energy fuels nuclear, inc.

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1515 arapahoe street • denver, colorado 80202

303-623-8317
twx 910-931-2561
fax 303-595-0930

February 28, 1997

Mr. Joseph J. Holonich, Branch Chief
High Level Waste and Uranium Recovery
Projects Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
2 White Flint North, Mail Stop T-7J9
11545 Rockville Pike
Rockville, MD 20852

Re: Transmittal of Reclamation Plan for the White Mesa Uranium Mill
Source Mill License SUA-1358 - Docket No. ~~48~~ 40-8681

Dear Mr. Holonich:

This letter transmits three complete copies of the Reclamation Plan (and appendices) for the White Mesa Uranium Mill. This document supersedes the Reclamation Plan submitted to the U.S. Nuclear Regulatory Commission ("NRC") by Umetco Mineral Corporation in June of 1988, although a few selected portions of that submittal are referenced in this Reclamation Plan.

The technical approaches applied by Energy Fuels Nuclear, Inc. ("EFN") in preparing this Reclamation Plan generally conform with the most current NRC regulatory guides. In addition, where appropriate, NRC staff have clarified methods for using selected guidance materials. For ease of review, key supporting documents have been reproduced as appendices.

Hopefully, the effort and care taken by Michelle Rehmann and Rick Van Horn in preparing this document will expedite the review process. After your initial review, we would like to schedule a meeting to discuss any preliminary questions. In the interim, please feel free to contact Michelle Rehmann at the letterhead phone or address, or Rick Van Horn at (970) 243-1968.

Sincerely,

Harold R. Roberts

HRR/pl
Enclosures

H MRR LETTERS 97 HOLORECPLAN LTR

NMSS/1

cc: William N. Deal
Earl E. Hoellen
Richard A. Munson
Michelle R. Rehmann
Rick A. Van Horn

H:\MRR\LETTERS\97\HOLORECPLAN.LTR

TAILINGS COVER DESIGN

WHITE MESA MILL, OCTOBER 1996

FOR

RECLAMATION

OF

WHITE MESA FACILITIES

BLANDING, UTAH

PREPARED BY

TITAN ENVIRONMENTAL

7939 EAST ARAPAHOE ROAD, SUITE 230

ENGLEWOOD, COLORADO 80112

TITAN Environmental

TAILINGS COVER DESIGN
White Mesa Mill

Prepared For:

Energy Fuels Nuclear, Inc.
1515 Arapahoe, Suite 900
Denver, CO 80202

October 1996

By:

TITAN Environmental Corporation
7939 East Arapahoe Road, Suite 230
Englewood, Colorado 80112

TABLE OF CONTENTS

LIST OF FIGURES

LIST APPENDICES

ENERGY FUELS NUCLEAR

WHITE MESA MILL

TAILINGS COVER DESIGN

1.0 SOIL COVER DESIGN

A six-foot thick soil cover for the uranium tailings Cells 2, 3 and 4A was designed using on-site materials that will contain tailings and radon emissions in compliance with regulations by the United States Nuclear Regulatory Commission (NRC) and by reference, the Environmental Protection Agency (EPA). The cover consists of a one-foot thick layer of clay, available from within the site boundaries (Section 16), below two-feet of random fill, available from stockpiles on-site. The clay is underlain with three feet (minimum) random fill soil, also available on site. The cover layers will be compacted to 95 percent maximum dry density using standard construction techniques. In addition to the soil cover, a minimum 3 inch (on the cover top) to 12-inch (on the cover slopes) layer of riprap material will be placed over the compacted random fill to stabilize slopes and provide long-term erosion resistance.

Uranium tailings soil cover design requirements for agency compliance include:

- Attenuate radon flux to an acceptable level (20 picoCuries-per meter squared-per second [pCi/m^2/sec]) (NRC, 1989);
- Minimize infiltration into the reclaimed tailings cells;
- Maintain a design life of up to 1,000 years or to the extent reasonably achievable and in any case for at least 200 years; and
- Provide long-term slope stability and geomorphic durability to withstand erosional forces of wind, the probable maximum flood event, and a horizontal ground acceleration of 0.1g due to seismic events.

Several models/analyses were utilized in simulating the soil cover effectiveness: radon flux attenuation, hydrologic evaluation of infiltration, freeze/thaw effects, soil cover erosion

protection, and static and pseudostatic slope stability analyses. These analyses and results are discussed in detail in Sections 1.1 through 1.5. The soil cover (from top to the bottom) will consist of: 1) minimum of three inches of riprap material; 2) two feet of compacted random fill; 3) one foot of compacted clay; and 4) minimum three feet of compacted random fill soil.

The soil cover design for the uranium tailings Cells 2, 3, and 4A was developed based on two construction options:

- An integrated soil cover over Disposal Cells 2, 3, and 4A; and
- A cover over Cells 2 and 3, where Cell 4A tailings are excavated and placed into Cell 3.

For modeling/analysis purposes it was assumed that the physical and radiological parameters of the tailings in Cells 2, 3, and 4A are not dependent on the tailing volume in each individual cell. Therefore, each of the two construction options above resulted in the same soil cover configuration. The only variation between the options is in the required volumes of cover materials, which is dependent only on the surface area to be covered (see Section 1.7).

The final grading plans for the two options are presented on Figures 1 and 2, respectively. As indicated on the figures, the top slope of the soil cover will be constructed at 0.2 percent and the side slopes, as well as transitional areas between cells, will be graded to five horizontal to one vertical (5H:1V).

A minimum of three feet random fill is located beneath the compacted fill and clay layers (see cross-sections on Figures 3 and 4). The purpose of the fill is to raise the base of the cover to the desired subgrade elevation. In many areas, the required fill thickness will be much greater. However, the models and analyses were performed conservatively assuming only a three-foot layer. For modeling purposes, this lower, random fill layer was considered as part of the soil cover for performing the radon flux attenuation calculation, as it effectively contributes to the reduction of radon emissions (see Section 1.1). The fill was also evaluated in the slope stability analysis (see Section 1.5). However, it is not defined as part of the soil cover for other design calculations (infiltration, freeze/thaw, and cover erosion).

The following sections describe design considerations, complete with calculations performed and parameters utilized, in developing the tailings impoundment soil cover to meet regulatory requirements.

1.1 Radon Flux Attenuation

The Environmental Protection Agency (EPA) rules in 40 Code of Federal Regulation (CFR) Part 192 require that a "uranium tailings cover be designed to produce reasonable assurance that the radon-222 release rate would not exceed 20 pCi/m^2/sec for a period of 1,000 years to the extent reasonably achievable and in any case for at least 200 years when averaged over the disposal area over at least a one year period" (NRC, 1989). NRC regulations presented in 10 CFR Part 40 also restrict radon flux to less than 20 pCi/m^2/sec. The following sections present the analyses and design for a soil cover which meets this requirement.

1.1.1 Predictive Analysis

The soil cover for the tailings cells at White Mesa Mill was evaluated for attenuation of radon gas using the digital computer program, RADON, presented in the NRC's Regulatory Guide 3.64 (Task WM 503-4) entitled "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers". The RADON model calculates radon-222 flux attenuation by multi-layered earthen uranium mill tailings covers, and determines the minimum cover thickness required to meet NRC and EPA standards. The RADON model uses the following soil properties in the calculation process:

- Soil layer thickness [centimeters (cm)];
- Soil porosity (percent);
- Density [grams-per-cubic centimeter (gm/cm^3)];
- Weight percent moisture (percent);
- Radium activity (piC/g);
- Radon emanation coefficient (unitless); and

- Diffusion coefficient [square centimeters-per-second (cm^2/sec)].

Physical and radiological properties for tailings and random fill were analyzed by Chen and Associates (1987) and Rogers and Associates (1988). Clay physical data from Section 16 was analyzed by Advanced Terra Testing (1996) and Rogers and Associates (1996). See Appendix A for laboratory test data results.

The RADON model was performed for the following cover section (from top to bottom):

- two feet compacted random fill;
- one foot compacted clay; and
- a minimum of three feet random fill occupying the freeboard space between the tailings and clay layer.

The three layers are compacted to 95 percent maximum dry density. The top riprap layer was not included as part of the soil cover for the radon attenuation calculation.

The results of the RADON modeling exercise show that the uranium tailings cover configuration will attenuate radon flux emanating from the tailings to a level of 17.6 pCi/m^2/sec. This number was conservatively calculated as it takes into account the freeze/thaw effect on the uppermost part (6.8 inches) of the cover (Section 1.3). The soil cover and tailing parameters used to run the RADON model, in addition to the RADON input and output data files, are presented in Appendix B as part of the Radon Calculation brief. Based on the model results, the soil cover design of six-foot thickness will meet the requirements of 40 CFR Part 192 and 10 CFR Part 40.

1.1.2 Empirical Data

Radon gas flux measurements have been made at the White Mesa Mill tailings piles over Cells 2 and 3 (see Appendix C). These cells are currently covered with three to four feet of random fill. Radon flux measurements, averaged over the covered areas, were as follows (EFN, 1996):

	1994	1995
Cell 2	7.7 pCi/m^2/sec	6.1 pCi/m^2/sec
Cell 3	7.5 pCi/m^2/sec	11.1 pCi/m^2/sec

Empirical data suggest that the random fill cover, alone, is currently providing an effective barrier to Radon flux. Thus, the proposed tailings cover configuration, which is thicker, moisture adjusted, contains a clay layer and is compacted, is expected to attenuate the Radon flux to a level below that predicted by the RADON model. The field radon flux measurements confirm the conservatism of the cover design. This conservatism is necessary, however, to guarantee compliance with NRC regulations under long term climatic conditions over the required design life of 200 to 1,000 years.

1.2 Infiltration Analysis

The tailings ponds at White Mesa Mill are lined with synthetic geomembrane liners which under certain climatic conditions, could potentially lead to the long-term accumulation of water from infiltration of precipitation. Therefore, the soil cover was evaluated to estimate the potential magnitude of infiltration into the capped tailings ponds. The Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.0 (EPA, 1994) was used for the analysis. HELP is a quasi two-dimensional hydrologic model of water movement across, into, through, and out of capped and lined impoundments. The model utilizes weather, soil, and engineering design data as input to the model, to account for the effects of surface storage, snowmelt, run-off, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, and unsaturated vertical drainage on the specific design, at the specified location.

The soil cover was evaluated based on a two-foot compacted random fill layer over a one-foot thick, compacted clay layer. The soil cover layers were modeled based on material placement at a minimum of 95 percent of the maximum dry density, and within two percent of the optimum moisture content per American society for Testing and Materials (ASTM) requirements. The top riprap layer and the bottom random fill layer were not included as part of the soil cover for infiltration calculations. These two layers are not playing any role in controlling the infiltration through the cover material.

The random fill will consist of clayey sands and silts with random amounts of gravel and rock-size materials. The average hydraulic conductivity of several samples of random fill was calculated, based on laboratory tests, to be 8.87×10^{-7} cm/sec. The hydraulic conductivity of the clay source from Section 16 was measured in the laboratory to be 3.7×10^{-8} cm/sec. Geotechnical soil properties and laboratory data are presented in Appendix A.

Key HELP model input parameters include:

- Blanding, Utah, monthly temperature and precipitation data, and HELP model default solar radiation, and evapotranspiration data from Grand Junction, Colorado. Grand Junction is located north east of Blanding in similar climate and elevation;

- Soil cover configuration identifying the number of layers, layer types, layer thickness, and the total covered surface area;

- Individual layer material characteristics identifying saturated hydraulic conductivity, porosity, wilting point, field capacity, and percent moisture; and

- Soil Conservation Service runoff curve numbers, evaporative zone depth, maximum leaf area index, and anticipated vegetation quality.

Water balance results, as calculated by the HELP model, indicate that precipitation would either run-off the soil cover or be evaporated. Thus, model simulations predict zero infiltration of surface water through the soil cover, as designed. These model results are conservative and take into account the freeze/thaw effects on the uppermost part (6.8 inches) of the cover (Section 1.3). The HELP model input and output for the tailings soil cover are presented in the HELP Model calculation brief included as Appendix D.

1.3 Freeze/Thaw Evaluation

The tailings soil cover of one foot of compacted clay covered by two feet of random fill was evaluated for freeze/thaw impacts. Repeated freeze/thaw cycles have been shown to increase the bulk soil permeability by breaking down the compacted soil structure.

The soil cover was evaluated for freeze/thaw effects using the modified Berggren equation as presented in Aitken and Berg (1968) and recommended by the NRC (U.S. Department of Energy, 1988). This evaluation was based on the properties of the random fill and clay soil, and meteorological data from both Blanding, Utah and Grand Junction, Colorado.

The results of the freeze/thaw evaluation indicate that the anticipated maximum depth of frost penetration on the soil cover would be less than 6.8 inches. Since the random fill layer is two feet thick, the frost depth would be confined to this layer and would not penetrate into the

underlying clay layer. The performance of the soil cover to attenuate radon gas flux below the prescribed standards, and prevent surface water infiltration, would not be compromised. The input data and results of the freeze/thaw evaluation are presented in the Effects of Freezing on Tailings Covers Calculation brief included as Appendix E.

1.4 Soil Cover Erosion Protection

A riprap layer was designed for erosion protection of the tailings soil cover. According to NRC guidance, the design must be adequate to protect the soil/tailings against exposure and erosion for 200 to 1,000 years (NRC, 1990). Currently, there is no standard industry practice for stabilizing tailings for 1,000 years. However, by treating the embankment slopes as wide channels, the hydraulic design principles and practices associated with channel design were used to design stable slopes that will not erode. Thus, a conservative design based on NRC guidelines was developed. Engineering details and calculations are summarized in the Erosion Protection Calculation brief provided in Appendix F.

Riprap cover specifications for the top and side slopes were determined separately as the side slopes are much steeper than the slope of the top of the cover. The size and thickness of the riprap on the top of the cover was calculated using the Safety Factor Method (NUREG/CR-4651, 1987), while the Stephenson Method (NUREG/CR-4651, 1987) was used for the side slopes. These methodologies were chosen based on NRC recommendations (1990).

By the Safety Factor Method, riprap dimensions for the top slope were calculated in order to achieve a slope "safety factor" of 1.1. For the top of the soil cover, with a slope of 0.2 percent, the Safety Factor Method indicated a median diameter (D_{50}) riprap of 0.28 inches is required to stabilize the top slope. However, this dimension must be modified based on the long-term durability of the specific rock type to be used in construction. The suitability of rock to be used as a protective cover must be assessed by laboratory tests to determine the physical characteristics of the rocks. The sandstones from the confluence of Westwater and Cottonwood Canyons require an oversizing factor of 25 percent. Therefore, riprap created from this sandstone source should have a D_{50} size of at least 0.34 inches and should have an overall layer thickness of at least three inches on the top of the cover.

Riprap dimensions for the side slopes were calculated using Stephenson Method equations. The side slopes of the cover are designed at 5H:1V. At this slope, Stephenson's Method indicated the unmodified riprap D_{50} of 3.24 inches is required. Again assuming that the on-site sandstone will be used, the modified D_{50} size of the riprap should be at least 4.05 inches with an overall layer thickness of at least 12 inches.

The potential of erosion damage due to overland flow, sheetflow, and channel scouring on the top and side slopes of the cover, including the riprap layer, has been evaluated. Overland flow calculations were performed using site meteorological data, cap design specifications, and guidelines set by the NRC (NUREG/CR-4620, 1986). These calculations are included in Appendix F. According to the guidelines, overland flow velocity estimates are to be compared to "permissible velocities", which have been suggested by the NRC, to determine the potential for erosion damage. When calculated, overland flow velocity estimates exceed permissible velocities, additional cover protection should be considered. The permissible velocity for the tailings cover (including the riprap layer) is 5.0 to 6.0 feet-per-second (ft./sec.) (NUREG/CR 4620). The overland flow velocity calculated for the top of the cover is less than 2.0 ft/sec., and the calculated velocity on the side slopes is 4.9 ft/sec. Therefore, the erosion potential of the slopes, due to overland flow/channel scouring, is within acceptable limits and no additional erosion protection is required.

1.5 Slope Stability Analysis

Static and pseudostatic analyses were performed to establish the stability of the side slopes of the tailings soil cover. The side slopes are designed at an angle of 5H:1V. Because the side slope along the southern section of Cell 4A is the longest and the ground elevation drops rapidly at its base, this slope was determined to be critical and is thus the focus of the stability analyses.

The computer software package GSLOPE, developed by MITRE Software Corporation, has been used for these analyses to determine the potential for slope failure. GSLOPE applies Bishop's Method of slices to identify the critical failure surface and calculate a factor of safety (FOS). The slope geometry and properties of the construction materials and bedrock are input into the model. These data and drawings are included in the Stability Analysis of Side Slopes Calculation brief included as Appendix G. For this analysis, competent bedrock is designated at 10 feet below the lowest point of the foundation [i.e., at a 5,540-foot elevation above mean sea

level (msl)]. This is a conservative estimate, based on the borehole logs supplied by Chen and Associates (1979), which indicate bedrock near the surface.

1.5.1 Static Analysis

For the static analysis, a FOS of 1.5 or more was used to indicate an acceptable level of stability. The calculated FOS is 2.91, which indicates that the slope should be stable under static conditions. Results of the computer model simulations are included in Appendix G.

1.5.2 Pseudostatic Analysis (Seismicity)

The slope stability analysis described above was repeated under pseudostatic conditions in order to estimate a FOS for the slope when a horizontal ground acceleration of 0.10g is applied. The slope geometry and material properties used in this analysis are identical to those used in the stability analysis. A FOS of 1.0 or more was used to indicate an acceptable level of stability under pseudostatic conditions. The calculated FOS is 1.903, which indicates that the slope should be stable under dynamic conditions. Details of the analysis and the simulation results are included in Appendix G.

Recently, Lawrence Livermore National Laboratory (LLNL) published a report on seismic activity in southern Utah, in which a horizontal ground acceleration of 0.12g was proposed for the White Mesa site. The evaluations made by LLNL were conservative to account for tectonically active regions that exist, for example, near Moab, Utah. Although, the LLNL report states that "...[Blanding] is located in a region known for its scarcity of recorded seismic events," the stability of the cap design slopes using the LLNL factor was evaluated. The results of a sensitivity analysis reveal that when considering a horizontal ground acceleration of 0.12g, the calculated FOS is 1.778 which is still above the required value of 1.0, indicating adequate safety under pseudostatic conditions. This analysis is also included in Appendix G.

1.6 Cover Material/Cover Material Volumes

Construction materials for reclamation will be obtained from on-site locations. Fill material will be available from the stockpiles that were generated from excavation of the cells for the tailings facility. If required, additional materials are available locally to the west of the site. A clay material source, identified in Section 16 at the southern end of the White Mesa Mill site, will be

used to construct the one-foot compacted clay layer. Riprap material will be taken from on-site sandstone, located at the confluence of Westwater and Cottonwood Canyons.

Material quantities have been calculated for each of the components of the reclamation cover. Volume estimates were made for the two soil cover design options, as follows:

- Option 1: an integrated soil cover which incorporates Disposal Cells 2, 3, and 4A, and
- Option 2: a cover which includes Cells 2 and 3, where Cell 4A tailings have been excavated and placed in Cell 3.

The quantity of random fill required to bring the pond elevation up to the soil cover subgrade and construct the final slope was not calculated. This layer will be a minimum of three feet in depth and is dependent on the final tailings grade, which is not known.

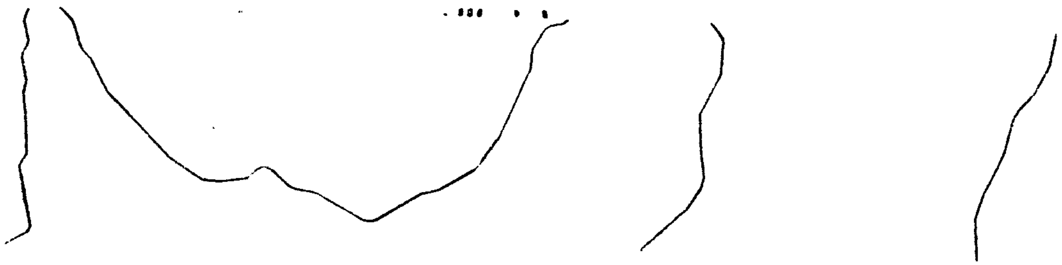
For Design Option 1, construction will require the following approximate quantities of materials:

Material	Volume (cubic yards)
Clay	365,082
Random Fill	737,717
Riprap (top of cover)	82,762
Riprap (side slopes)	41,588

For Design Option 2, construction will require the following approximate quantities of materials:

Material	Volume (cubic yards)
Clay	289,514
Random Fill	585,334
Riprap (top of cover)	64,984
Riprap (side slopes)	35,885

Material quantities calculations are provided in Appendix H as part of the Tailings Cover Material Volume Calculation brief.



