factor (CF) | 1 | | *Refer to NUREG/CR-4620, page 68, for discussion of Flow Concentration Factor* (enter 0 if not PMP application) |

| | | | |
|---|---|---|---|
| Slope (S) | 0.06 | ft/ft | |
| Slope; angle from horizontal (θ) | 3.30 | degrees | |
| Area; unit-width basis (Aw) | 0.05 | acres | |
| Time of Concentration (tc) | 0.15 | hours | *(Kirich Method)* |
| | 9.12 | minutes | $tc = (11.9\,L^3 / H)^{0.385}$ |
| % of 1-hour PMP | 59.00 | | *(determined from Table 2.1 NUREG 4620)* |
| PMP rainfall depth | 5.13 | inches | *PMP x % of 1-hour PMP* |
| Rainfall Intensity (I), see Note 1 | 33.78 | inches/hour | I = PMP rainfall depth x (60/tc) *Eq. 4.52; 4620* |
| Peak Flow Rate (q) | 1.79 | cfs/ft | q = (C i Aw) CF *Eq. 4.43; 4620* *(Rational Formula for unit width analysis)* |

**Riprap Design:**

| | | | |
|---|---|---|---|
| Rockfill Porosity (n) | 0.4 | | |
| Relative Density of Rock (s) | 2.56 | | |
| Angle of Friction (ϕ) | 40 | degrees | |
| Empirical Factor (C) | 0.25 | | *(varies from 0.22 for gravel and pebbles to 0.27 for crushed granite; NUREG/CR-4620 page 48)* |

**$D_{50}$ = 0.16246 feet**
**1.95 inches**

$D_{50} = [q(\tan\theta)^{7/6}\, n^{1/6} / C\, g^{1/2}\, ((1-n)(s-1)\cos\theta\,(\tan\phi - \tan\theta))^{5/3}]^{2/3}$ *Eq 4.28; 4620*
*acceleration of gravity (g) = 32.174 feet/second$^2$*

Note 1 : If Tc <= 2.5 min then: I = PMP rainfall depth x (60/2.5 min)

TYPICAL VALUES:

Porosity of Rock Layer (n) 0.39 to 0.46
Angle of Friction 37 to 42
Relative Density of Rock (s):
Limestone - 2.42 to 2.74
Limy Sandstone - 2.14 to 2.67
Sandstone - 2.20 to 2.50
Quartzite - 2.66
Basalt - 2.58
Granite - 2.41

*Flow Concentration Factor:*

*The Flow Concentration Factor is multiplied by the peak flow rate. Flow Concentration Factor is incorporated into the design process to account for cover modifications resulting from differential settlement, collapsing soils, marginal quality control in cover placement, erosion, major hydraulic events and monitoring disturbance. It is reasonable to assume that values between 2 and 3 are attainable with only a slight evolutionary chage in the cover. Flow Concentration Factor is not utilized in NRC/STP or DOE/TAD design procedures.*

# Appendix B
# Constructability Verification Field Tests

Field Test Photographs, and
Gradation Plot of Materials Used In Field Tests

# Appendix B
# Constructability Verification Field Test Photographs


Test pad location at the Rattlesnake Quarry (pre-preparation).



The test pad area was shaped and compacted prior to the placement of Type C erosion protection material.


The completed sub-grade for the test pad prior to placement of Type C erosion protection material.


Type C erosion protection placement on the test pad slope. Riprap was placed to provide a minimum layer thickness of 12 inches.



Type C erosion protection placement. Riprap was graded, tracked walked and rolled with a smooth drum compactor to duplicate the placement techniques employed on the AGTI and A-9 Repositories.


The completed Type C erosion protection material test pad.

The test pad is approximately 100 feet wide by 100 feet long with slopes varying from 7(H):1(V) to 4(H):1(V) which replicates the existing slopes on the AGTI and A-9 Repositories.

**Blending and placement of the 30/70 blended bedding material. Bedding blend consisted of 30% quarry fines and 70% imported 1-inch minus crushed rock**


Photograph of the 30/70 blended bedding material.


Loader spreading/sprinkling of bedding material on the surface of the riprap.

Conventional dumping of 30/70 bedding material on the surface, spread with a dozer.

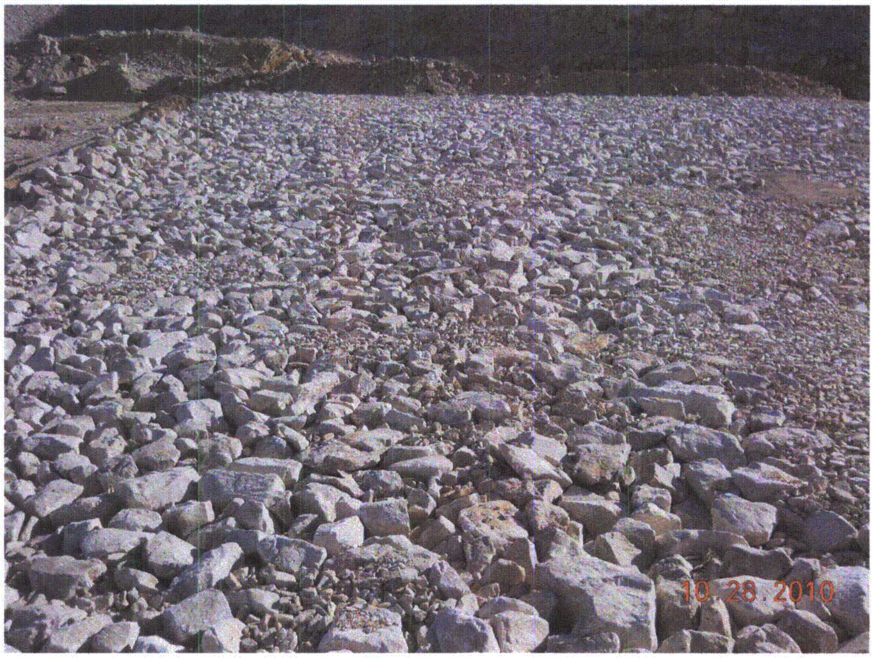

Both placement methods (loader spread and conventional dump/dozer spread), were tracked walked and rolled with a vibratory smooth drum compactor.

Smooth drum rolling the 30/70 blend bedding material placed by conventional methods.

The surface of the riprap layer after the bedding material placements were track walked and rolled with a vibratory compactor. The area in the bottom of the photograph is the area where the bedding was placed by sprinkling over the surface. The bedding material in this area was worked down to the bottom of the riprap layer. The area at the top of the photograph was placed by the conventional method, where the bedding material is visible on the surface. While, the bedding filled the voids throughout the riprap layer, the more conventional dump/spread placement method resulted in wasted bedding material.

**Placement of the Type A bedding material.**


Type A bedding material, loader spread/sprinkled across the riprap slope. The amount of material placed on the surface varies from 1 to 2 inches on the right side of the photo to 4 to 5 inches on the left side.




The finished surface of the Type A Bedding material placement area after the area was dozer tracked walked and rolled by a vibratory smooth drum compactor. The Type A material was worked into the bottom of the of the riprap layer.

**Verification Results**



Type A bedding placed by loader spreading (various surface amounts) and track walked/vibrated into place. Note, full section/depth penetration with the bedding worked into the bottom of the riprap section.