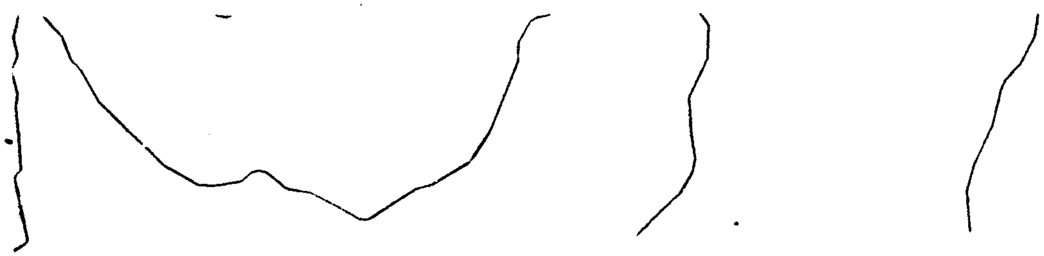
RECLAMATION COVER
GRADING PLAN FOR CELLS 2, 3 & 4A

PREPARED FOR

ENERGY FUELS NUCLEAR
BLANDING, UTAH

TITAN Environmental

DATE: 8-12-96	FIGURE 1	DRAWING NUMBER 6111-E1	△1
SCALE: AS SHOWN			



RECLAMATION COVER

GRADING PLAN FOR CELLS 2 & 3

PREPARED FOR

ENERGY FUELS NUCLEAR
BLANDING, UTAH

TITAN Environmental

ATE:	8-12-96	FIGURE 2	DRAWING NUMBER 6111-E2	△1
CALE:	AS SHOWN			

HORIZONTAL SCALE

200 0 200 400 FEET

RECLAMATION COVER

CROSS SECTIONS & DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR
BLANDING, UTAH

TITAN Environmental

DATE: 8-12-96	FIGURE 3	DRAWING NUMBER	△1
SCALE: AS SHOWN		6111-E3	

HORIZONTAL SCALE

200 0 200 400 FEET

RECLAMATION COVER
CROSS SECTIONS & DETAILS
PREPARED FOR

ENERGY FUELS NUCLEAR
BLANDING, UTAH

TITAN Environmental

DATE: 8-12-96	FIGURE 4	DRAWING NUMBER	1
SCALE: AS SHOWN		6111-E4	

APPENDIX A

Laboratory Test Data

Table 3.4-1

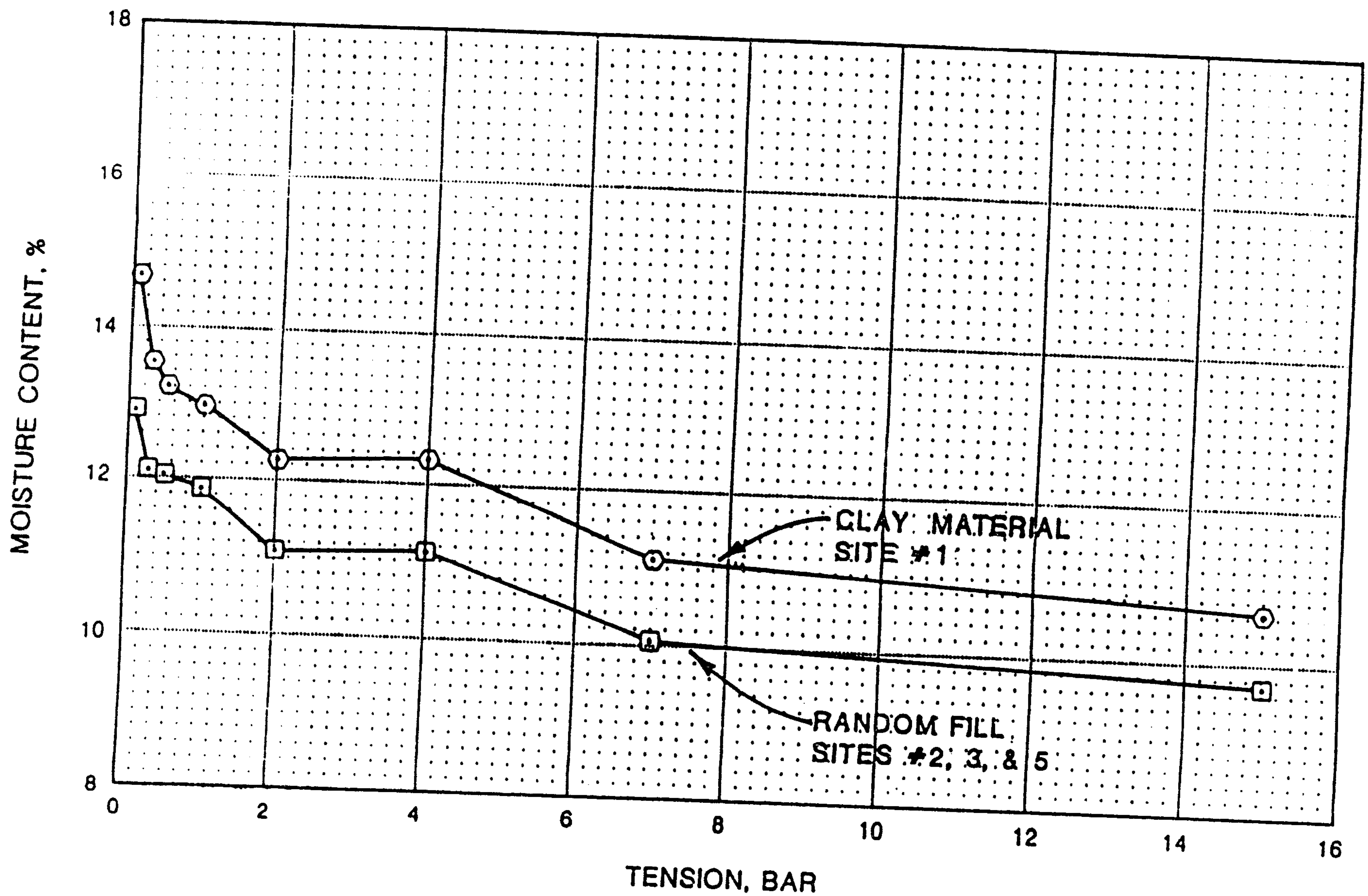
Physical Properties of Tailings

and

Proposed Cover Material

Material Type	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity	% Passing No. 200 Sieve	Maximum Dry Density (pcf)	Optimum Moisture Content
Tailings	28	6	2.85	46	104.0	18.1
Random Fill	22	7	2.67	48	120.2	11.8

Note: Physical Soil Data from Chen and Associates (1987).

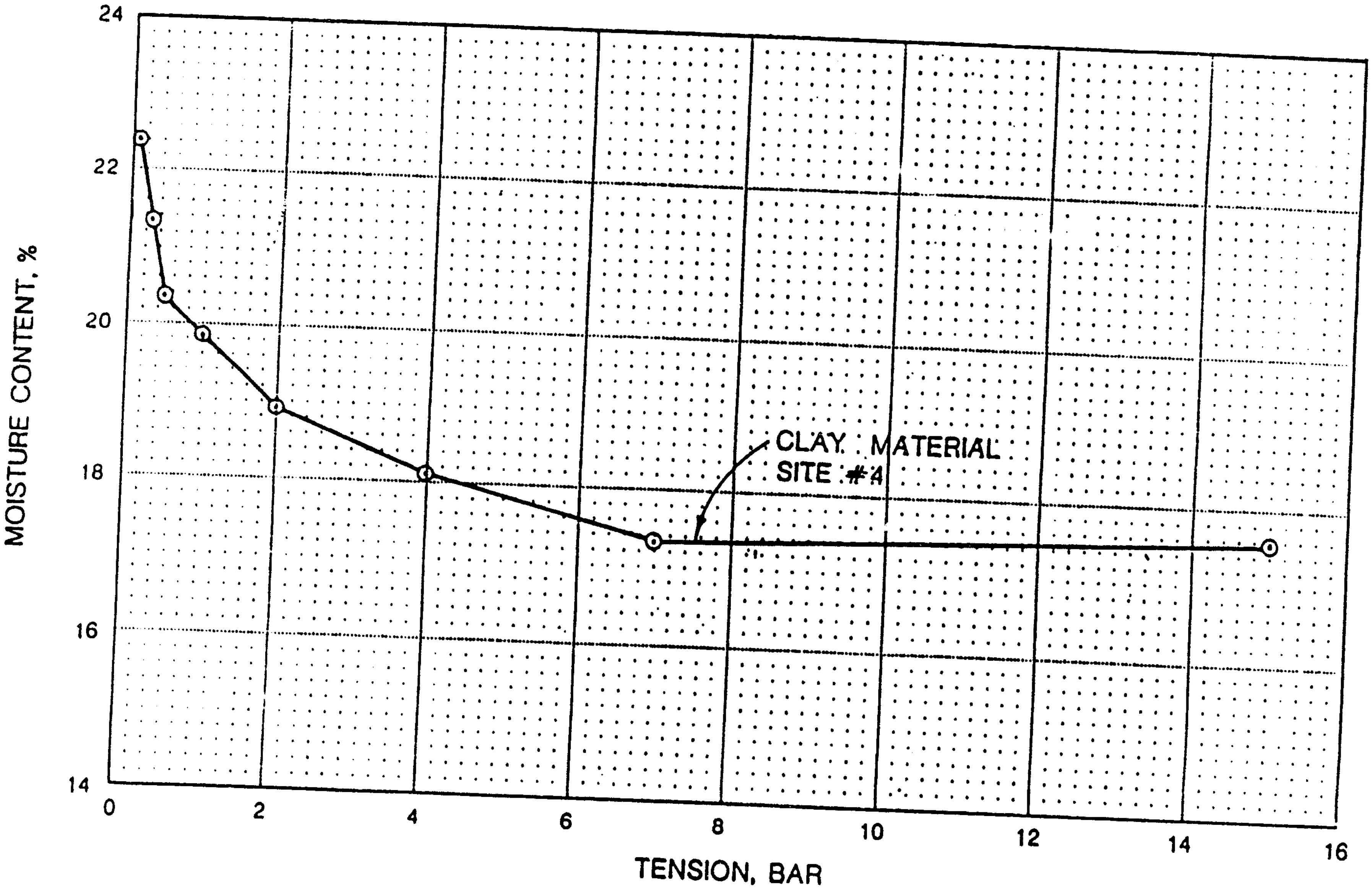


DATA FROM CHEN & ASSOCIATES

SUMMARY OF CAPILLARY MOISTURE RELATIONSHIP TEST RESULTS

WHITE MESA PROJECT

FIGURE 3.5-1



DATA FROM CHEN & ASSOCIATES

SUMMARY OF CAPILLARY MOISTURE RELATIONSHIP TEST RESULTS
WHITE MESA PROJECT
FIGURE 3.5-2

SECTION 6

ROGERS AND ASSOCIATES ENGINEERING
CORPORATION

Letter Dated March 4, 1988
Letter Dated May 9, 1988

Radiological Properties

R
A
E

Rogers & Associates Engineering Corporation

Post Office Box 330
Salt Lake City, Utah 84110
(801) 263-1600

March 4, 1988

Mr. C.O.Sealy
Umetco Minerals Corporation
P.O. Box 1029
Grand Junction, CO 81502

C8700/22

Dear Mr. Sealy:

We have completed the tests ordered on the four samples shipped to us. The results are as follows:

Sample	Radium pCi/gm	Emanation Fraction	Diffusion Coeffic.	(g/cm^3) Density	Moisture	Saturation
Tailings	981±4	0.19±0.01	2.0E-02	1.45	13.2	0.39
			8.4E-03	1.44	19.1	0.56
Composite (2,3,&5)			1.6E-02	1.85	6.5	0.40
			4.5E-04	1.84	12.5	0.75
Site #1			1.6E-02	1.85	8.1	0.48
			1.4E-03	1.84	12.6	0.76
Site #4			1.1E-02	1.65	15.4	0.63
			4.2E-04	1.65	19.3	0.80

The samples will be shipped back to you in the next few weeks. If you have any questions regarding the results on the samples please feel free to call.

Sincerely,

Renee Y. Bowser

Renee Y. Bowser
Lab Supervisor

RYB/b

R
A
E

Rogers & Associates Engineering Corporation

Post Office Box 330
Salt Lake City, Utah 84110
(801) 263-1600

MAY 12 1988

May 9, 1988

Mr. C.O. Sealy
UMETCO Minerals Corporation
P.O. Box 1029
Grand Junction, CO 81502

C8700/22

Dear Mr. Sealy:

The tests for radium content and radon emanation coefficient in the following samples have been completed and the results are as follows:

Sample	Radium (pCi/g)	Radon Emanation Coefficient
Random (2,3 & 5)	1.9 ± 0.1	0.19 ± 0.04
Site 1	2.2 ± 0.1	0.20 ± 0.03
Site 4	2.0 ± 0.1	0.11 ± 0.04

If you have any questions regarding these results please feel free to call Dr. Kirk Nielson or me.

Sincerely,

Renee Y. Bowser
Lab Supervisor

RYB:ms

ADVANCED TERRA TESTING inc

833 Parfet Street
Lakewood, Colorado 80215
(303) 232-8308

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT Titan Env.

JOB NO. 2234-04

BORING NO.
DEPTH
SAMPLE NO. UT-1
SOIL DESCR.
TEST TYPE ATTERBERG

DATE SAMPLED
DATE TESTED 7-25-96 WEB, RV

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	3.34	4.06	3.42
Wt Dish & Dry Soil	2.96	3.57	3.03
Wt of Moisture	0.38	0.49	0.39
Wt of Dish	1.05	1.11	1.06
Wt of Dry Soil	1.91	2.46	1.97
Moisture Content	19.90	19.92	19.80

Liquid Limit Determination Device Number 0258

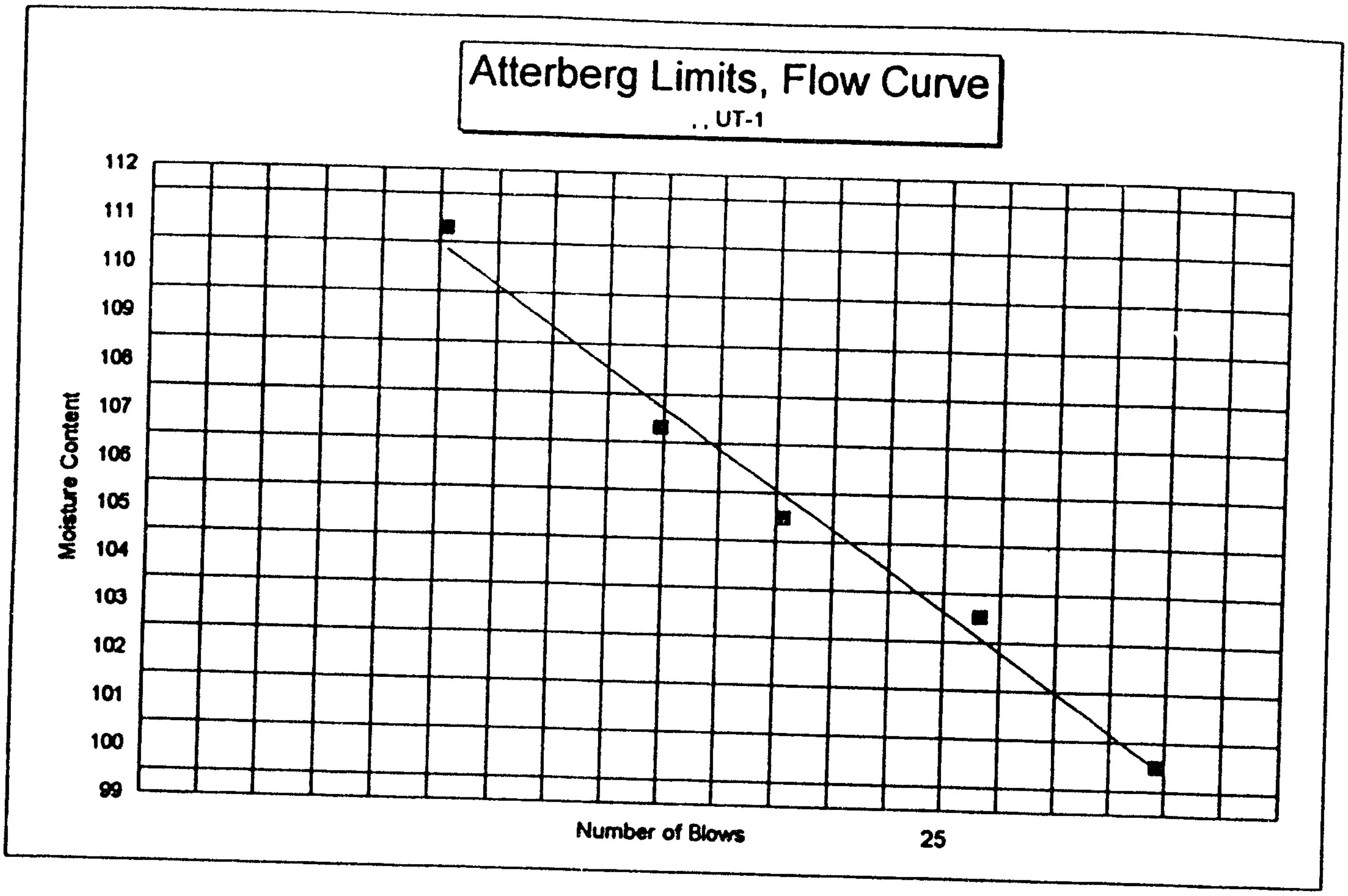
	1	2	3	4	5
Number of Blows	39	27	18	14	9
Wt Dish & Wet Soil	12.18	10.42	10.92	12.33	10.06
Wt Dish & Dry Soil	6.64	5.67	5.87	6.53	5.34
Wt of Moisture	5.54	4.75	5.05	5.80	4.72
Wt of Dish	1.10	1.06	1.06	1.10	1.08
Wt of Dry Soil	5.54	4.61	4.81	5.43	4.26
Moisture Content	100.00	103.04	104.99	106.81	110.80

Liquid Limit 103.1
Plastic Limit 19.9
Plasticity Index 83.3

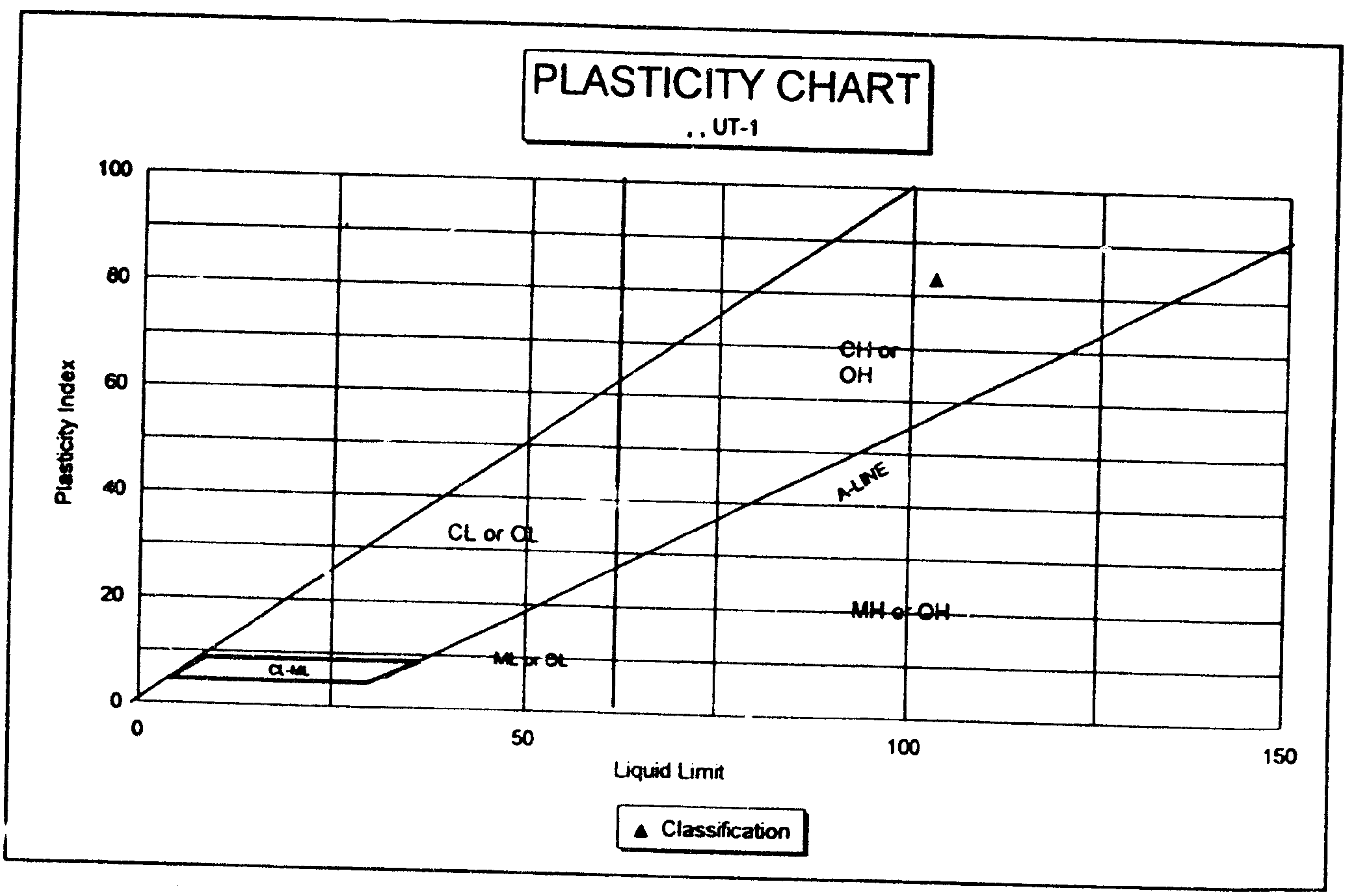
Atterberg Classification CH

Data entry by: NAA Date: 7-26-96
Checked by: [signature] Date: 7-26-96
FileName: TIGOUT1

ADVANCED TERRA TESTING, INC.



Atterberg Limits, Flow Curve
, , UT-1
112
111
110
109
108
107
106
105
104
103
102
101
100
99
Moisture Content
Number of Blows
25



PLASTICITY CHART
, , UT-1
100
80
60
40
20
0
Plasticity Index
0
50
100
150
Liquid Limit
CH or
OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

COMPACTION TEST
ASTM D 1557 A

CLIENT: Titan Env. JOB NO. 2234-04

BORING NO.
PTH
SAMPLE NO. UT-1

SOIL DESCR.
DATE SAMPLED
DATE TESTED 7-25-96 RV

Moisture determination

	1	2	3	4	5
Wt of Moisture added (ml)	100.00	150.00	250.00	350.00	450.00
Wt. of soil & dish (g)	384.26	393.92	291.42	244.20	281.17
Dry wt. soil & dish (g)	350.60	355.61	251.40	202.69	225.04
Net loss of moisture (g)	33.66	38.31	40.02	41.51	56.13
Wt. of dish (g)	8.01	8.34	8.31	8.29	8.43
Net wt. of dry soil (g)	342.59	347.27	243.09	194.40	216.61
Moisture Content (%)	9.83	11.03	16.46	21.35	25.91
Corrected Moisture Content					

Density determination

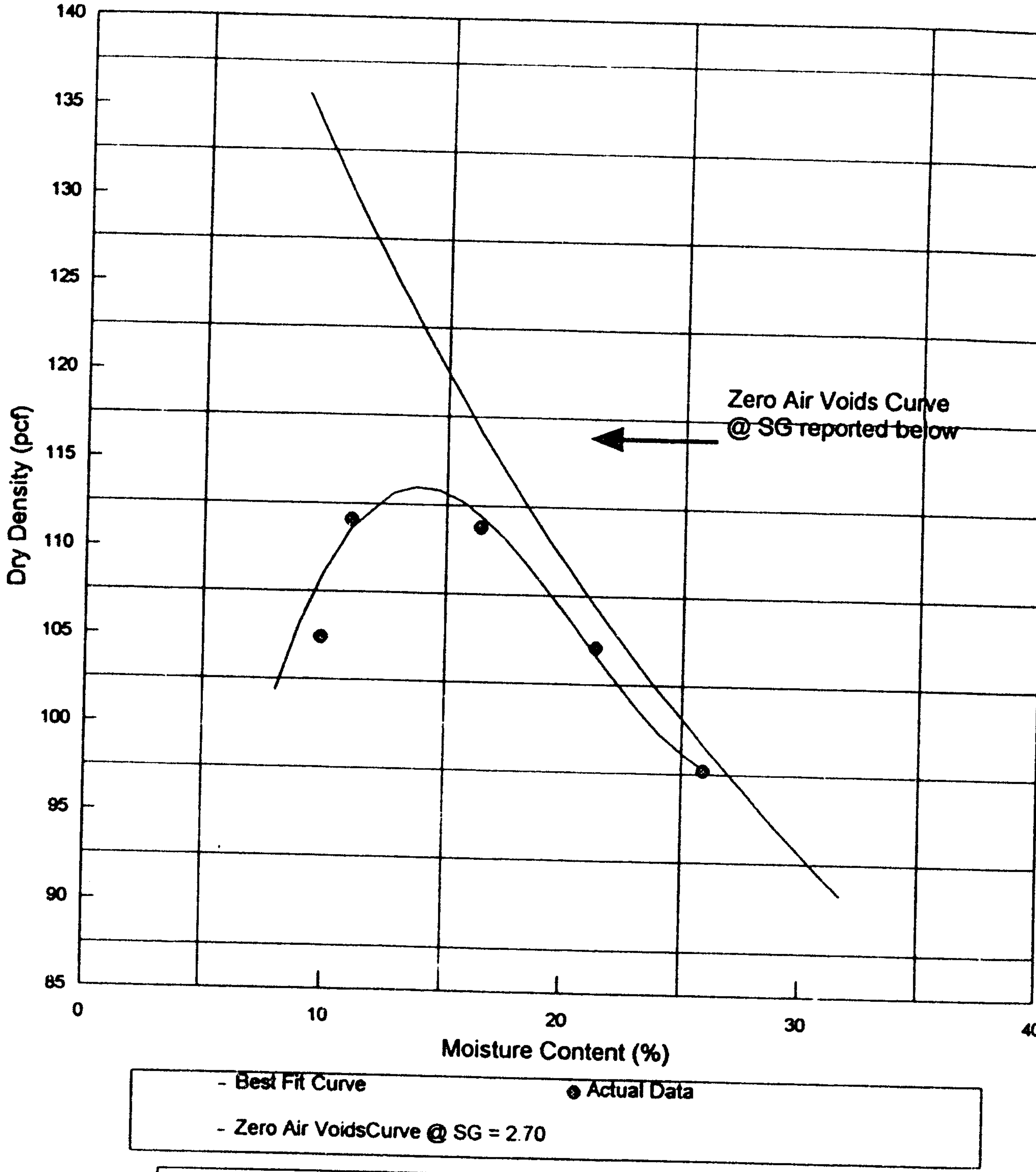
Wt of soil & mold (lb)	14.20	14.49	14.68	14.59	14.46
Wt. of mold (lb)	10.36	10.36	10.36	10.36	10.36
Net wt. of wet soil (lb)	3.84	4.13	4.32	4.23	4.10
' wt of dry soil (lb)	3.50	3.72	3.71	3.49	3.26
y Density, (pcf)	104.89	111.59	111.28	104.57	97.69
Corrected Dry Density (pcf)					
Volume Factor	30	30	30	30	30

Data entered by: RV Date: 7-26-96
a checked by: [signature] Date: 7-26-96
FileName: TIPRUT-1

ADVANCED TERRA TESTING, INC

Proctor Compaction Test

, , UT-1



OPTIMUM MOISTURE CONTENT = 13.9 MAXIMUM DRY DENSITY = 113.5
ASTM D 1557 A, Rock correction applied? N

ADVANCED TERRA TESTING, INC.

PERMEABILITY DETERMINATION
FALLING HEAD
FIXED WALL

CLIENT Titan Environmental

JOB NO. 2234-04

BORING NO.
DEPTH
SAMPLE NO. UT-1
SOIL DESCR. Remolded 95% Mod Pt. @ OMC
SURCHARGE 200

SAMPLED
TEST STARTED 7-28-96 CAL
TEST FINISHED 8-7-96 CAL
SETUP NO. 1

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil & Ring(s) (g)	386.9	404.5
Wt. Ring(s) (g)	93.0	93.0
Wt. Soil (g)	293.9	311.4
Wet Density PCF	122.3	120.5
Wt. Wet Soil & Pan (g)	302.4	319.9
Wt. Dry Soil & Pan (g)	266.2	266.2
Wt. Lost Moisture (g)	36.2	53.8
Wt. of Pan Only (g)	8.5	8.5
Wt. of Dry Soil (g)	257.7	257.7
Moisture Content %	14.1	20.9
Dry Density PCF	107.2	99.7
Max. Dry Density PCF	113.5	113.5
Percent Compaction	94.4	87.8

ELAPSED TIME (MIN)	BURETTE READING h1 (CC)	BURETTE READING h2 (CC)	PERCOLATION RATE FT/YEAR	PERCOLATION RATE CM/SEC
	0.2			
2599	10.8	10.8	0.14	1.4E-07
1427	14.2	14.2	0.09	8.4E-08
1440	16.8	16.8	0.07	6.5E-08
1440	18.6	18.6	0.05	4.6E-08
1440	20.2	20.2	0.04	4.1E-08
1440	21.6	21.6	0.04	3.7E-08
1469	23.0	23.0	0.04	3.6E-08
1440		24.4	0.04	3.7E-08

Data Entered By: NAA Date: 8-8-96
Date Checked By: JCl Date: 8-8-96
Filename:TIFHUT1

ADVANCED TERRA TESTING, INC.

RAE

Rogers & Associates Engineering Corporation

Post Office Box 330
Salt Lake City, Utah 84110-0330
(801) 263-1600 • FAX (801) 262-1527

September 3, 1996

Pamela Anderson
Titan Environmental Corporation
7939 E. Arapahoe Rd., Suite 230
Englewood, CO 80112

C9600/9

Dear Ms. Anderson:

Enclosed are the results from the radium content, specific gravity, and radon emanation and diffusion coefficient measurements that were performed on the sample sent to our laboratory. We will be returning the sample within the month.

If you have any questions or if we can be of further assistance, please call.

Sincerely,

Bret Rogers

Bret C. Rogers
Scientist

515 East 4500 South • Salt Lake City, UT 84107-2918
Additional Offices in: Idaho Falls, ID • Santa Fe, NM • Washington DC

Rogers & Associates Engineering Corporation

REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

Report Date: 9/3/96

Contract: C9600/9

By: BCR

Date Received: 8/96

Sample Identification: Titan Environmental

Sample ID	Moisture (Dry Wt. %)	Density (g/cm^3)	Radon Diffusion Coefficient (cm^2/s)	Saturation (Mρ/P)	Specific Gravity (g/cm^3)
UT-1	14.5%	1.72	9.1E-03	0.89	2.39

RAE

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Salt Lake City • Utah 84110
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Rogers & Associates Engineering Corporation

REPORT OF RADIUM CONTENT AND EMANATION COEFFICIENT MEASUREMENTS

(LAB PROCEDURE RAE-SQAP-3.1)

Report Date: 9/3/96

Contract: C9600/9

By: BCR

Date Received: 8/96

Sample Identification: Titan Environmental

Sample ID	Moisture (Dry Wt. %)	Radon Emanation Coefficient	Radium-226 (pCi/g)	Comments
UT-1	14.6%	0.22 ± 0.04	1.5 ± 0.3	

RAE

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SOIL & FOUNDATION ENGINEERING
96 S. ZUNI · DENVER, COLORADO 80223 · 303/744-7105
1924 EAST FIRST STREET · CASPER, WYOMING 82601 · 307/234-2126

SECTION 2

Extracted Data From

SOIL PROPERTY STUDY
EARTH LINED TAILINGS RETENTION CELLS
WHITE MESA URANIUM PROJECT
BLANDING, UTAH

Prepared for:

ENERGY FUELS NUCLEAR, INC.

PARK CENTRAL
1515 ARAPAHOE STREET
DENVER, COLORADO 80202

Job No. 16,406

July 18, 1978

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

Test Hole	Depth (Ft.)	NATURAL Moisture Content (%)	NATURAL Dry Density (pcf)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	ATTERBERG LIMITS Liquid Limit (%)	ATTERBERG LIMITS Plasticity Index (%)	GRADATION ANALYSIS Maximum Size	GRADATION ANALYSIS Passing #200 (%)	GRADATION ANALYSIS Less than 2 μ (%)	REMOLDED Dry Density (pcf)	REMOLDED Moisture Content (%)	PERMEABILITY ft./yr.	PERMEABILITY cm./sec.	Specific Gravity	Soil Type
2	0-5			117.5	10.8	20	3	#16	58	19	111.6	16.4	0.57	5.5×10^{-7}		Sandy Silt
3	7-8	7.2				21	6	#16	62							Sandy Clayey Silt
5	7½-10			104.1	18.5	33	8	3/4 In.	56	12	102.1	22.0	0.085	8.2×10^{-8}	2.65	Calcareous Silty Clay
6	1-2	10.3				25	7	#16	77							Sandy Clayey Silt
6	8½-9	6.1				27	8	#4	70							Sandy Clay
8	5-5½	13.1					NP	3/4 In.	62							Calcareous Sandy Silt
9	0-1	8.1					NP	#16	53							Sand - Silt
10	4-6½					24	10	#4	73							Sandy Clay
11	5½-6½	14.0				26	6	#16	65							Siltstone-Claystone
12	2-5			101.0	20.6	53	35	#16	8	59	95.0	18.3	0.068	6.6×10^{-8}	2.67	Weathered Claystone
13	7-8	13.1				39	13	#8	84							Calcareous Silt Clay
14	1-2	19.3				40	21	#4	89							Weathered Claystone
15	1½-4½			106.8	19.0	26	8	3/8 In.	65	27	103.4	18.0	0.012	1.2×10^{-8}	2.64	Mod. Calcareous Sandy Clay
17	2-3	11.4				19	4	#8	59							Sandy Silt
19	0-3			117.5	12.8	23	6	#16	70		109.9	12.4	0.035	3.4×10^{-8}		Sandy Clayey Silt
22	1-2	13.2				26	10	#4	73							Sandy Clay
23	1-3					48	24	#30	87							Weathered Claystone
23	6-8					61	30	#30	96							Claystone
25	1-3½	13.3				26	9	#4	57							Sandy Clay
26	4½-5	15.3				41	20	#4	91							Weathered Claystone
28	0-2	12.7				28	10	3/8 In.	72							Sandy Clay
29	2-3	8.5				19	2	#16	59							Sandy Silt
32	8-8½	5.6				23	6	#30	73							Sandy Clayey Silt
37	0-4			118.8	11.5	23	5	#8	72		110.5	11.5	0.63	6.1×10^{-7}		Sandy Clayey Silt
38	5-7			111.0	16.7	29	14	3/8 In.	69		102.4	17.9	0.041	4.0×10^{-8}		Sandy Clay
40	4-5½			110.0	16.2	26	9	#8	64	27	106.4	16.4	0.017	1.6×10^{-8}	2.65	Sandy Clay

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

Test Hole	Depth (Ft.)	NATURAL Moisture Content (%)	NATURAL Dry Density (pcf)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	ATTERBERG LIMITS Liquid Limit (%)	ATTERBERG LIMITS Plasticity Index (%)	GRADATION ANALYSIS Maximum Size	GRADATION ANALYSIS Passing #200 (%)	GRADATION ANALYSIS Less than 2 µ (%)	REMOLDED Dry Density (pcf)	REMOLDED Moisture Content (%)	PERMEABILITY ft./yr.	PERMEABILITY cm./sec.	Specific Gravity	Soil Type
40	9-9½	6.8				22	8	3/8 in.	60							Sandy Clay
42	13½-14½	7.6				26	10	3/8 in.	73							Sandy Clay
43	11-12	12.1				41	22	#4	86							Claystone
43	13½-16½			110.0	16.9	40	24	3/8 in.	85	44	104.1	15.8	0.024	2.3×10^{-8}	2.62	Claystone
44	6½-7	7.5				30	11	3/8 in.	79							Calcareous Sandy Clay
46	0-2	12.3				22	6	#16	76							Sandy Clayey Silt
48	5-5½					30	9	3/8 in.	65							Sandy Clay
49	5-7			110.7	15.6	25	9	#16	71		105.2	13.9	0.33	3.2×10^{-8}		Sandy Clay
49	14-15					28	5	#8	55							Calcareous Sandy Silt
54	0-2	12.1				23	9	#8	64							Sandy Clay
55	5-5½	7.8				28	14	#30	71							Sandy Clay
55	9½-10½					28	13	#4	71							Sandy Clay
58	5½-6	12.5				35	11	#4	75							Sandy, Silty Clay
61	0-1	11.5				21	4	#16	75							Sandy Silt
62	11-11½	8.1					NP	1 in.	34							Calcareous Sand & Silt
63	4-5					30	14	#8	68							Sandy Clay
65	1-2	9.0					NP	#16	44							Silty Sand
68	7½-8	8.6				28	13	#8	67							Sandy Clay
70	3½-4½	16.4				27	4	1½ in.	46							Calcareous Sand & Silt
72	0-2	12.2				22	8	#16	59							Sandy Clay
75	10-11	12.4				41	25	#4	75							Weathered Claystone
75	12-14					45	22	#16	93							Claystone

416,406

TABLE II

LABORATORY PERMEABILITY TEST RESULTS

Sample	Soil Type	Compaction			Surcharge Pressure (psf)	Permeability	
		Dry Density (pcf)	Moisture Content (%)	% of ASTM D698		(Ft/Yr)	(Cm/
TH 2 @ 0'-5'	Sandy Silt	111.6	16.4	95	500	0.57	5.5x1
TH 5 @ 7½'-10'	Calcareous Silty Clay	102.1	22.0	101	500	0.085	8.2x1
TH 12 @ 2'-5'	Weathered Claystone	95.0	18.3	94	500	0.068	6.6x1
TH 15 @ 1½'-4½'	Calcareous Sandy Clay	103.4	18.0	97	500	0.012	1.2x1
TH 19 @ 0'-3'	Sandy, Clayey Silt	109.9	12.4	94	500	0.035	3.4x1
TH 37 @ 0'-4'	Sandy, Clayey Silt	110.5	11.5	93	500	0.63	6.1x1
TH 38 @ 5'-7'	Sandy Clay	102.4	17.9	92	500	0.041	4.0x1
TH 40 @ 4'-5½'	Sandy Clay	106.4	16.4	97	500	0.017	1.6x1
TH 43 @ 13½-16½'	Claystone	104.1	15.8	95	500	0.024	2.3x1
TH 49 @ 5'-7'	Sandy Clay	105.2	13.9	95	500	0.33	3.2x1

TABLE III

RESULTS OF ATTERBERG LIMITS

SAMPLE	SOIL TYPE	PERCENT PASSING NO. 200 SIEVE	ATTERBERG LIMITS			SHRINKAGE RATIO
			Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)	
2 @ 0 - 5'	Sandy Silt	58	20	17	17.	1.81
5 @ 7½ - 10'	Calcareous Silty Clay	56	33	25	25	1.62
15 @ 1½-4½'	Calcareous Sandy Clay	65	26	18	17.5	1.76
19 @ 0-3'	Sandy, Clayey Silt	70	23	17	18	1.80
26 @ 4½-5'	Weathered Claystone	91	41	21	12	1.90
30 @ 5 - 7'	Sandy Clay	69	29	15	14	1.89

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SECTION 3

Extracted Data From

SOIL PROPERTY STUDY
PROPOSED TAILINGS RETENTION CELLS
WHITE MESA URANIUM PROJECT
BLANDING, UTAH

Prepared for:

ENERGY FUELS NUCLEAR, INC.
1515 ARAPAHOE STREET
DENVER, COLORADO 80202

Job No. 17,130

January 23, 1979

CHEN AND ASSOCIATES

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTICITY INDEX (%)	UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS DEVIATOR STRESS (PSF)	TRIAXIAL SHEAR TESTS CONFINING PRESSURE (PSF)	PERCENT PASSING NO. 200 SIEVE	SOIL TYPE
76	0 - 1	4.5		21	5				78	Sandy silt
	9.5 - 10	4.4			NP				26	Silty, gravelly sand
77	7.5 - 8	8.6		30	15				71	Sandy clay
79	0 - 1	4.1		20	5				83	Sandy silt
	5 - 5.5	5.5			NP				4[illegible]	Calcareous sandy clay
80	4.5 - 7			39	20				78	Calcareous sandy clay
	8 - 8.5	10.1		40	20				86	Weathered claystone
81	3 - 4	6.3		26	8				64	Silty, sandy clay
83	4 - 6			24	7				64	Sandy, clayey silt
84	0 - 2			18	2				65	Sandy silt
	9 - 9.5	2.7			NP				27	Silty sand
86	8 - 8.5	2.6			NP				12	Sandstone
87	0 - 1	3.1		16	1				61	Sandy silt
89	0 - 3			21	5				66	Sandy silt
90	8 - 8.5	12.9		35	15				61	Weathered claystone
92	0 - 1	5.9		21	5				80	Sandy silt
94	5 - 5.5	13.7		27	10				68	Sandy clay
95	6 - 7			23	5				62	Sandy silt
96	0 - 2	5.2		21	4				79	Sandy silt
	8.5 - 9.5			32	6				66	Calcareous sandy clay
98	0 - 1	3.8		20	5				74	Sandy silt
	4 - 4.5	17.8		49	25				76	Weathered claystone
99	8 - 9.5			40	20				89	Weathered claystone

CHEN AND ASSOCIATES

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS		PERCENT PASSING NO. 200 SIEVE	SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
99	11 - 12	13.5		26	10					
100	0 - 1			17	NP				73	Claystone
	5.5 - 6	12.0			NP				44	Silty sand
102	6.5 - 7	16.7		30	8				61	Sandstone-siltstone
	13.5 - 14	9.5		23	6				79	Calcareous sandy cla[y]
103	10 - 10.5	7.0		28	12				87	Claystone-siltstone
104	8 - 8.5	9.2		33	9				57	Sandy clay
105	0 - 1	5.4		22	6				70	Calcareous sandy clay
	6.5 - 7	4.5			NP				77	Sandy silt
106	5 - 5.5	10.4		28	6				86	Sandy silt
107	7.5 - 9				NP				59	Claystone-sandstone
108	0 - 1	4.0		18	3				23	Sandstone
	9.5 - 10	9.9		38	16				69	Sandy silt
109	4 - 5			25	7				93	Claystone
111	9 - 9.5	5.8		25	10				75	Sandy, clayey silt
113	5 - 8			40	20				53	Claystone
	10.5 - 11			24	10				84	Weathered claystone
114	0 - 2			22	6				54	Claystone-sandstone
115	4.5 - 6				NP				58	Sandy, clayey silt
116	0 - 3			22	5				58	Calcareous
	7 - 8			24	10				72	Sandy silt
117	1 - 2	10.6		25	5				42	Claystone-sandstone
118	0 - 2			25	6				77	Sandy silt
									77	Sandy silt

191

CHEN AND ASSOCIATES

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS		PERCENT PASSING NO. 200 SIEVE	SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
118	6.5 - 8.5			40	20				89	Weathered claystone
119	4.5 - 5	10.0		26	12				68	Sandy clay
120	1 - 2			25	8				69	Sandy, clayey silt
	5 - 5.5	15.5		29	10				78	Sandy clay
	11 - 11.5	11.6		42	24				90	Claystone
122	4 - 6			25	8				66	Sandy, silty clay
	14.5 - 15	6.4		26	8				66	Sandy clay
123	1 - 3			23	7				71	Sandy, clayey silt
124	4.5 - 5	6.0		23	7				69	Sandy, clayey silt
125	0 - 1	3.8		22	6				67	Sandy silt
127	5 - 6			54	34				89	Claystone
128	6 - 8			41	24				90	Claystone

.E II

LABORATORY PERMEABILITY TEST RESULTS

Sample	Classification	Compaction: Dry Density (pcf)	Compaction: Moisture Content (%)	% of ASTM D698	Surcharge Pressure (psf)	Permeability Ft./Yr.	Permeability Cm/Sec
TH 80 @ 4½-7'	Calcareous sandy clay -200=78; LL=39; PI=20	100.2	19.4	96	500	0.81	7.8×10^{-7}
TH 84 @ 0-2'	Sandy silt -200=65; LL=18; PI=2	113.8	11.7	96	500	4.45	4.3×10^{-6}
TH 96 @ 8½-9½'	Calcareous sandy clay -200=66; LL=32; PI=6	96.9	20.7	97	500	1.55	1.5×10^{-6}
TH 96 @ 8½-9½'	Calcareous sandy clay	95.7	20.3	96	500	26.90*	2.6×10^{-5}
TH 99 @ 8-9½'	Weathered claystone -200=89; LL=40; PI=20	99.8	18.5	95	500	0.22	2.1×10^{-7}
TH 100 @ 0-1'	Very silty sand -200=44; PI=NP	117.5	9.7	98	500	0.38	3.7×10^{-7}
TH 114 @ 0-2'	Sandy, clayey silt -200=58; LL=22; PI=6	112.4	12.9	95	500	0.60	5.8×10^{-7}
TH 120 @ 1-2'	Sandy, clayey silt -200=69; LL=24; PI=6	108.2	14.7	95	500	0.11	1.1×10^{-7}
TH 122 @ 4-6'	Sandy, silty clay -200=66; LL=25; PI=8	108.8	15.5	96	500	0.43	4.2×10^{-7}
TH 123 @ 1-3'	Sandy, clayey silt -200=71; LL=23; PI=7	110.9	12.6	95	500	0.56	5.4×10^{-7}
TH 128 @ 6-7'	Claystone -200=89; LL=41; PI=24	92.4	23.9	93	500	0.12	1.2×10^{-7}
TH 128 @ 6-7'	Claystone -200=89; LL=41; PI=4	93.1	22.1	94	500	0.52*	5.0×10^{-7}*

* 1.5 pH sulfuric acid liquor used during percolation test interval.

MRAP - 71000007 - GEOTECHNICAL DATA BASE FOR MONTICELLO MILLSITE CHARACTERIZATION - [illegible]; CREATED [illegible]; LAST UPDATED [illegible]

AREA	DATA SOURCE	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING #4 SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARBONATE PILE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MRAP - 7100007 - GEOTECHNICAL DATA ... FOR MONTICELLO MILLSITE CHARACTER... ION - R.K. MORRIS; CREATED 08/08/91; LAST UPDATED 11/02/91

AREA	DATA SOURC	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING #4 SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
CARBONATE PILE	DAM	TP-6	4ST	10.5	11.0	10.75	CL	Tails-cm	73.6	40.3	NA	NA	NA	NA	NA	NA	NA	
CARBONATE PILE	DAM	TP-6	8ST	17.0	17.5	17.25	SM	Tails-cm	72.3	19.8	NA	NA	NA	NA	NA	NA	NA	
CARBONATE PILE	DAM	TP-4	-BULK	10.0	10.0	10.00	SM	Tails-cm(?)	NA	18.8	NA	100.0	48.4	NA	NA	92.1	18.9	
CARBONATE PILE	DAM	TP-11	-BULK	6.0	6.6	[illegible]	SM	Tails-cm(?)	NA	18.7	2.70	100.0	47.9	NA	NA	102.7	18.0	Dir Shear, Perm, Mat Prop
CARBONATE PILE	DAM	TP-11	-BULK	13.0	16.6	14.80	CL	Tails-cm	NA	23.1	NA	100.0	91.3	NA	NA	98.6	24.9	
VANADIUM PILE	BENDIX	MRAP-88-04	MHB-88/ST	4.0	6.0	5.00	SC	Tails-cm/alm	88.7	26.8	2.62	100.0	44.5	27.0	18.0	NA	NA	Consol w/perm, CMR @15 bar
VANADIUM PILE	BENDIX	MRAP-88-07	MHB-70/BULK	1.0	1.0	1.00	ML	Cover	NA	NA	NA	NA	71.5	NA	NA	114.3	12.7	
VANADIUM PILE	BENDIX	MRAP-88-07	MHB-70/BULK	2.0	2.0	2.50	SP	Tails-cm	NA	NA	2.67	NA	NA	NA	NA	107.8	13.2	
VANADIUM PILE	BENDIX	MRAP-88-07	MHB-70/BULK	7.0	7.0	7.00	ML	Tails-cm	NA	NA	2.60	NA	NA	NA	NA	112.0	16.3	
VANADIUM PILE	BENDIX	MRAP-88-05	MHB-67/ST	6.0	8.0	[illegible]	CL-ML	Tails-cm	78.1	41.7	2.63	100.0	84.8	21.0	3.0	NA	NA	Consol w/perm, CMR @15 bar
VANADIUM PILE	DAM	315W01-001	3ST	5.5	7.5	6.50	SM	Tails-cm	NA	9.4	2.60	100.0	21.6	30.1	17.1	NA	NA	
VANADIUM PILE	DAM	315W01-002	1/SS	2.0	3.5	2.75	SM/GC	Cover	NA	10.8	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	3/SS	3.5	5.0	4.25	SM/CL	Tails-cm/alm	NA	18.8	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	4/SS	5.0	6.5	5.75	SM	Tails-cm(?)	NA	19.6	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	5/SS	8.5	10.0	9.25	ML	Tails-cm	NA	34.1	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	6/SS	10.5	11.0	10.75	SM	Tails-cm/alm	NA	11.5	2.60	100.0	21.3	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	7/SS	11.5	13.0	12.25	ML	Tails-cm	NA	25.0	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	9/SS	15.0	16.5	15.75	SM/CL	Tails-cm/alm	NA	26.0	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-002	10/SS	16.5	18.0	17.25	SM/CL	Tails-cm/alm	NA	18.3	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	11/SS	18.0	19.5	18.75	CL	Alluvium	NA	23.9	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	12/SS	19.0	21.5	20.50	CL	Alluvium	NA	10.7	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	13/SS	21.5	23.5	22.50	CL	Alluvium	NA	23.1	NA	NA	NA	44.2	34.0	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	14/SS	24.0	25.0	24.50	CL	Alluvium	NA	13.6	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	15/SS	26.5	27.5	26.25	CL	Alluvium	NA	23.6	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	16/SS	27.5	29.5	28.50	CL	Alluvium	NA	17.8	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	17/SS	29.5	31.5	30.50	CL	Alluvium	NA	17.9	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	18/SS	31.5	32.5	32.00	CL	Alluvium	NA	15.6	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	19/SS	32.5	34.5	34.10	CL	Alluvium	NA	17.8	NA	NA	NA	37.9	19.1	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	20/SS	32.5	37.5	35.50	CL	Alluvium	NA	23.7	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	21/SS	37.0	39.5	38.30	CL	Alluvium	NA	22.3	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	22/SS	39.5	41.0	40.25	CL	Alluvium	NA	23.1	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	23/SS	41.5	42.5	42.10	CL	Alluvium	NA	23.2	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	24/SS	43.5	44.5	44.20	SC/CL	Alluvium	NA	18.9	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	25/SS	45.5	46.0	45.70	[illegible]	Shale	NA	16.6	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	3ST	6.0	7.5	6.75	CL	Tails-cm	NA	23.3	NA	NA	NA	46.7	34.0	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	8/SS	13.5	14.5	14.12	CL	Tails-cm	95.1	20.3	2.90	NA	NA	46.7	22.8	NA	NA	Perm, CMR
VANADIUM PILE	DAM	315W01-0[illegible]	9/SS	18.5	20.5	19.00	CL	Tails-cm	NA	12.4	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-0[illegible]	11/SS	23.5	25.5	24.40	CL	Tails-cm	NA	22.4	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	1/SS	5.5	6.0	6.00	CL	Tails(?)-alm(?)	NA	23.5	NA	NA	NA	31.7	14.0	NA	NA	
VANADIUM PILE	DAM	315W01-011	2/SS	10.0	11.0	10.00	CL	Alluvium	NA	21.3	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	3/SS	14.0	15.6	15.00	CL	Alluvium	NA	10.5	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	5/SS	24.0	25.0	25.00	CL	Alluvium	NA	14.9	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	6/SS	29.5	31.0	30.00	CL	Alluvium	NA	16.3	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	8/SS	34.5	35.0	35.25	CL	Alluvium	NA	27.7	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	9/SS	38.0	40.0	38.50	SC	Alluvium	NA	15.2	NA	100.0	48.1	NA	NA	NA	NA	
VANADIUM PILE	DAM	315W01-011	10/SS	44.0	44.5	44.25	SM	Sandstone	NA	9.3	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	TP-4	1ST	4.5	5.0	4.75	SM	Tails-cm	90.1	7.4	NA	NA	NA	NP	NP	NA	NA	
VANADIUM PILE	DAM	TP-5	2ST	5.5	8.0	6.75	CL	Tails-cm	76.7	81.5	NA	NA	NA	NA	NA	NA	NA	Unsat Comp
VANADIUM PILE	DAM	TP-6	4ST	9.0	9.5	9.25	CL	Tails-cm	71.9	40.7	NA	NA	NA	NA	NA	NA	NA	Unsat Comp
VANADIUM PILE	DAM	TP-5	6ST	11.0	11.5	11.25	CL	Tails-cm	84.5	16.5	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	TP-5	7ST	14.0	14.5	14.25	CL	Tails(?)-alm(?)	68.5	81.5	NA	NA	NA	NA	NA	NA	NA	
VANADIUM PILE	DAM	TP-12	-BULK	6.0	6.0	6.00	CL	Tails-cm	NA	24.3	2.78	NA	NA	29.2	12.3	115.0	14.9	Perm, Mat Prop
VANADIUM PILE	DAM	TP-12	-BULK	12.0	12.0	12.00	CL	Tails-cm	NA	23.9	2.94	NA	NA	44.7	20.5	100.7	21.2	Triax-CU/PP, Perm, Mat Prop, CMR
EAST PILE	BENDIX	MRAA-88-01	MHB-88/ST	2.0	4.0	3.00	SM	Tails-cm	96.4	5.2	2.67	100.0	41.9	NP	NP	NA	NA	Consol w/perm, CMR @15 bar
EAST PILE	BENDIX	MRAP-88-07	MHB-77/BULK	1.0	1.0	1.00	ML	Cover	NA	NA	NA	100.0	22.9	NA	NA	111.2	14.1	
EAST PILE	BENDIX	MRAP-88-07	MHB-78/BULK	3.0	3.0	3.00	SM(?)	Tails-cm	NA	NA	NA	NA	NA	NA	NA	107.1	16.2	
EAST PILE	BENDIX	MRAP-88-07	MHB-78/BULK	15.0	15.0	15.00	SP(?)	Tails-cm(?)	NA	NA	2.70	NA	NA	NA	NA	102.0	15.9	
EAST PILE	BENDIX	MRAA-88-07	MHB-61/ST	2.0	4.0	3.00	SM	Tails-cm	94.0	9.9	2.61	100.0	19.8	NP	NP	NA	NA	Consol w/perm, CMR @15 bar
EAST PILE	BENDIX	MRAA-88-09	MHB-71/ST	12.0	14.0	13.00	CL	Tails-cm	102.0	34.4	2.70	100.0	61.0	41.0	22.0	NA	NA	Consol w/perm, CMR @15 bar
EAST PILE	BENDIX	MRAA-88-09	MHB-78/ST	4.0	6.0	5.00	ML	Tails-cm	100.7	21.4	2.63	100.0	90.0	42.0	13.0	NA	NA	Consol w/perm, CMR @15 bar
EAST PILE	DAM	315W01-0[illegible]	1/SS	3.5	5.5	4.00	SP	Tails-cm	NA	12.6	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	315W01-0[illegible]	2/SS	8.5	10.5	9.50	SM/ML	Tails-cm/alm	NA	16.6	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	315W01-0[illegible]	3/SS	13.5	15.5	14.00	SM/ML	Tails-cm/alm	NA	18.3	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	315W01-0[illegible]	NA	24.0	25.0	24.00	CL	Alluvium	NA	16.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	315W01-0[illegible]	10/SS	28.5	30.0	29.00	CL	Alluvium	NA	16.8	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	315W01-0[illegible]	3/SS	7.0	8.3	7.50	ML	MVP sand	NA	7.2	NA	NA	NA	NA	NA	NA	NA	

/20

MRAP - [illegible] - GEOTECHNICAL DATA BASE FOR MONTICELLO MILLSITE CHARACTERIZATION - R.N. MORRIS; CREATED [illegible]: LAST UPDATED [illegible]

AREA	DATA SOURC	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING #4 SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
EAST PILE	DAM	31SW01-[illegible]	[illegible]	20.5	22.0	21.25	CL	Tailings-sand	NA	28.2	NA	NA	NA	48.4	22.3	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	11/SS	24.5	26.0	25.25	CL/ML	Tailings-sand/slm	NA	34.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	12/SS	26.5	28.0	27.25	CL/ML/ML	Tailings-sand/slm	NA	28.1	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	13/SS	28.5	30.0	29.25	ML	Tailings-sand/slime	NA	28.7	NA	100.0	72.5	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	16/SS	40.0	42.5	41.25	ML	Alluvium	NA	24.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	42.5	43.7	43.25	ML	Alluvium	NA	23.0	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	45.0	47.5	45.75	ML	Alluvium	NA	28.6	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	46.5	48.7	46.85	ML	Alluvium	NA	24.0	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	1/SS	3.5	5.0	4.25	CL	MVP sand	NA	18.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	2/SS	8.5	10.0	9.75	SM	Tailings-sand	NA	28.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	3/U	14.5	15.0	14.75	CL	Tailings-slm	88.1	23.1	NA	NA	NA	38.6	12.7	NA	NA	
EAST PILE	DAM	31SW01-404	4/U	18.5	20.0	19.75	CL	Alluvium	96.0	22.1	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	[illegible]	22.5	26.0	24.25	CL	Alluvium	NA	19.8	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	[illegible]	27.0	28.4	27.70	CL	Alluvium	NA	19.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	[illegible]	28.5	30.0	29.25	CL	Alluvium	NA	18.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-404	[illegible]	32.6	35.0	34.25	CL	Alluvium	NA	22.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	[illegible]	[illegible]	38.75	CL	Alluvium	100.2	22.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	4.5	5.0	4.75	SM	Tailings-sand	99.2	7.9	NA	100.0	21.0	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	[illegible]	[illegible]	16.25	CL	Tailings-slm	94.1	88.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	7/U	18.5	20.0	19.75	CL	Tailings-slm	94.3	20.1	NA	NA	NA	23.2	2.6	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	22.5	26.0	24.25	ML	Alluvium	97.5	27.4	NA	NA	NA	81.4	13.6	NA	NA	Triax-CUPP
EAST PILE	DAM	31SW01-[illegible]	[illegible]	28.5	30.0	29.25	CH	Alluvium	91.1	34.2	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	16.5	17.0	16.75	CL	Tailings-sand/slime	91.1	26.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	20.6	22.0	21.00	CL	Tailings-slm	92.0	88.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	8.0	9.5	8.75	CL	Alluvium	NA	10.8	NA	NA	NA	38.5	18.6	NA	NA	Unsat Cons, Consol, Perm, CHR
EAST PILE	DAM	31SW01-[illegible]	[illegible]	[illegible]	[illegible]	16.25	CL	Alluvium	NA	11.2	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	24.0	25.5	24.75	CL	Alluvium	NA	14.8	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	28.0	29.5	28.75	CL	Alluvium	NA	16.1	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	34.0	35.5	34.75	CL	Alluvium	NA	17.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	[illegible]	[illegible]	38.75	CL	Alluvium	NA	17.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	44.5	45.0	44.75	CL	Alluvium	NA	21.1	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	48.0	48.5	48.25	CL/SC	Alluvium	NA	12.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-413	[illegible]	10.5	12.5	11.50	SC	Tailings-slm	90.0	27.2	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-413	[illegible]	[illegible]	[illegible]	28.50	CL	Tailings-sand/slm	98.7	88.6	NA	NA	NA	NA	NA	NA	NA	Unsat Cons
EAST PILE	DAM	31SW01-413	[illegible]	[illegible]	[illegible]	28.50	CL/ML	Tailings-sand/slm	NA	28.7	NA	NA	NA	NA	NA	NA	NA	Triax-CUPP, Consol
EAST PILE	DAM	31SW01-414	1/U	4.5	5.0	4.75	CL	MVP sand	102.6	8.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-414	2/U	8.5	10.0	9.75	SM	Tailings-sand	91.7	7.8	NA	100.0	22.6	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-414	3/U	14.5	15.0	14.75	CL	Alluvium(?)	92.4	25.1	NA	NA	NA	NA	NA	NA	NA	Dir Shear
EAST PILE	DAM	31SW01-414	7/U	18.5	20.0	19.75	CL	Alluvium(?)	98.0	79.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-414	8/U	24.0	24.5	24.25	CL	Alluvium(?)	62.0	62.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-414	[illegible]	40.0	40.5	40.45	Sh	Shale	NA	12.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-412b	[illegible]	2.5	3.0	3.13	SM	Tailings-sand	88.3	7.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-412b	[illegible]	7.5	8.1	8.15	SM	Alluvium	80.0	21.4	2.81	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-412b	[illegible]	12.5	12.7	13.10	CL/SC	Alluvium	NA	14.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	5.5	6.5	6.00	ML	Tailings-sand/slime(?)	NA	10.3	NA	100.0	88.4	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	6.0	6.5	6.75	SM	Tailings-sand	NA	13.4	NA	99.2	45.1	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	11.0	12.5	11.75	SM	Tailings-sand	NA	8.2	NA	99.5	80.6	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	12.5	14.0	13.75	SM	Tailings-sand	NA	9.9	NA	100.0	33.2	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	14.0	15.5	14.75	SM	Tailings-sand	NA	17.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	15.0	17.5	16.25	SM	Tailings-sand	NA	17.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	17.0	18.5	17.75	CL	Tailings-slm	NA	42.7	NA	NA	NA	38.0	13.9	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	18.5	20.0	19.25	CL	Tailings-slm	NA	34.4	NA	NA	NA	44.7	10.3	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	20.0	21.5	20.75	CL	Alluvium(?)	NA	28.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	21.5	23.0	22.25	CL	Alluvium(?)	NA	24.7	NA	NA	NA	30.0	19.0	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	22.0	22.5	22.25	SC	Alluvium	NA	8.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	4.5	5.0	4.75	CL	Alluvium	NA	10.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	8.5	10.0	9.75	CL	Alluvium	NA	13.2	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	14.0	15.5	14.75	CL	Alluvium	NA	15.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	18.5	20.0	19.75	CL	Alluvium	NA	13.6	NA	NA	NA	45.0	23.5	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	24.0	25.5	24.75	CL	Alluvium	NA	16.8	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	28.0	30.5	29.75	SC	Alluvium	NA	21.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-[illegible]	[illegible]	34.0	35.0	34.50	SC	Alluvium	NA	16.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-423	[illegible]	13.0	12.7	13.25	CL	Alluvium	101.0	22.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-423	4/U	18.0	19.5	19.75	CL	Alluvium	96.0	25.3	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-423	[illegible]	24.0	24.5	24.75	SC(?)	Alluvium	97.0	23.2	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	DAM	31SW01-423	6/U	29.3	29.4	29.50	Sh	Shale	112.4	18.1	NA	NA	NA	NA	NA	NA	NA	