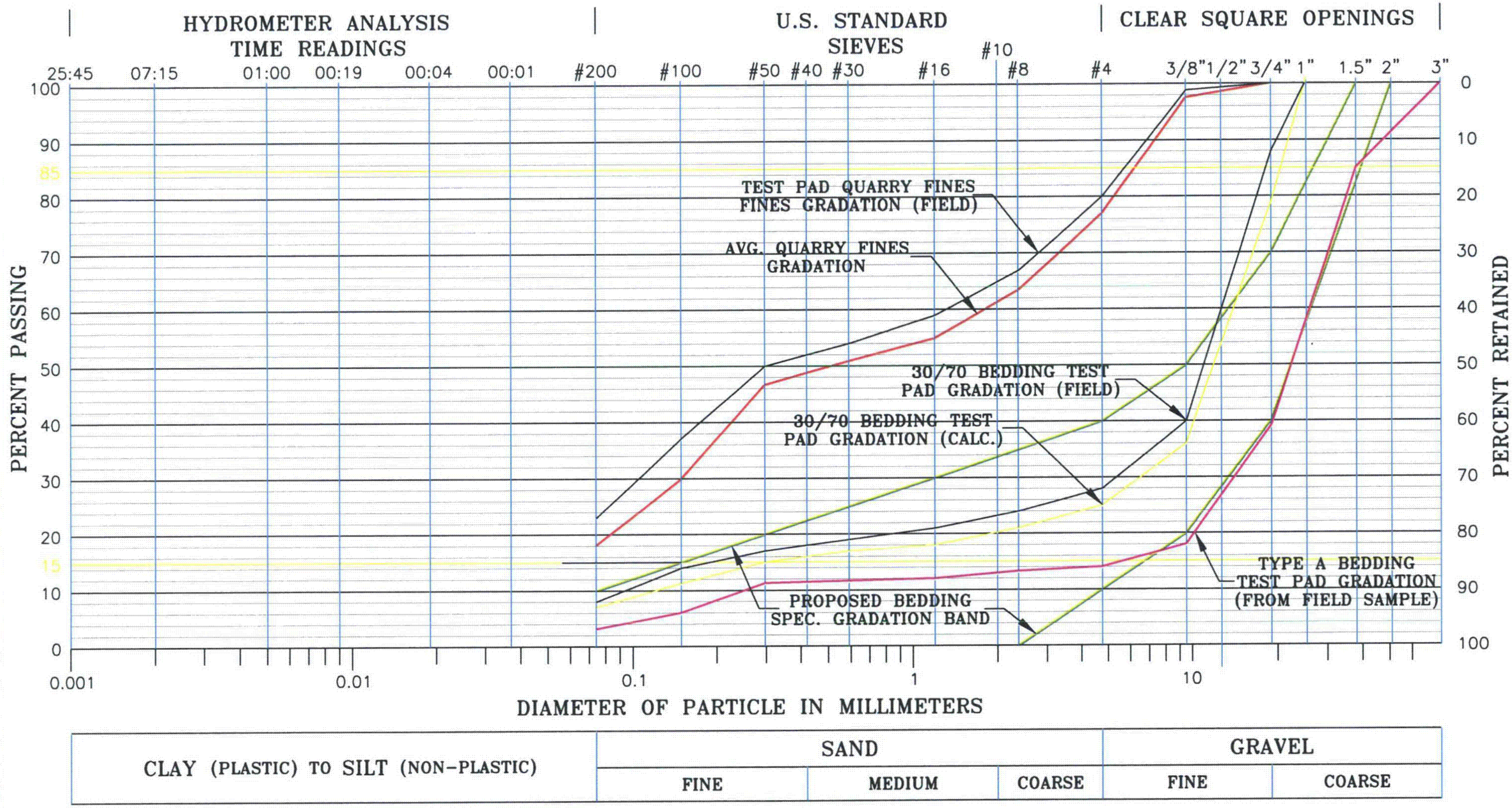
30/70 Blend bedding material placed by conventional dump/dozer spread and dozer track walked/vibrated into place. Note full penetration of bedding material in riprap layer, visible bedding material on surface and amount of waste.



30/70 Blend bedding placed by loader spread/sprinkling 1 to 3 inches thick then dozer tracked and vibratory rolled with a smooth drum roller 4 passes with each piece of equipment. The bedding material fills the voids in the bottom portion of the riprap section. The upper portion of the riprap section is clean (no waste).


View of the area where the 30/70 Blend bedding material was sprinkled from 1 inch thick on the right side to 3 inches thick on the left side of the photograph.

In conclusion, the results of field testing indicate that the bedding materials up to and including 3-inch minus material, can effectively be worked into the existing Type C erosion protection material layer. Loader spreading of the material is the most desirable and economical bedding placement method. Therefore, a bedding material comprised of 70 percent 2-inch minus crushed rock and 30 percent quarry fines and spread with loader type equipment is proposed as a viable method to introduce bedding material into the existing Type C erosion protection material where no rill damage has occurred on the AGTI and A-9 Repositories.




NOTES:
FIELD BLEND OF 30% QUARRY FINES (EXISTING STOCKPILE) AND 70% 1" MINUS CRUSHED ROCK (IMPORTED).
TYPE A MATERIAL OBTAINED FROM EXISTING QUARRY STOCKPILE.
THE VARIOUS BEDDING MATERIALS WERE SPREAD OVER A PREPARED TEST PAD OF TYPE C RIPRAP (9" MINUS ROCK) AND TRACK WALKED, THEN VIBRATED INTO THE 1' THICK SECTION OF TYPE C RIPRAP. BEDDING MATERIALS WERE SUCCESSFULLY VIBRATED DOWN TO THE BOTTOM OF THE RIPRAP SECTION (LAYER THICKNESS), FORMING A BEDDING LAYER EXTENDING UP FROM THE BOTTOM OF THE SECTION OF BETWEEN 3" TO FULL SECTION PENETRATION.