194

MRAP - [illegible] - GEOTECHNICAL DATA BASE FOR MONTICELLO MILLSITE CHARACTERIZATION = R.H. MORRIS: CREATED 08/08/91; LAST UPDATED 11/22/91

AREA	DATA SOURC	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING #4 SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
EAST PILE	D&M	TP-1	1/ST	6.5	7.0	6.75	CL	MVP soil	100.3	11.1	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-1	-4BULK	7.0	7.0	7.00	CL	MVP soil	NA	16.2	NA	NA	NA	NA	NA	103.1	10.1	Perm, Mod Proc
EAST PILE	D&M	TP-1	2/ST	9.0	9.5	9.25	CL	MVP soil	90.3	28.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-1	3/ST	14.0	14.5	14.25	SM	Tails-sand	101.9	1.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-2	-4BULK	15.0	15.0	15.00	SM	Tails-sand	NA	16.0	NA	90.0	31.0	NA	NA	100.4	14.2	
EAST PILE	D&M	TP-2	1/ST	8.0	8.5	8.25	SM	Tails-slm	91.5	27.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-2	-4BULK	10.0	10.0	10.00	ML	Tails-slm	NA	22.0	NA	NA	NA	NA	NA	106.9	20.0	Consol, CMR
EAST PILE	D&M	TP-2	2/ST	10.5	11.0	10.75	SM	Tails-sand	87.2	1.7	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-2	3/ST	13.5	14.0	13.75	ML	Tails-sand&slm(?)	88.5	22.5	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-2	-4BULK	14.0	14.0	14.00	ML	Tails-sand&slm(?)	NA	7.3	NA	100.0	84.4	NA	NA	108.6	17.1	CMR
EAST PILE	D&M	TP-2	4/ST	14.5	15.0	14.75	ML	Tails-sand&slm(?)	74.0	25.4	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-4	-4BULK	9.0	9.0	9.00	ML	Tails-sand&slm	NA	22.4	NA	100.0	91.0	NA	NA	88.0	21.0	Dir Shear, Perm, CMR
EAST PILE	D&M	TP-4	2/ST	8.5	9.0	8.75	ML	Tails-sand&slm	91.8	7.9	NA	NA	NA	NA	NA	NA	NA	
EAST PILE	D&M	TP-4	-4BULK	14.0	14.0	14.00	ML	Tails-sand&slm	NA	14.7	2.71	100.0	98.0	NA	NA	101.8	17.3	Perm, CMR
EAST PILE	D&M	TP-4	5/ST	14.5	15.0	14.75	ML	Tails-sand&slm	91.0	27.1	NA	100.0	96.1	NA	NA	NA	NA	
ACID PILE	BENDIX	MRAP-86-10	MKB-72/ST	4.0	6.0	5.00	CL	Tails-slm	86.1	41.5	2.63	100.0	78.0	NA	NA	NA	NA	
ACID PILE	BENDIX	MRAP-86-10*	MKB-70/BULK	1.0	1.0	1.00	SM	Cover	NA	NA	NA	100.0	40.0	29.0	11.0	111.6	10.9	
ACID PILE	BENDIX	MRAP-86-10*	MKB-70/BULK	3.0	3.0	3.00	SP	Tails-sand	NA	NA	NA	NA	NA	NA	NA	110.4	12.4	
ACID PILE	BENDIX	MRAP-86-10*	MKB-70/BULK	6.0	6.0	6.00	CL	Tails-slm	NA	NA	2.75	NA	NA	NA	NA	94.6	20.3	
ACID PILE	BENDIX	MRAP-86-11	MKB-71/ST	4.0	6.0	5.00	CL	Tails-slm	74.8	20.0	2.60	100.0	72.0	44.0	20.0	NA	NA	Consol-[illegible], CMR @15 bar
ACID PILE	BENDIX	MRAP-86-12	MKB-72/ST	4.0	6.0	5.00	ML	Tails-slm	78.4	40.5	2.60	100.0	87.0	47.0	16.0	NA	NA	Consol-[illegible], CMR @15 bar
ACID PILE	D&M	310901-426	1/SS	4.5	5.0	4.75	CL	Tails-sand&slm	NA	20.0	NA	NA	NA	33.0	13.1	NA	NA	
ACID PILE	D&M	310901-426	3/SS	8.5	9.0	8.75	CL	Alluvium	NA	12.0	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-426	5/SS	13.5	14.5	14.50	CL	Alluvium	NA	17.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-427	2/ST	6.0	8.0	7.00	CH	Alluvium	71.5	42.6	NA	NA	NA	66.0	29.7	NA	NA	Triax-CU/PP, Unconf Comp, Perm, CMR
ACID PILE	D&M	310901-427	4/ST	9.0	11.5	10.25	CH	Alluvium	88.8	71.3	NA	NA	NA	66.0	31.4	NA	NA	Triax-CU/PP, Unconf Comp, Consol
ACID PILE	D&M	310901-427	6/ST	19.0	20.5	19.75	CL/SC	Alluvium	100.3	10.5	NA	NA	NA	37.4	21.0	NA	NA	Triax-CU/PP, Unconf Comp, Perm, CMR
ACID PILE	D&M	310901-428	2/SS	4.0	6.0	5.00	SM	Tails-sand(?)	NA	17.2	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	3/SS	6.0	6.9	6.45	SM	Tails-sand	NA	17.2	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	4/SS	9.0	10.0	9.50	CL-ML	Tails-slm	NA	27.0	2.70	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	5/SS	10.5	12.0	11.25	ML	Tails-slm	NA	22.0	NA	NA	NA	34.0	9.4	NA	NA	
ACID PILE	D&M	310901-428	6/SS	13.5	15.0	14.25	ML	Tails-sand&slm	NA	27.0	NA	100.0	21.7	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	7/SS	15.0	17.0	16.00	SM	Tails-sand&slm	NA	10.8	NA	100.0	34.7	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	8/SS	18.0	19.8	18.90	ML	Tails-slm	NA	42.3	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	9/SS	19.0	21.0	20.00	ML	Tails-slm	NA	30.0	NA	100.0	65.0	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	10/SS	22.5	23.0	22.75	SM	Tails-sand	NA	22.8	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	11/SS	24.0	25.0	24.50	ML/CL	Tails-sand&slm	NA	12.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	12/SS	25.0	27.0	26.00	ML/CL	Tails-sand&slm	NA	22.3	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	13/SS	27.0	29.0	28.00	CL	Tails-sand&slm	NA	22.9	NA	100.0	92.0	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	14/SS	28.0	29.5	28.75	ML/CL	Tails-sand&slm	NA	61.4	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	15/SS	31.0	33.0	32.00	CL	Tails-sand&slm	NA	64.7	NA	NA	NA	48.0	21.2	NA	NA	
ACID PILE	D&M	310901-428	16/SS	33.5	34.0	33.75	ML	Tails-sand&slm	NA	41.3	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	17/SS	35.0	37.0	36.00	ML/SC	Alluvium(?)	NA	12.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	18/SS	37.5	39.0	38.25	SC/CL	Alluvium	NA	22.9	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-428	19/SS	39.0	41.0	40.00	CL	Alluvium	NA	24.5	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-434	1/SS	5.0	6.0	5.50	ML/CL	Tails-slm	NA	17.2	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-434	3/SS	14.0	16.0	15.00	CL-ML	Tails-slm	NA	17.3	2.60	NA	NA	47.4	17.8	NA	NA	
ACID PILE	D&M	310901-434	7/SS	20.0	21.5	20.75	[illegible]	Shale	NA	10.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-436	3/SS	4.0	4.5	4.25	SM	Tails-sand	NA	4.0	NA	100.0	20.7	NA	NA	NA	NA	
ACID PILE	D&M	310901-436	5/SS	10.0	10.5	10.25	SM	Tails-sand	NA	2.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	310901-436	6/SS	12.0	12.5	12.25	SM	Tails-sand	NA	10.3	NA	100.0	78.0	NA	NA	NA	NA	
ACID PILE	D&M	310901-436	8/ST	19.0	20.0	19.50	SM	Tails-sand	102.0	12.4	NA	100.0	17.2	NA	NA	NA	NA	
ACID PILE	D&M	310901-436	12/SS	24.5	25.0	24.75	CL-ML	Tails-slm	NA	19.4	NA	NA	NA	46.0	18.2	NA	NA	Dir Shear, Perm, CMR
ACID PILE	D&M	TP-7	-4BULK	2.0	2.0	2.00	SM	Tails-sand	NA	8.6	2.71	100.0	42.5	NP	NP	100.0	14.5	Triax-CU/PP, Consol, Perm, Mod Proc, CMR
ACID PILE	D&M	TP-7	2/ST	3.0	3.5	3.25	CL	Tails-slm	82.5	62.0	NA	NA	NA	NA	NA	NA	NA	Unconf Shear
ACID PILE	D&M	TP-7	3/ST	6.5	7.0	6.75	CL	Tails-slm	86.1	84.4	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-7	4/ST	8.5	9.0	8.75	CL	Tails-slm	91.3	66.0	NA	NA	NA	NA	NA	NA	NA	Unconf Shear
ACID PILE	D&M	TP-7	5/ST	12.5	13.0	12.75	CL	Tails-slm	93.1	23.1	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-7	6/ST	16.5	17.0	16.75	CL	Tails-slm	81.4	22.1	NA	NA	NA	NA	NA	NA	NA	Unconf Shear
ACID PILE	D&M	TP-8	1/ST	2.5	3.0	2.75	SM/ML	Tails-sand&slm	78.0	11.0	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-8	2/ST	4.5	5.0	4.75	SM	Tails-sand	90.0	6.5	2.82	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-8	-4BULK	4.5	4.5	4.50	SM	Tails-sand	NA	7.5	NA	100.0	26.9	NA	NA	103.0	15.5	Dir Shear, Perm, Mod Proc, CMR
ACID PILE	D&M	TP-8	3/ST	6.0	6.5	6.25	SM	Tails-sand(?)	82.5	14.3	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-8	4/ST	10.0	10.5	10.25	ML	Tails-slm	84.7	30.0	2.70	100.0	62.5	NA	NA	NA	NA	
ACID PILE	D&M	TP-8	5/ST	12.0	12.5	12.25	CL	Tails-slm	90.2	70.9	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-8	-4BULK	13.0	13.0	13.00	CL	Tails-slm	NA	NA	NA	NA	NA	NA	NA	NA	NA	Perm

/20

MRAP - 71088007 - GEOTECHNICAL DATA BASE FOR MONTICELLO MILLSITE CHARACTERIZATION -- S.R. MORRIS: CREATED 08/20/91: LAST UPDATED 11/22/91

AREA	DATA SOURC	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING #4 SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
ACID PILE	D&M	TP-6	[illegible]	1.5	2.0	1.75	SM	Tailings-sand	88.4	4.6	NA	NA	NA	NA	NA	NA	NA	
ACID PILE	D&M	TP-6	[illegible]	2.6	3.5	3.25	SM	Tailings-sand	88.8	8.8	NA	100.0	10.5	NA	NA	NA	NA	
ACID PILE	D&M	TP-6	4/BULK	10.0	10.0	10.00	[illegible]	[illegible]	NA	23.4	NA	93.8	61.0	24.2	10.1	114.8	14.9	Perm, Mod Proct, CMR
SOMERVILLE TRACT	BENDIX	[illegible]	[illegible]	0.0	2.0	1.00	CL	Alluvium	NA	40.9	2.67	100.0	31.0	33.0	16.0	NA	NA	Perm, CMR @16 bar
SOMERVILLE TRACT	BENDIX	[illegible]	[illegible]	0.0	5.0	2.50	CL	Alluvium(Shale?)	NA	NA	NA	97.8	81.0	NA	NA	108.3	17.8	
SOMERVILLE TRACT	BENDIX	[illegible]	[illegible]	0.0	2.0	1.00	CL	Alluvium	NA	14.3	2.91	100.0	88.6	32.9	14.8	NA	NA	Perm, Consol w/perm, CMR @16 bar
SOMERVILLE TRACT	BENDIX	[illegible]	[illegible]	0.0	5.0	2.50	CL	Alluvium	NA	NA	NA	100.0	88.8	NA	NA	108.3	13.8	
BLM COMPOUND	BENDIX	[illegible]	[illegible]	0.0	2.0	1.00	CL	Alluvium	NA	16.6	2.62	100.0	88.3	44.8	7.8	NA	NA	Perm, CMR @15 bar
BLM COMPOUND	BENDIX	[illegible]	[illegible]	0.0	2.0	1.00	CL	Alluvium	NA	NA	NA	100.0	71.8	NA	NA	101.9	11.0	
BLM COMPOUND	D&M	[illegible]	[illegible]	3.3	4.5	4.00	CL	Alluvium	NA	23.4	NA	NA	NA	40.7	20.0	NA	NA	
BLM COMPOUND	D&M	[illegible]	[illegible]	4.5	5.5	5.00	CL	Alluvium	NA	31.0	NA	NA	NA	30.0	16.8	NA	NA	
BLM COMPOUND	D&M	[illegible]	4/88	8.0	10.5	9.75	CL	Alluvium	NA	17.1	NA	100.0	71.2	NA	NA	NA	NA	
VALLEY BOTTOM	BENDIX	[illegible]	[illegible]	0.0	2.0	1.00	CL	Alluvium	NA	7.8	2.68	NA	NA	30.9	13.9	NA	NA	
VALLEY BOTTOM	BENDIX	[illegible]	[illegible]	0.0	3.5	1.80	SM	Tailings-sand	NA	NA	NA	100.0	43.8	NA	NA	NA	NA	Perm, CMR @15 bar
VALLEY BOTTOM	D&M	[illegible]	3/88	3.5	4.8	4.16	CL	Alluvium	NA	12.8	NA	NA	NA	NA	NA	119.3	12.8	
VALLEY BOTTOM	D&M	[illegible]	7/88	8.5	10.0	9.25	CL	Alluvium	NA	16.8	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	8/88	12.5	14.3	13.00	CL	Alluvium	NA	16.3	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	11/BULK	24.0	25.0	24.50	CL	Alluvium	NA	16.5	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	8.8	8.9	8.75	[illegible]	Alluvium	NA	9.9	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	12.5	13.0	13.00	[illegible]	Alluvium	NA	8.4	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	1/88	4.0	6.0	5.00	[illegible]	Alluvium	NA	16.8	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	8.5	11.5	10.25	CL	Alluvium	NA	12.8	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	14.3	14.7	14.50	SC	Alluvium	NA	12.3	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	1/88	3.5	4.0	3.75	[illegible]	Shale	NA	10.2	NA	83.1	46.7	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	4/88	8.5	10.0	9.75	[illegible]	Alluvium	NA	8.1	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	6/88	14.0	14.5	14.25	[illegible]	Alluvium	NA	13.0	NA	88.4	18.8	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	1/88	4.5	5.0	4.75	SP	Alluvium	NA	10.7	NA	97.3	71.3	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	8.5	8.5	8.25	SP	Alluvium(?)	NA	8.8	NA	100.0	94.6	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	4/88	16.0	16.5	16.25	SP	Alluvium(?)	NA	8.6	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	[illegible]	3/88	13.5	14.5	14.00	[illegible]	Alluvium(?)	NA	13.2	NA	NA	NA	NA	NA	NA	NA	
VALLEY BOTTOM	D&M	TP-13	4/BULK	2.0	5.0	3.50	[illegible]	Alluvium	NA	28.1	NA	65.1	41.9	25.4	17.8	116.1	12.2	
MAIN MILLSITE	D&M	[illegible]	5/88	6.6	6.5	6.25	CL	Alluvium	NA	27.7	NA	NA	NA	NA	NA	NA	NA	
MAIN MILLSITE	D&M	[illegible]	9/88	8.1	8.5	8.25	CL	Alluvium	NA	28.5	NA	NA	NA	NA	NA	NA	NA	
MAIN MILLSITE	D&M	[illegible]	10/88	12.5	12.0	12.50	CL	Alluvium	NA	21.5	NA	NA	NA	NA	NA	NA	NA	
MAIN MILLSITE	D&M	[illegible]	3/88	3.5	4.5	4.16	CL	Alluvium	NA	23.9	NA	NA	NA	NA	NA	NA	NA	
MAIN MILLSITE	D&M	[illegible]	10/88	0.5	2.0	1.25	CL	Alluvium(Shale?)	NA	11.8	NA	NA	NA	40.3	23.9	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	3/88	16.0	10.5	10.25	CL	Fill	NA	72.6	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	4/88	8.5	8.5	8.75	CL	Alluvium(Shale?)	NA	7.3	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	4/88	16.0	16.5	16.25	CL	Alluvium	NA	10.0	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	1/88	2.0	2.5	2.25	CL	Alluvium	NA	8.6	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	3/88	9.0	10.3	9.66	CL	Alluvium	NA	14.2	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	4/88	10.3	11.4	10.86	CL	Alluvium	NA	14.0	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	5/88	14.0	14.3	14.10	SC	Alluvium	NA	12.2	NA	NA	NA	NA	NA	NA	NA	
SOUTH VALLEY WALL	D&M	[illegible]	4/88	4.5	5.0	4.75	CL	Alluvium	NA	11.4	NA	NA	NA	NA	NA	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	15/88	3.5	5.5	4.50	CL	Alluvium(?)	NA	12.9	NA	100.0	80.4	42.9	22.4	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	20/88	8.5	10.5	9.50	CL	Alluvium(?)	NA	28.1	NA	NA	NA	28.3	17.1	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	1/88	2.0	4.0	3.00	CL	Alluvium	NA	14.2	NA	100.0	97.8	NA	NA	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	3/88	0.0	11.0	10.50	CL	Alluvium	NA	18.9	NA	NA	NA	NA	NA	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	20/88	0.6	8.0	8.75	CL	Alluvium(?)	NA	21.2	NA	NA	NA	32.4	12.8	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	8/88	14.5	13.0	14.75	CL	Alluvium(?)	NA	23.8	2.70	NA	NA	NA	NA	NA	NA	
NORTH VALLEY WALL	D&M	[illegible]	7/88	16.0	16.0	16.75	CL	Alluvium(?)	NA	23.8	NA	NA	NA	40.3	22.8	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	1/88	2.5	3.5	3.00	CL	Alluvium	NA	11.9	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	12.5	14.3	13.00	CL	Alluvium	NA	13.8	NA	NA	NA	30.3	15.8	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	4/88	28.0	30.3	29.26	CL	Alluvium	NA	28.1	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	5.0	6.5	5.75	CL	Alluvium	NA	22.9	NA	NA	NA	44.9	22.8	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	4/88	9.5	10.0	9.75	CL	Alluvium	NA	17.5	NA	NA	NA	41.3	28.7	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	5/88	15.0	15.5	15.25	CL	Alluvium	NA	16.8	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	7/88	24.0	25.5	24.50	CL	Alluvium	NA	13.1	NA	NA	NA	27.9	9.4	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	3.5	4.3	3.90	CL	Alluvium(Loess?)	NA	17.4	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	8.5	8.5	8.50	CL	Alluvium(Loess?)	NA	15.6	NA	NA	NA	40.9	21.7	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	8.5	9.0	8.50	CL	Alluvium	NA	18.0	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	12.5	14.3	13.50	CL	Alluvium	NA	18.6	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	0.0	2.0	1.50	CL	Alluvium	NA	15.9	NA	NA	NA	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	10.0	10.5	10.40	SW	Alluvium	NA	8.9	NA	NA	NA	44.7	22.4	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	2.5	4.0	3.75	SM	Alluvium	NA	6.1	NA	80.9	38.4	NA	NA	NA	NA	
BLM PROPERTY-NORT	D&M	[illegible]	3/88	8.5	10.1	9.50	CL	Alluvium(?)	NA	23.5	NA	NA	NA	NA	NA	NA	NA	