DESIGNATION: TYPE C BEDDING TEST PAD SAMPLE No: FIELD BLENDS OBTAINED ON 10/28/2010 DATE: 11/10/2010

Umetco Minerals Corp.
Remedial Activities
GAS HILLS
BEDDING TEST BLENDS

NOVEMBER 10, 2010 Figure 3

# Appendix C
# 2011 Construction Cost Estimates

Above Grade Tailings Impoundment, 2011 Construction Cost Estimate, and
A-9 Repository, 2011 Construction Cost Estimate

## Above Grade Tailings Impountment, 2011 Construction Cost Estimate

| Reclamation Construction Task | Quantity | Unit | Unit Cost | Overhead (10%) | Profit (10%) | Unit Cost w/O&P | Amount |
|---|---|---|---|---|---|---|---|
| *Erosion Protection Repair* | | | | | | | |
| Mobilization/Demobilization | 1 | Lump Sum | $50,000.00 | $5,000.00 | $5,000.00 | $60,000.00 | $60,000.00 |
| Develop Constr. Water Source | 1 | Lump Sum | $12,500.00 | $1,250.00 | $1,250.00 | $15,000.00 | $15,000.00 |
| Establish Access Routes | 1 | Lump Sum | $12,500.00 | $1,250.00 | $1,250.00 | $15,000.00 | $15,000.00 |
| Process 30/70 Bedding (Quarry) | 17,260 | Cubic Yards | $7.50 | $0.75 | $0.75 | $9.00 | $155,340.00 |
| Place Type A Bedding | 11,425 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $137,100.00 |
| Place 30/70 Bedding | 17,260 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $207,120.00 |
| R&R Existing Type C Riprap | 31,380 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $376,560.00 |
| *Launch Rock Filter* | | | | | | | |
| Exc. Launch Rock Filter Trenches | 2,950 | Cubic Yards | $5.00 | $0.50 | $0.50 | $6.00 | $17,700.00 |
| Place Launch Rock Filter (U/S & D/S) | 2,300 | Cubic Yards | $20.00 | $2.00 | $2.00 | $24.00 | $55,200.00 |
| Backfill Launch Rock Filter Trench (U/S) | 1,800 | Cubic Yards | $5.00 | $0.50 | $0.50 | $6.00 | $10,800.00 |
| *Channel Apron* | | | | | | | |
| Establish Access Routes | 1 | Lump Sum | $15,000.00 | $1,500.00 | $1,500.00 | $18,000.00 | $18,000.00 |
| Prepare Apron Channel Sub-Grade | 300 | Linear Feet | $50.00 | $5.00 | $5.00 | $60.00 | $18,000.00 |
| Place Type A Bedding | 700 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $8,400.00 |
| Place Type C Riprap | 1,900 | Cubic Yards | $20.00 | $2.00 | $2.00 | $24.00 | $45,600.00 |
| Reclaim Overall AGTI Site | 1 | Lump Sum | $27,500.00 | $2,750.00 | $2,750.00 | $33,000.00 | $33,000.00 |
| | | | | | | Total Cost = | $1,172,820.00 |
| | | | | | | Contingency (15%) = | $175,923.00 |
| | | | | | | Total Estimated Cost = | **$1,348,743.00** |

**A-9 Repository, 2011 Construction Cost Estimate**

| Reclamation Construction Task | Quantity | Unit | Unit Cost | Overhead (10%) | Profit (10%) | Unit Cost w/O&P | Amount |
|---|---|---|---|---|---|---|---|
| *Erosion Protection Repair* | | | | | | | |
| Mobilization/Demobilization | 1 | Lump Sum | $50,000.00 | $5,000.00 | $5,000.00 | $60,000.00 | $60,000.00 |
| Develop Constr. Water Source | 1 | Lump Sum | $12,500.00 | $1,250.00 | $1,250.00 | $15,000.00 | $15,000.00 |
| Establish Access Routes | 1 | Lump Sum | $12,500.00 | $1,250.00 | $1,250.00 | $15,000.00 | $15,000.00 |
| Process 30/70 Bedding (Quarry) | 2,860 | Cubic Yards | $7.50 | $0.75 | $0.75 | $9.00 | $25,740.00 |
| Place Type A Bedding | 2,380 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $28,560.00 |
| Place 30/70 Bedding | 2,860 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $34,320.00 |
| R&R Existing Type C Riprap | 9,520 | Cubic Yards | $10.00 | $1.00 | $1.00 | $12.00 | $114,240.00 |
| | | | | | | Total Cost = | $292,860.00 |
| | | | | | | Contingency (15%) = | $43,929.00 |
| | | | | | | Total Estimated Cost = | **$336,789.00** |

Total Estimated 2011 Construction Cost = **$1,685,532.00**

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