7/20

MAAP - [illegible] - GEOTECHNICAL DATA BASE FOR MONTICELLO MILLSITE CHARACTERIZATION - R.H. MORRIS: CREATED 09/20/91: LAST UPDATED 11/22/91

AREA	DATA SOURC	BORING OR TEST PIT NUMBER	SAMPLE NUMBER & TYPE	TOP OF SAMPLE (FEET)	BASE OF SAMPLE (FEET)	SAMPLE MIDPOINT (FEET)	USCS SYMBOL	MATERIAL TYPE	IN-PLACE DRY DENSITY (PCF)	NATURAL MOISTURE CONTENT (PERCENT)	SPECIFIC GRAVITY	FRACTION PASSING [illegible] SIEVE (PERCENT)	FRACTION PASSING #200 SIEVE (PERCENT)	LIQUID LIMIT	PLASTICITY INDEX	ASTM D 698 MAXIMUM DRY DENSITY (PCF)	ASTM D 698 OPTIMUM MOISTURE CONTENT (PERCENT)	OTHER TESTS
BLM PROPERTY-NORTH	D&M	TP-10	1BULK	3.0	3.0	3.00	CL	Loess(?)	NA	12.0	NA	100.0	88.8	23.5	11.1	107.7	14.2	Mod Proct
BLM PROPERTY-NORTH	D&M	TP-10	2ST	6.0	6.5	6.25	CL	Loess(?)	91.7	8.2	NA	NA	NA	27.3	9.8	NA	NA	Unconf Comp
BLM PROPERTY-NORTH	D&M	TP-10	4ST	11.0	11.5	11.25	CL	Loess(?)	100.3	10.7	NA	NA	NA	48.5	21.8	NA	NA	Perm

KEY:

USCS United Soil Classification System group symbol, ASTM D 2487 or D2488 ([illegible])
ASTM Test designation of the American Society for Testing and Materials
[illegible] "Data Collection for Engineering for the Uranium Mill Tailings Site and Adjacent Peripheral Properties, Monticello, Utah," [illegible] Field Engineering Corporation, September 198[illegible]
D&M "Final Report, Monticello Remedial Action Project, 1991 Millsite Characterization Study," Dames & Moore, September 17, 1991
* Sample taken from a test pit excavated next to the designated borehole.
(?) Questionable value or identification

MATERIAL TYPE:

Tails-sand	Tailings sands
Tails-slim	Tailings slimes
Tails-[illegible]	Tailings sands and slimes, interbedded
Tails-[illegible]	Tailings sands and slimes, mixed
Cover	Cover material in place on tailings piles
MVP spoils	Material removed from Monticello Vicinity Properties
Alluvium	Miscellaneous surficial deposits, mostly stream-laid
Loess	Windblown fine-grained deposits
Shale	Mancos Shale, usually weathered
Sandstone	Dakota Sandstone
Fill	Miscellaneous man-made fill

OTHER TESTS:

Mod Proct	Modified Proctor compaction
Unconf Comp	Unconfined compressive strength
Dr Shear	Direct shear, consolidated-drained
Triax-CUPP	Triaxial shear, consolidated-undrained with pore pressure measurements
Consol	One-dimensional consolidation
Perm	Permeability, falling-head or flexible-membrane
CMR	Capillary moisture [illegible]

SAMPLE TYPES:

BULK	Disturbed bag sample of loose cuttings or materials from test pit.
SS	Disturbed sample from 2.0" O.D. standard split-spoon drive sampler
ST	Relatively undisturbed sample from 3.0" O.D. thin-walled (Shelby) tube sampler
U	Relatively undisturbed sample from Dames & Moore Type "U" ring-lined drive sampler

All data in this table compiled or interpreted from consultant's reports by R.H. Morris, Chem-Nuclear Geotech, Inc., October 1991. Checked by L.K. [illegible] & corrected by R.H. Morris, November 1991.

APPENDIX B

Radon Calculation

Purpose: To determine the required soil cover thicknesses to limit radon emissions from the White Mesa tailings impoundments to 20 pCi/m^2/sec using United States Nuclear Regulatory Commission (NRC) approved methods and inputs. The White Mesa Mill site is located in Blanding, Utah.

Method: Determine the geotechnical and radiological properties of the tailings and cover materials based on NRC-accepted methods and existing database values previously collected. Input parameters into the computer modeling program "RADON" to determine the radon flux values through the cover materials. A variety of scenarios adjusting cover thicknesses were run to determine the optimum thickness of cover materials to meet NRC specifications. It was assumed that the tailings located in the three cells at the White Mesa Mill site (Cells 2, 3, and 4A) have similar properties (Figure 1). Therefore, cover layer configurations as determined by the RADON model are applicable to the three tailings cells.

Results: A 2-layer uranium mill tailings cover composed of (from top to bottom) a 2-foot layer of random fill and a 1-foot compacted clay layer will meet NRC specifications. In addition to the tailings cover materials, a minimum of 3 feet of random fill will be placed between the tailings and soil cover to fill the currently existing freeboard. This 3 foot layer was included for modeling purposes since it will assist in reducing the radon flux from the tailings impoundments. This layer, however, is not considered a part of the actual soil cover. The resulting radon flux exiting the top cover layer of the tailings impoundment will be 13.6 pCi/m^2/sec (see Appendix A1 for RADON output).

As indicated in the "Effects of Freezing on Uranium Mill Tailings Covers Calculation Brief" (6/17/96), 6.8 inches of the top random fill cover layer will be effected by freeze/thaw conditions at Blanding Utah. This suggests that 6.8 inches of the top layer may not contribute to reductions of radon emanation from the tailings covers. To conservatively compensate for effects from freezing and thawing, 6.8 inches were subtracted from the top random fill cover layer. Executing the RADON model based on this cover configuration resulted in a radon flux emanation of 17.6 pCi/m^2/sec (see Appendix A2 for RADON output).

NRC specifications (Regulatory Guide 3.64) requires that a uranium tailings cover "..produce resonable assurance that the radon-222 release rate would not exceed 20 pCi/m^2/sec for a period of 1,000 years to the extent reasonably achievable and in any case for at least 200 years when averaged over the disposal area over at

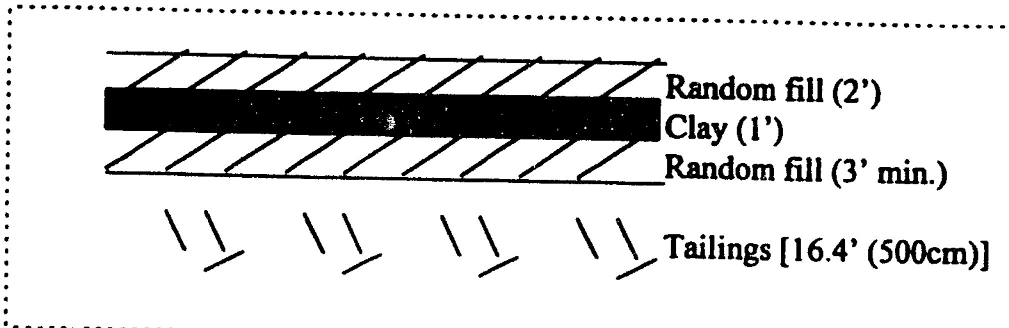
least a one-year period" (NRC, 1989). Therefore, the above design with accounting for freezing and thawing conditions is adequate.

Parameters: The RADON model requires input of the following parameters for all tailings and soil cover layers:

- layer thickness (centimeter (cm));
- porosity;
- mass density (g/cm^3);
- radium activity (pCi/gr), source term, or ore grade percentage;
- emanation coefficient;
- weight percent moisture (long-term) (percent), and;
- diffusion coefficient (cm^2/sec).

Physical and radiological properties for Tailings and Random Fill were analyzed by Chen and Associates (1987) and Rogers and Associates (1988) respectively. See Appendix B1 for analysis results. Clay physical data input for RADON modeling are included in Appendix B2 and were analyzed by Advanced Terra Testing (1996) and Rogers and Associates (1996).

The following cover profile was modeled.



This cover configuration represents the actual cover layer thicknesses which would be constructed on site. The cover profile above was adjusting for modeling purposes to account for freezing and thawing conditions. The modeled profile is identical to the one above with the exception of the top random fill layer which was reduced to 1.4 feet (2 feet minus 6.8 inches). It is assumed that 6.8 inches of the top cover layer effected by freeze/thaw conditions will not contribute to reductions in radon emanation from the tailings covers.

Layer thicknesses

The thickness of the tailings was assumed to be effectively an infinitely thick radon source. In accordance with NRC criteria (Reg. Guide 3.64, p. 3.64-5) a tailings thickness greater than about 100-200 cm is considered to be effectively, infinitely thick. A value of 500 cm represents an equivalent infinitely thick tailings source. The actual tailings thickness of Cell 3 at White Mesa is approximately 28 feet (850 cm), therefore, a value of 500 cm was used for the RADON model.

A minimum of 3-feet (91.5 cm) of random fill will cover the tailings to fill the existing freeboard and bring the tailings piles up to the subgrade elevation of the soil cover. A 1-foot (30.5 cm) layer of compacted clay covers the random fill with an additional 2 feet (61 cm) of random fill overlying the clay layer. Adjusting for freeze/thaw conditions results in a (43 cm) random fill layer overlaying the clay layer.

Porosity

Porosity is calculated from the specific gravity and dry bulk density according to the following equations;

1. Dry bulk density = [(specific gravity)(density of water)]/[1 + e] (Ref.: Principles & Practice of Civil Engineering, 1996, equation 14.5.6). See Appendix C.
2. Porosity = [e / (1+e)] x 100 (Ref.: Principles & Practice of Civil Engineering, 1996, equation 14.5.4). See Appendix C.

	Max. Dry Density (lb/ft^3)	Bulk Dry Density (lb/ft^3) (1)	Specific Gravity	Density of Water (lb/ft^3)	"e" (2)	porosity (3)
Tailings (4)	104.0	98.8	2.85	62.4	0.80	44%
Clay (5)	113.5	107.8	2.39	62.4	0.38	28%
Random fill (4)	120.2	114.2	2.67	62.4	0.46	31.5%

Notes:

1. Bulk dry density is 95% of the ASTM Proctor maximum dry density for all materials.
2. Calculated using Equation 1 above where "e" is the volume of voids per volume of solids.
3. Calculated using Equation 2 above.
4. Physical tailings and random fill data from Chen and Associates (1987) included in Appendix B1.
5. Clay physical data from Advanced Terra Testing (1996) and Rogers and Associates (1996) included in Appendix B2.

Mass Density

Mass densities were measured by Rogers and Associates (1988 and 1996) to be (see Appendix B1 and B2):

Tailings	=	1.45 g/cm^3
Clay	=	1.72 g/cm^3
Random Fill	=	1.85 g/cm^3

Radium Activity, Source Term, or Ore Grade %

Radium activity values from Rogers & Associates (1988 and 1996), were input for White Mesa tailings and cover materials (Appendix B1 and B2). The radium activity values are:

Tailings	=	981 pCi/gm
Clay	=	1.5 pCi/gm
Random Fill	=	1.9 pCi/gm.

Emanation Coefficient

Emanation coefficient input for the tailings and cover materials are measured values from Rogers & Associates (1988 and 1996), included in Appendix B1 and B2. The coefficients are:

Tailings	=	0.19
Clay	=	0.22
Random Fill	=	0.19

Note: Use of NRC's default value of E=0.35 is not considered appropriate since laboratory analyses of emanation coefficients are available.

Weight Percent Moisture

Long-term moisture content (weight percent moisture) was assumed to be 6% for the tailings. NRC Regulatory Guide 3.64 states, "if acceptable documented alternative information is not furnished by the applicant, the staff will use a reference value of 6% for the tailings moisture content because 6% is a lower bound for moisture in western soils" (NRC, 1989). Laboratory data does not exist to determine the actual weight percent moisture of tailings therefore, this is a conservative assumption.

The weight percent moisture of the new clay source (UT-1) is also unknown therefore, it was assumed that the average weight percent moisture from clay (site #1 and site #4) would be equivalent to the new clay source (UT-1). This is also a conservative assumption as the new clay

source is believed to be of better quality. Weight percent moisture values for clay and random fill were derived from the "Summary of Capillary Moisture Relationship Test Results" figures included in Appendix B1. Weight percent moisture values used for modeling purposes are:

Tailings	= 6%
Clay	= 14.1%
Random Fill	= 9.8%

Diffusion Coefficient

Diffusion coefficient input for the tailings and cover materials are measured values from Rogers & Associates (1988 and 1996), included in Appendix B1 and B2. The coefficients used for tailings and random fill were an average of the two values presented. The coefficients for each material are as follows:

Tailings	= 0.0142 cm^2/sec
Clay	= 0.0091 cm^2/sec
Random Fill	= 0.0082 cm^2/sec

References:

Advanced Terra Testing, 1996, Physical soil data, White Mesa Project, Blanding Utah, July 25, 1996.

Chen and Associates, 1987. Physical soil data, White Mesa Project Blanding Utah.

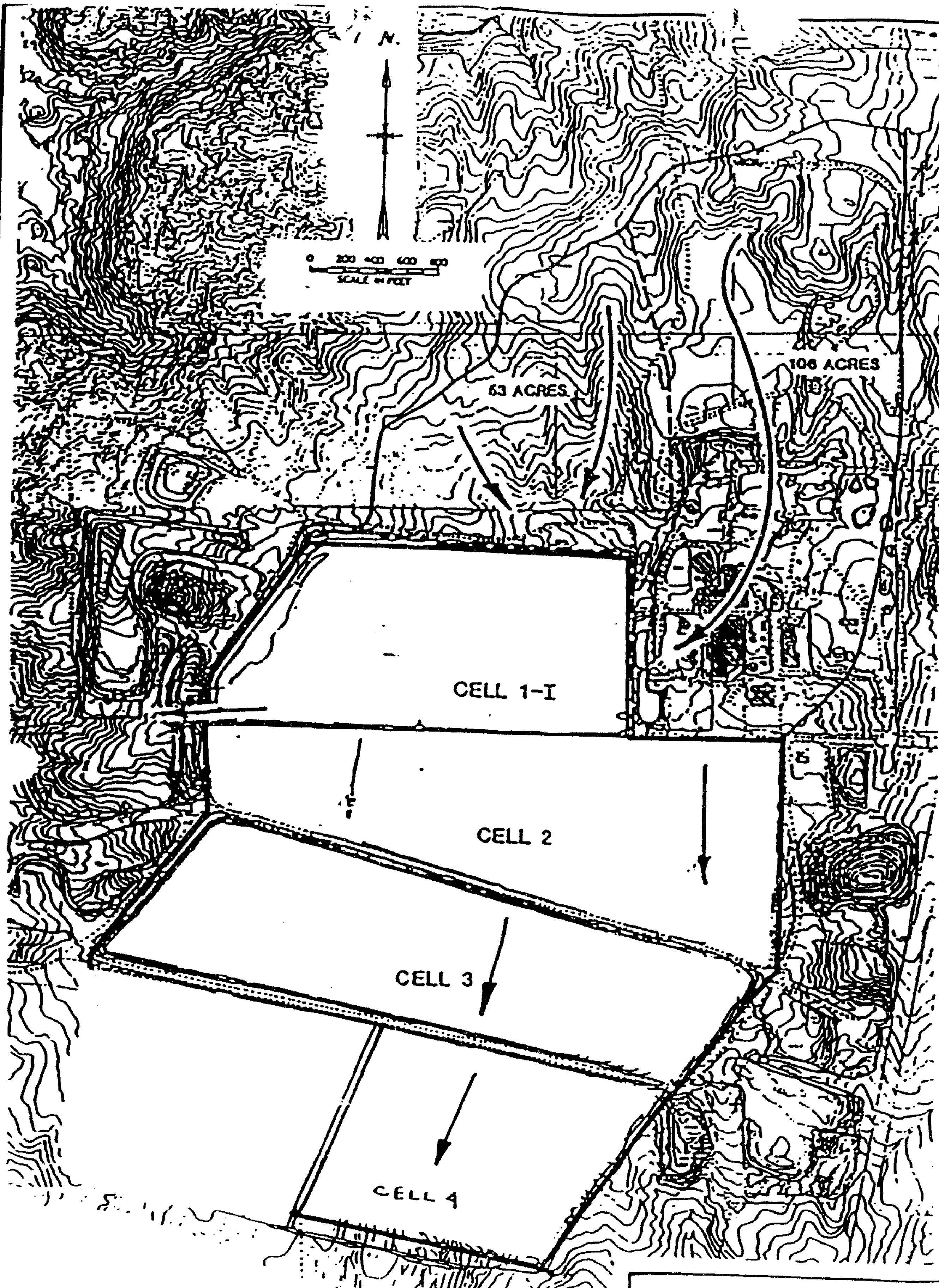
Freeze R. Allan and Cherry, John A., 1979, "Groundwater".

Principles & Practice of Civil Engineering, 2nd Edition, 1996.

Rogers and Associates Engineering Company, 1988. Radiological Properties Letters to C.O. Sealy from R.Y. Bowser dated March 4 and May 9, 1988.

Rogers and Associates Engineering Company, 1996. Report of Radon Diffusion Coefficient Measurements, Radium Content, and Emanation Coefficient Measurements, September 3, 1996.

U.S. Nuclear Regulatory Commission (NRC), 1989. "Regulatory Guide 3.64 (Task WM 503-4) Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers", March 1989.



WHITE MESA PROJECT

SITE DRAINAGE

FIGURE: 1

Appendix A1

-----*****! RADON !*****-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000 8/32
U.S. Nuclear Regulatory Commission Office of Research

RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS

DATE/TIME OF THIS RUN
09-10-1996/18:06:33

EFN - WHITE MESA

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	4	
DESIRED RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
RADON FLUX INTO LAYER 1	0	pCi m^-2 s^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 TAILINGS

THICKNESS	500	cm
POROSITY	.44	
MEASURED MASS DENSITY	1.45	g cm^-3
MEASURED RADIUM ACTIVITY	981	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	1.290D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.198	
MEASURED DIFFUSION COEFFICIENT	.0142	cm^2 s^-1

LAYER 2 RANDOM FILL (FILL FREEBOARD)

THICKNESS	91.5	cm
POROSITY	.315	
MEASURED MASS DENSITY	1.85	g cm^-3
MEASURED RADIUM ACTIVITY	1.9	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	4.452D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	9.800000000000001	%
MOISTURE SATURATION FRACTION	.576	
MEASURED DIFFUSION COEFFICIENT	8.200000000000001D-03	cm^2 s^-1

9/32

LAYER 3 CLAY (UT-1)

THICKNESS	30.5	cm
ROSITY	.28	
MEASURED MASS DENSITY	1.72	g cm^-3
MEASURED RADIUM ACTIVITY	1.5	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.22	
CALCULATED SOURCE TERM CONCENTRATION	4.257D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	14.1	%
MOISTURE SATURATION FRACTION	.866	
MEASURED DIFFUSION COEFFICIENT	.0091	cm^2 s^-1

LAYER 4 RANDOM FILL

THICKNESS	61	cm
POROSITY	.315	
MEASURED MASS DENSITY	1.85	g cm^-3
MEASURED RADIUM ACTIVITY	1.9	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	4.452D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	9.800000000000001	%
MOISTURE SATURATION FRACTION	.576	
MEASURED DIFFUSION COEFFICIENT	8.200000000000001D-03	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DEFAULT DRIVE

N	F01	CN1	ICOST	CRITJ	ACC
4	0.000D+00	0.000D+00	0	2.000D+01	1.000D-03

LAYER	DX	D	P	Q	XMS	RHO
1	5.000D+02	1.420D-02	4.400D-01	1.290D-03	1.977D-01	1.450
2	9.150D+01	8.200D-03	3.150D-01	4.452D-06	5.756D-01	1.850
3	3.050D+01	9.100D-03	2.800D-01	4.257D-06	8.661D-01	1.720
4	6.100D+01	8.200D-03	3.150D-01	4.452D-06	5.756D-01	1.850

BARE SOURCE FLUX FROM LAYER 1: 4.667D+02 pCi m^-2 s^-1

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	5.000D+02	1.233D+02	4.519D+05
2	9.150D+01	2.562D+01	7.892D+04
3	3.050D+01	1.962D+01	2.276D+04
4	6.100D+01	1.361D+01	0.000D+00

Appendix A2

-----*****! RADON !*****-----

Version 1.2 - MAY 22, 1989 - G.F. Birchard tel.# (301)492-7000
U.S. Nuclear Regulatory Commission Office of Research

RADON FLUX, CONCENTRATION AND TAILINGS COVER THICKNESS

12/32

DATE/TIME OF THIS RUN
09-10-1996/14:46:46

EFN - WHITE MESA (ACCOUNTING FOR FREEZE/THAW CONDITIONS)

CONSTANTS

RADON DECAY CONSTANT	.0000021	s^-1
RADON WATER/AIR PARTITION COEFFICIENT	.26	
SPECIFIC GRAVITY OF COVER & TAILINGS	2.65	

GENERAL INPUT PARAMETERS

LAYERS OF COVER AND TAILINGS	4	
DESIRED RADON FLUX LIMIT	20	pCi m^-2 s^-1
LAYER THICKNESS NOT OPTIMIZED		
DEFAULT SURFACE RADON CONCENTRATION	0	pCi l^-1
RADON FLUX INTO LAYER 1	0	pCi m^-2 s^-1
SURFACE FLUX PRECISION	.001	pCi m^-2 s^-1

LAYER INPUT PARAMETERS

LAYER 1 TAILINGS

THICKNESS	500	cm
POROSITY	.44	
MEASURED MASS DENSITY	1.45	g cm^-3
MEASURED RADIUM ACTIVITY	981	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	1.290D-03	pCi cm^-3 s^-1
WEIGHT % MOISTURE	6	%
MOISTURE SATURATION FRACTION	.198	
MEASURED DIFFUSION COEFFICIENT	.0142	cm^2 s^-1

LAYER 2 RANDOM FILL

THICKNESS	91.5	cm
POROSITY	.315	
MEASURED MASS DENSITY	1.85	g cm^-3
MEASURED RADIUM ACTIVITY	1.9	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	4.452D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	9.800000000000001	%
STURE SATURATION FRACTION	.576	
MEASURED DIFFUSION COEFFICIENT	8.20000000C000001D-03	cm^2 s^-1

13/32

LAYER 3 CLAY

THICKNESS	30.5	cm
POROSITY	.28	
MEASURED MASS DENSITY	1.72	g cm^-3
MEASURED RADIUM ACTIVITY	1.5	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.22	
CALCULATED SOURCE TERM CONCENTRATION	4.257D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	14.1	%
MOISTURE SATURATION FRACTION	.866	
MEASURED DIFFUSION COEFFICIENT	.0091	cm^2 s^-1

LAYER 4 RANDOM FILL

THICKNESS	43	cm
POROSITY	.315	
MEASURED MASS DENSITY	1.85	g cm^-3
MEASURED RADIUM ACTIVITY	1.9	pCi/g^-1
MEASURED EMANATION COEFFICIENT	.19	
CALCULATED SOURCE TERM CONCENTRATION	4.452D-06	pCi cm^-3 s^-1
WEIGHT % MOISTURE	9.800000000000001	%
MOISTURE SATURATION FRACTION	.576	
MEASURED DIFFUSION COEFFICIENT	8.200000000000001D-03	cm^2 s^-1

DATA SENT TO THE FILE 'RNDATA' ON DEFAULT DRIVE

N	F01	CN1	ICOST	CRITJ	ACC
4	0.000D+00	0.000D+00	0	2.000D+01	1.000D-03

LAYER	DX	D	P	Q	XMS	RHO
1	5.000D+02	1.420D-02	4.400D-01	1.290D-03	1.977D-01	1.450
2	9.150D+01	8.200D-03	3.150D-01	4.452D-06	5.756D-01	1.850
3	3.050D+01	9.100D-03	2.800D-01	4.257D-06	8.661D-01	1.720
4	4.300D+01	8.200D-03	3.150D-01	4.452D-06	5.756D-01	1.850

BARE SOURCE FLUX FROM LAYER 1: 4.667D+02 pCi m^-2 s^-1

14/32

RESULTS OF THE RADON DIFFUSION CALCULATIONS

LAYER	THICKNESS (cm)	EXIT FLUX (pCi m^-2 s^-1)	EXIT CONC. (pCi l^-1)
1	5.000D+02	1.237D+02	4.514D+05
2	9.150D+01	2.679D+01	7.622D+04
3	3.050D+01	2.123D+01	1.944D+04
4	4.300D+01	1.756D+01	0.000D+00

Appendix B1

TAILINGS AND RANDOM FILL PROPERTIES

Table 3.4-1

Physical Properties of Tailings

and

Proposed Cover Materials

Material Type	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity	% Passing No. 200 Sieve	Maximum Dry Density (pcf)	Optimum Moisture Content
Tailings	28	6	2.85	46	104.0	18.1
Random Fill	22	7	2.67	48	120.2	11.8
Clay	29	14	2.69	56	121.3	12.1
Clay	36	19	2.75	68	108.7	18.5

Note: Physical Soil Data from Chen and Associates (1987).

R
A
E

Rogers & Associates Engineering Corporation

Post Office Box 330
Salt Lake City, Utah 84110
(801) 263-1600

17/32

March 4, 1988

Mr. C.O.S aly
Umetco Minerals Corporation
P.O. Box 102[illegible]
Grand Junction, CO 81502

C8700/22

Dear Mr. Sealy:

We have completed the tests ordered on the four samples shipped to us. The results are as follows:

Sample	Radium pCi/gm	Emanation Fraction	Diffusion Coeffic.	(g/cm^3) Density	Moisture	Saturation
Tailings	981±4	0.19±0.01	2.0E-02	1.45	13.2	0.39
Composite (2,3,&5)			8.4E-03	1.44	19.1	0.56
			1.6E-02	1.85	6.5	0.40
Site #1			4.5E-04	1.84	12.5	0.75
			1.6E-02	1.85	8.1	0.48
Site #4			1.4E-03	1.84	12.6	0.76
			1.1E-02	1.65	15.4	0.63
			4.2E-04	1.65	19.3	0.80

The samples will be shipped back to you in the next few weeks. If you have any questions regarding the results on the samples please feel free to call.

Sincerely,

Renee Y. Bowser
Lab Supervisor

RYB/b

R
A
E

Rogers & Associates Engineering Corporation

Post Office Box 330
Salt Lake City, Utah 84110
(801) 263-1600

18/32

MAY 12 1988

May 9, 1988

Mr. C.O. Sealy
UMETCO Minerals Corporation
P.O. Box 1029
Grand Junction, CO 81502

C8700/22

Dear Mr. Sealy:

The tests for radium content and radon emanation coefficient in the following samples have been completed and the results are as follows:

Sample	Radium (pCi/g)	Radon Emanation Coefficient
Random (2,3 & 5)	1.9 ± 0.1	0.19 ± 0.04
Site 1	2.2 ± 0.1	0.20 ± 0.03
Site 4	2.0 ± 0.1	0.11 ± 0.04

If you have any questions regarding these results please feel free to call Dr. Kirk Nielson or me.

Sincerely,

Renee Y. Bowser
Lab Supervisor

RYB:ms

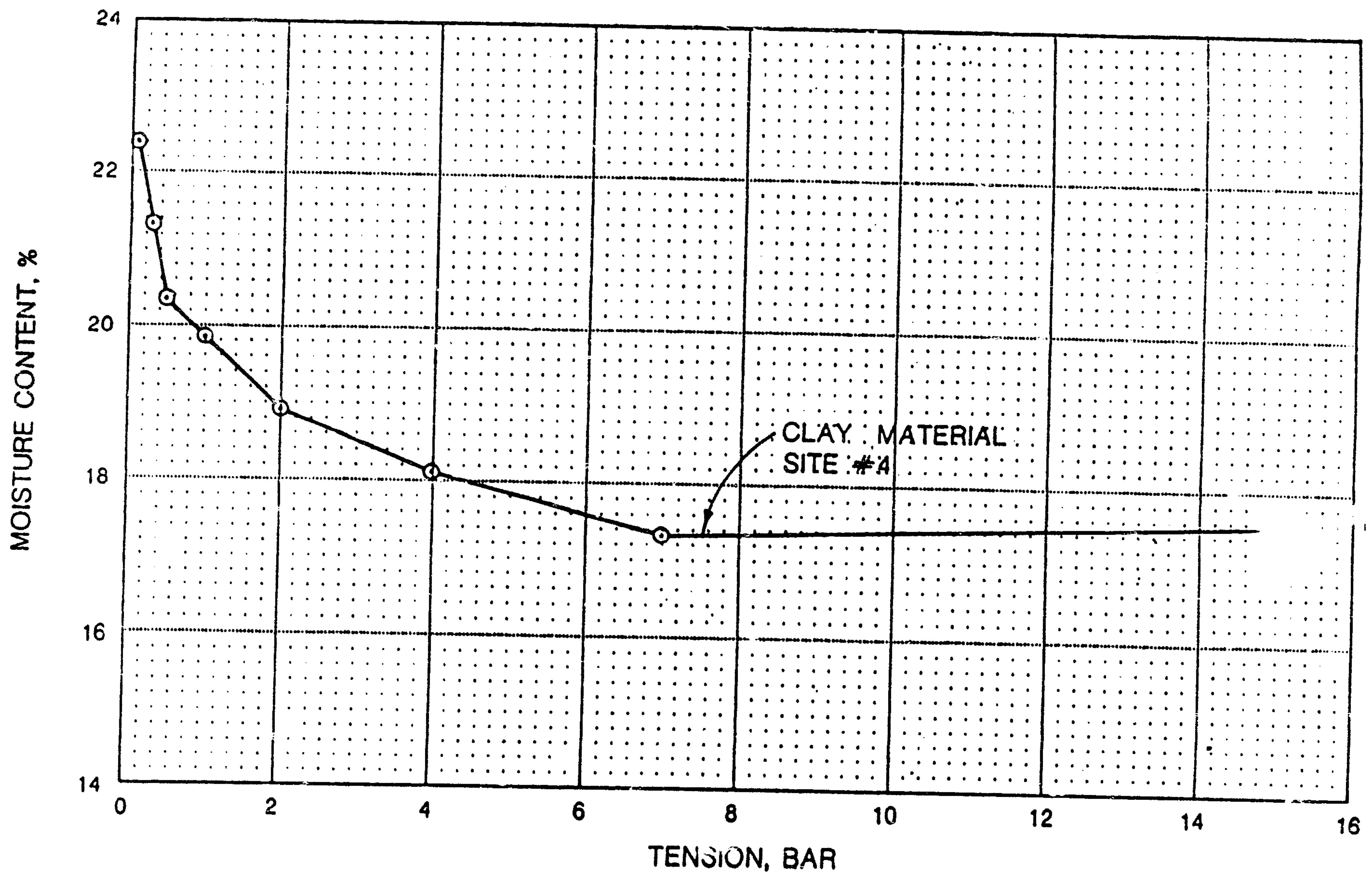


FIGURE 4.4-2
SUMMARY OF CAPILLARY MOISTURE RELATIONSHIP TEST RESULTS
WHITE MESA PROJECT

DATA FROM CHEN & ASSOCIATES

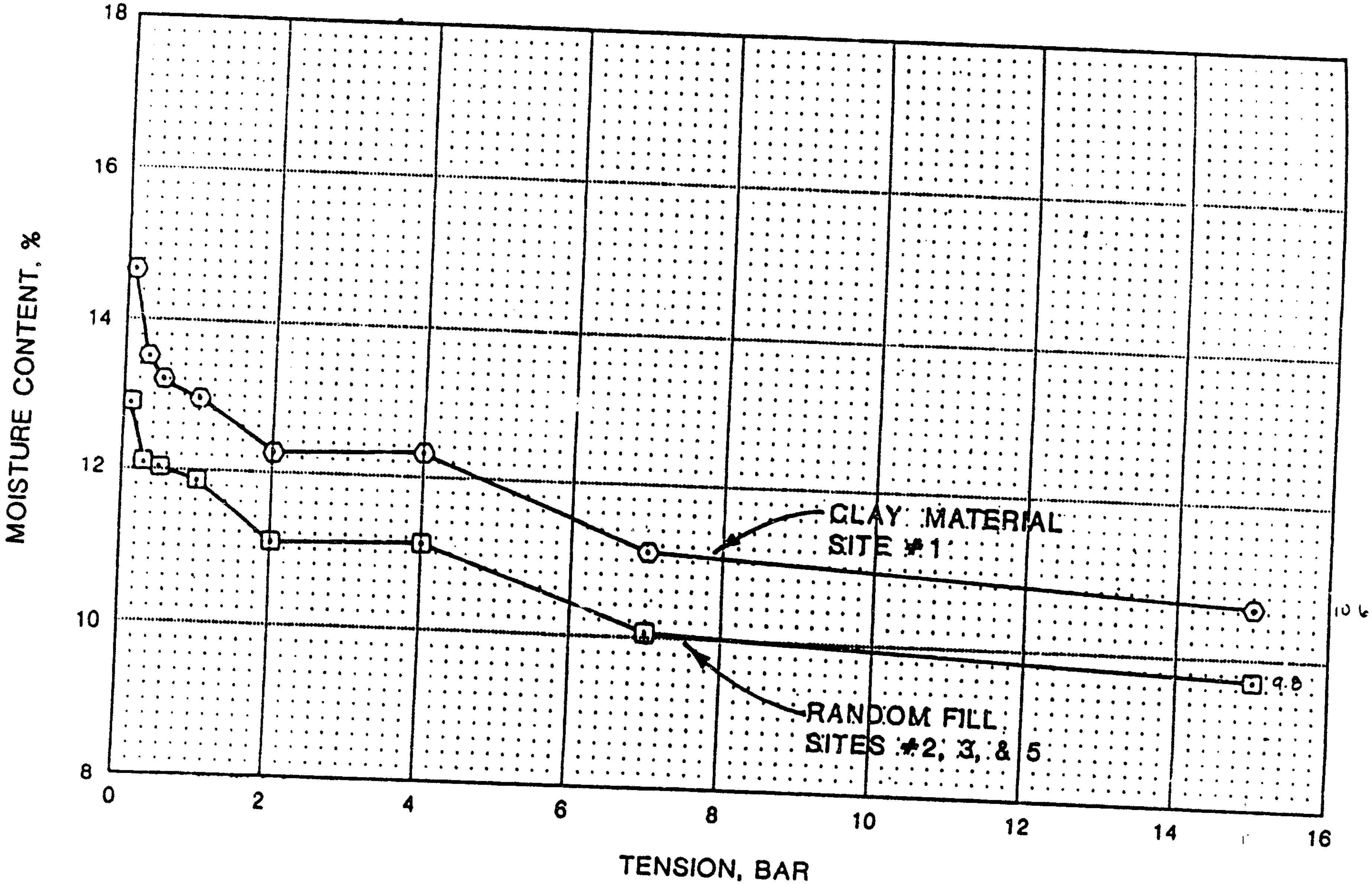


FIGURE 4.4-1
SUMMARY OF CAPILLARY MOISTURE RELATIONSHIP TEST RESULTS
WHITE MESA PROJECT

DATA FROM CHEN & ASSOCIATES

20/32

Appendix B2

22/32

ADVANCED TERRA TESTING inc

833 Parfet Street
Lakewood, Colorado 80215
(303) 232-8308

23/32

ATTERBERG LIMITS TEST
ASTM D 4318

CLIENT	Titan Env.	JOB NO.	2234-04
BORING NO.			
DEPTH		DATE SAMPLED	
SAMPLE NO.	UT-1	DATE TESTED	7-25-96 WEB, RV
SOIL DESCR.			
TEST TYPE	ATTERBERG		

Plastic Limit Determination

	1	2	3
Wt Dish & Wet Soil	3.34	4.06	3.42
Wt Dish & Dry Soil	2.96	3.57	3.03
Wt of Moisture	0.38	0.49	0.39
Wt of Dish	1.05	1.11	1.06
Wt of Dry Soil	1.91	2.46	1.97
Moisture Content	19.90	19.92	19.80

Liquid Limit Determination   Device Number   0258

	1	2	3	4	5
Number of Blows	39	27	18	14	9
Wt Dish & Wet Soil	12.18	10.42	10.92	12.33	10.06
Wt Dish & Dry Soil	6.64	5.67	5.87	6.53	5.34
Wt of Moisture	5.54	4.75	5.05	5.80	4.72
Wt of Dish	1.10	1.06	1.06	1.10	1.08
Wt of Dry Soil	5.54	4.61	4.81	5.43	4.26
Moisture Content	100.00	103.04	104.99	106.81	110.80

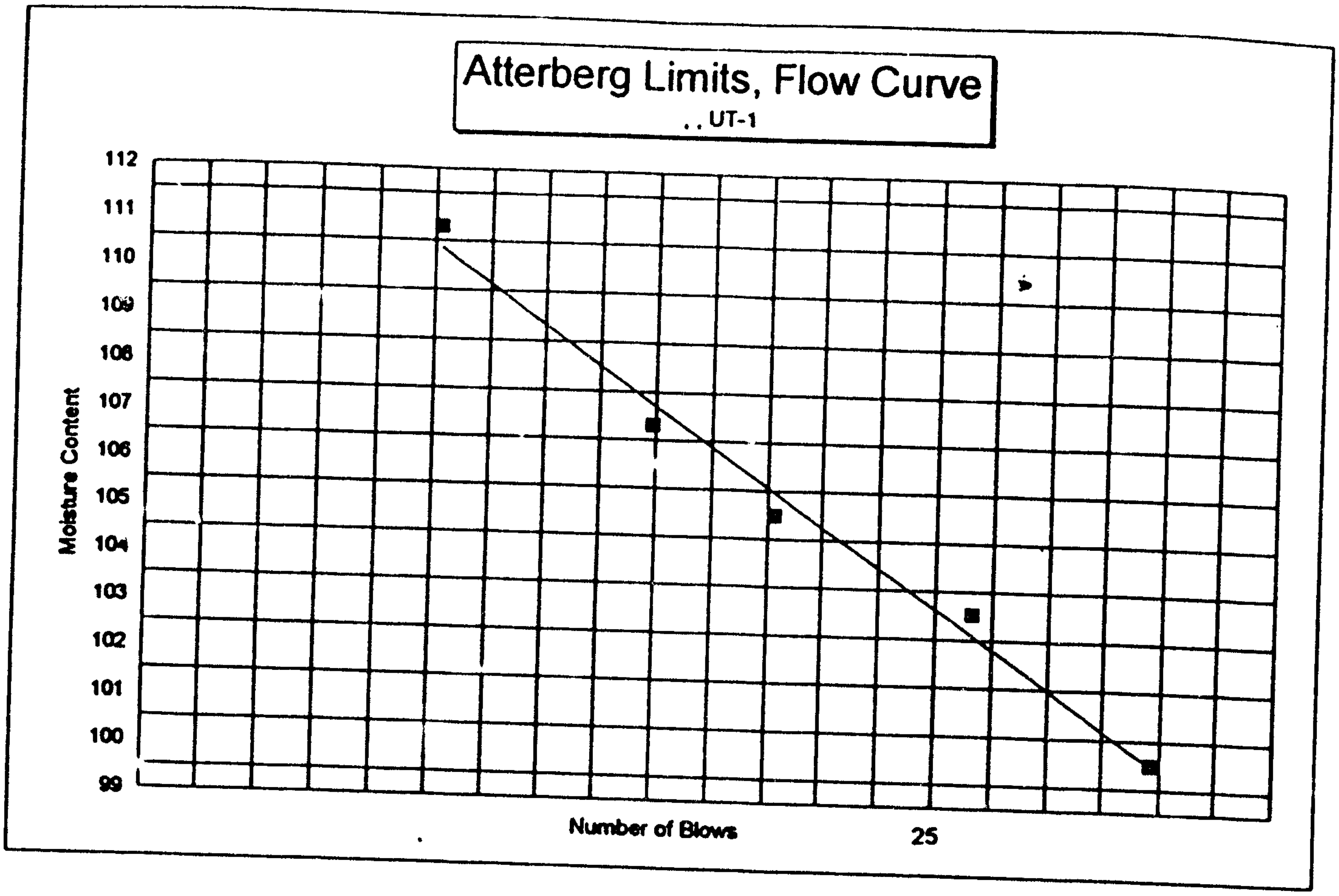
Liquid Limit 103.1
Plastic Limit 19.9
Plasticity Index 83.3

Atterberg Classification CH

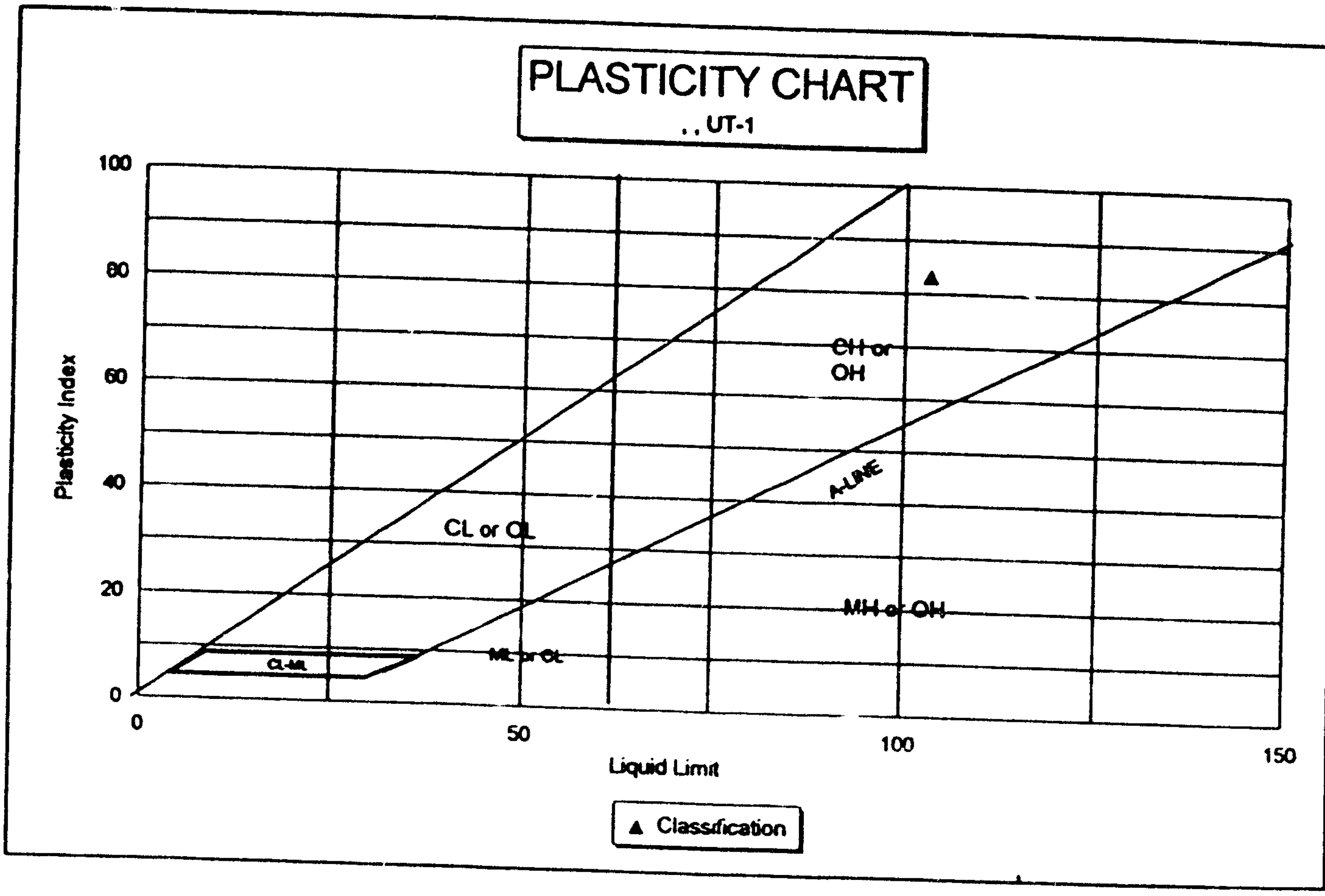
Data entry by: NAA Date: 7-26-96
Checked by: [signature] Date: 7-26-96
FileName: TIGOUT1

ADVANCED TERRA TESTING, INC.

24/32



Atterberg Limits, Flow Curve
, , UT-1
112
111
110
109
108
107
106
105
104
103
102
101
100
99
Moisture Content
Number of Blows
25



PLASTICITY CHART
, , UT-1
100
80
60
40
20
0
Plasticity Index
0
50
100
150
Liquid Limit
CH or
OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

C :PACTION TEST
ASTM D 1557 A

CLIENT: Titan Env. JOB NO. 2234-04

25/32

BORING NO.
:PTH
-AMPLE NO. UT-1

SOIL DESCR.
DATE SAMPLED
DATE TESTED 7-25-96 RV

Moisture determination

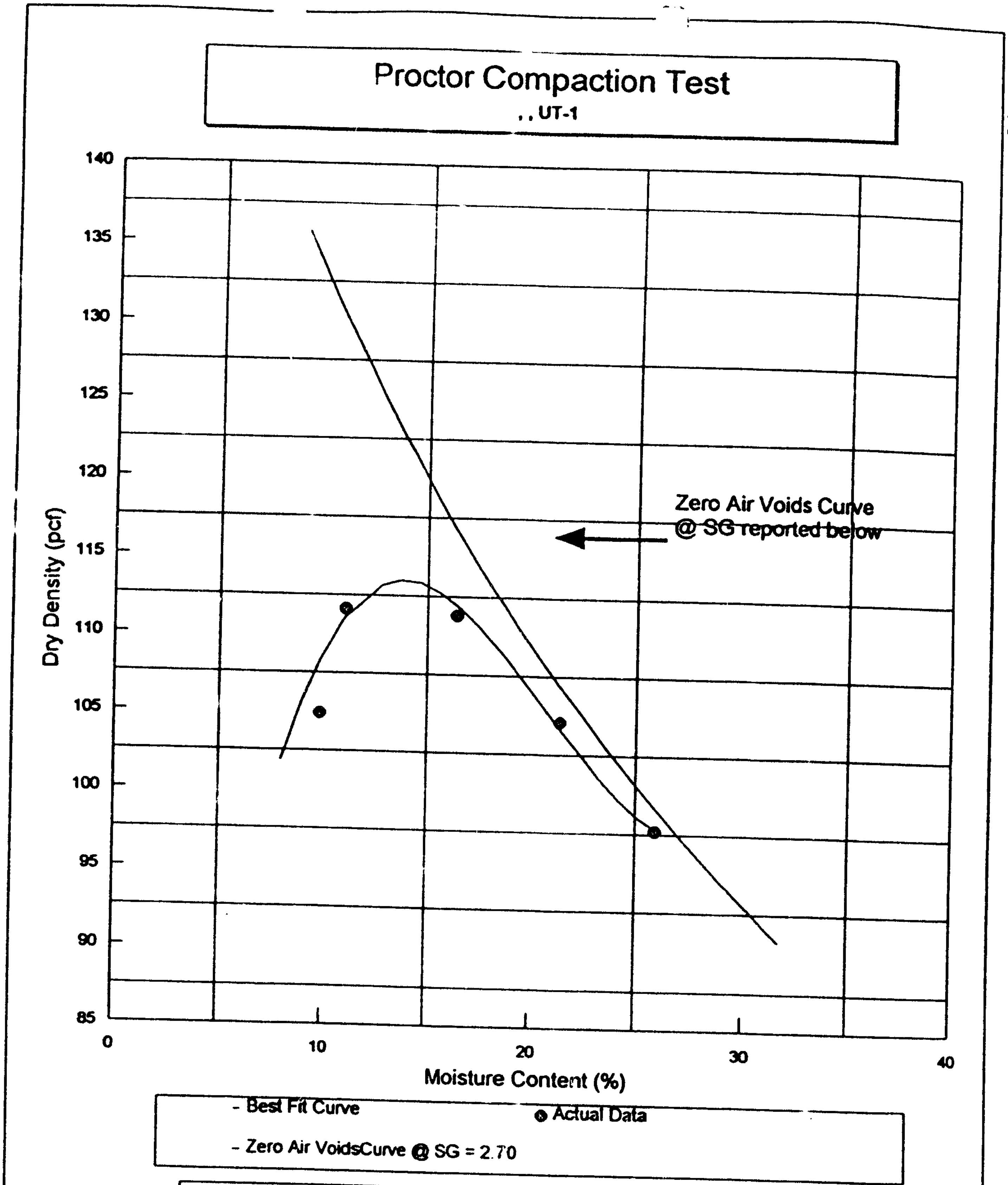
	1	2	3	4	5
Wt of Moisture added (ml)	100.00	150.00	250.00	350.00	450.00
Wt. of soil & dish (g)	384.26	393.92	291.42	244.20	281.17
Dry wt. soil & dish (g)	350.60	355.61	251.40	202.69	225.04
Net loss of moisture (g)	33.66	38.31	40.02	41.51	56.13
Wt. of dish (g)	8.01	8.34	8.31	8.29	8.43
Net wt. of dry soil (g)	342.59	347.27	243.09	194.40	216.61
Moisture Content (%)	9.83	11.03	16.46	21.35	25.91
Corrected Moisture Content					

Density determination

Wt of soil & mold (lb)	14.20	14.49	14.68	14.59	14.46
Wt. of mold (lb)	10.36	10.36	10.36	10.36	10.36
Net wt. of wet soil (lb)	3.84	4.13	4.32	4.23	4.10
''t wt of dry soil (lb)	3.50	3.72	3.71	3.49	3.26
, Density, (pcf)	104.89	111.59	111.28	104.57	97.69
Corrected Dry Density (pcf)					
Volume Factor	30	30	30	30	30

Data entered by: RV Date: 7-26-96
a checked by: [signature] Date: 7-26-96
FileName: TIPRUT-1

ADVANCED TERRA TESTING, INC



26/32

OPTIMUM MOISTURE CONTENT = 13.9 MAXIMUM DRY DENSITY = 113.5
ASTM D 1557 A, Rock correction applied? N

ADVANCED TERRA TESTING, INC.

PERMEABILITY DETERMINATION
FALLING HEAD
FIXED WALL

27/32

CLIENT	Titan Environmental	JOB NO.	2234-04
BORING NO.		SAMPLED	
DEPTH		TEST STARTED	7-28-96 CAL
SAMPLE NO.	UT-1	TEST FINISHED	8-7-96 CAL
SOIL DESCR.	Remolded 95% Mod Pt. @ OMC	SETUP NO.	1
SURCHARGE	200		

MOISTURE/DENSITY DATA	BEFORE TEST	AFTER TEST
Wt. Soil & Ring(s) (g)	386.9	404.5
Wt. Ring(s) (g)	93.0	93.0
Wt. Soil (g)	293.9	311.4
Wet Density PCF	122.3	120.5
Wt. Wet Soil & Pan (g)	302.4	319.9
Wt. Dry Soil & Pan (g)	266.2	266.2
Wt. Lost Moisture (g)	36.2	53.8
Wt. of Pan Only (g)	8.5	8.5
Wt. of Dry Soil (g)	257.7	257.7
Moisture Content %	14.1	20.9
Dry Density PCF	107.2	99.7
Max. Dry Density PCF	113.5	113.5
Percent Compaction	94.4	87.8

ELAPSED TIME (MIN)	BURETTE READING h1 (CC)	BURETTE READING h2 (CC)	PERCOLATION RATE FT/YEAR	PERCOLATION RATE CM/SEC
	0.2			
2599	10.8	10.8	0.14	1.4E-07
1427	14.2	14.2	0.09	8.4E-08
1440	16.8	16.8	0.07	6.5E-08
1440	18.6	18.6	0.05	4.6E-08
1440	20.2	20.2	0.04	4.1E-08
1440	21.6	21.6	0.04	3.7E-08
1469	23.0	23.0	0.04	3.6E-08
1440		24.4	0.04	3.7E-08

Data Entered By: NAA Date: 8-8-96
Date Checked By: [signature] Date: 8-8-96
Filename:TIFHUT1

ADVANCED TERRA TESTING, INC.

Rogers & Associates Engineering Corporation

REPORT OF RADON DIFFUSION COEFFICIENT MEASUREMENTS
(TIME-DEPENDENT DIFFUSION TEST METHOD RAE-SQAP-3.6)

28/32

Report Date: 9/3/96
Contract: C960019
By: BCR
Date Received: 8/96

Sample Identification: Titan Environmental

Sample ID	Moisture (Dry Wt. %)	Density (g/cm^3)	Radon Diffusion Coefficient (cm^2/s)	Saturation (Mρ/P)	Specific Gravity (g/cm^3)
UT-1	14.6%	1.72	9.1E-03	0.89	2.39

RAE

Post Office Box 330
Salt Lake City • Utah 84110
(801) 263-1600

Rogers & Associates Engineering Corporation

29/32

REPORT OF RADIUM CONTENT AND EMANATION COEFFICIENT MEASUREMENTS

(LAB PROCEDURE RAE-SQAP-3.1)

Report Date: 9/3/96

Contract: C96009

By: BCR

Date Received: 8/96

Sample Identification: Titan Environmental

Sample ID	Moisture (Dry Wt. %)	Radon Emanation Coefficient	Radium-226 (pCi/g)	Comments
UT-1	14.6%	0.22 ± 0.04	1.5 ± 0.3	

RAE

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Appendix C

31/32

...from the Professors who know it best...

PRINCIPLES & PRACTICE OF CIVIL ENGINEERING

—2nd Edition—

The most efficient and authoritative review book for the PE License Exam

Editor: MERLE C. POTTER, PhD, PE
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	Richard W. Furlong, PhD, PE	Structures
	David A. Hamilton, MS, PE	Hydrology
	Ronald Harichandran, PhD, PE	Structures
	Thomas L. Maleck, PhD, PE	Transportation
	George E. Mase, PhD	Mechanics
	Merle C. Potter, PhD, PE	Fluid Mechanics
	David C. Wiggert, PhD,PE	Hydraulics
	Thomas F. Wolff, PhD, PE	Soils

The authors are professors at Michigan State University, with the exception of R. W. Furlong, who teaches at the University of Texas at Austin and D. A. Hamilton who is employed by the Michigan Department of Natural Resources.

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GREAT LAKES PRESS

P.O. Box 483

Okemos, MI 48805-0483

14.5 Other Useful Equations for Weight-Volume Problems

It is strongly recommended that weight-volume problems be solved using phase diagrams rather than only formulas, as completing a phase diagram clearly indicates whether sufficient information is known to complete the problem, whether information is insufficient and assumptions must be made, or whether too much information is present and the problem is overconstrained. For example, it may not be immediately apparent from the information given whether a soil is saturated until all quantities are calculated. Nevertheless, following are given additional useful equations that may be used to solve certain classes of weight-volume problems.

A very useful equation relating four different quantities is

$$Se = wG_s \tag{14.5.1}$$

For saturated soils (S = 100%) there results

$$e = wG_s \tag{14.5.2}$$

The relationships between the void ratio and porosity are

$$e = \frac{n}{1-n} \tag{14.5.3}$$

and

$$* \quad n = \frac{e}{1+e} \tag{14.5.4}$$

n = porosity
e = Volume of Voids / Volume of Solids

The total unit weight can be obtained as

$$\gamma = \frac{(G_s + Se)\gamma_w}{1+e} = \frac{(1+w)\gamma_w}{w/S + 1/G_s} \tag{14.5.5}$$

The dry unit weight can be obtained as

$$* \quad \gamma_d = \frac{G_s\gamma_w}{1+e} = \frac{G_s\gamma_w}{1+(wG_s/S)} \tag{14.5.6}$$

γ_d: Dry Bulk Density
G_s: Specific Gravity
γ_w: Density of Water

EXAMPLE 14.8

Rework example 14.6 using equations introduced in this section.

Solution.

$$Se = wG_s$$

$$S = wG_s/e = (.20)(2.65)/(0.800) = 0.6625 \text{ or } 66.3\%$$

$$n = \frac{e}{1+e} = \frac{0.800}{1+0.800} = 0.444$$

$$\gamma = \frac{(1+w)\gamma_w}{w/S + 1/G_s} = \frac{(1.20)(62.4)}{0.2/0.6625 + 1/2.65} = 110.2 \text{ lb/ft}^3$$

$$\gamma_d = \frac{G_s\gamma_w}{1+e} = \frac{(2.65)(62.4)}{1+0.800} = 91.9 \text{ lb/ft}^3$$

APPENDIX C

Radon Flux Measurments

1994 Results

Site Specific Sample Results (reference Figure 6-1)

(a) The mean radon flux for each region within each cell is as follows:

Cell 2 - Cover Area = 7.7 pCi/m^2-s (based on 225,882 m^2 area)
- Beach Areas = 23.3 pCi/m^2-s (based on 41,761 m^2 area)
- Standing Liquid Areas = 0 pCi/m^2-s (based on 2,982 m^2 area)

Cell 3 - Cover Area = 7.5 pCi/m^2-s (based on 82,762 m^2 area)
- Beach Areas = 39.7 pCi/m^2-s (based on 62,761 m^2 area)
- Standing Liquid Areas = 0 pCi/m^2-s (based on 143,335 m^2 area)

Note: Reference Appendix B of this report for entire summary for individual measurement results and specific sample region maps.

(b) Using the data presented above, we have calculated the total mean radon flux for each pile (cell) as follows:

Cell 2 = 10.0 pCi/m^2-s

$$\frac{(7.7)(225,882) + (23.3)(41,761) + (0)(2,982)}{270,625}$$

Cell 3 = 10.8 pCi/m^2-s

$$\frac{(7.5)(82,762) + (39.7)(62,761) + (0)(143,335)}{288,858}$$

1995 Results

6.0 SAMPLE RESULTS/CALCULATIONS

Referencing 40 CFR, Part 61, Subpart W, Appendix B, Method 115 - Monitoring for Radon-222 Emissions, Subsection 2.1.7 - Calculations, "the mean radon flux for each region of the pile and for the total pile shall be calculated and reported as follows:

(a) The individual radon flux calculations shall be made as provided in Appendix A EPA 86(1). The mean radon flux for each region of the pile shall be calculated by summing all individual flux measurements for the region and dividing by the total number of flux measurements for the region.

(b) The mean radon flux for the total uranium mill tailings pile shall be calculated as follows:

$$J_s = \frac{J_1A_1 + \ldots J_2A_2 [+] \ldots J_iA_i}{A_t}$$

Where: J_s = Mean flux for the total pile (pCi/m²-s)
J_i = Mean flux measured in region i (pCi/m²-s)
A_i = Area of region i (m²)
A_t = Total area of the pile (m²)

2.1.8 Reporting. The results of individual flux measurements, the approximate locations on the pile, and the mean radon flux for each region and the mean radon flux for the total stack [pile] shall be included in the emission test report. Any condition or unusual event that occurred during the measurements that could significantly affect the results should be reported."

Site Specific Sample Results (reference Figure 6-1)

(a) The mean radon flux for each region within each cell is as follows:

Cell 2 - Cover Area = 6.1 pCi/m²-s (based on 225,882 m² area)
- Beach Areas = 28.4 pCi/m²-s (based on 41,761 m² area)
- Standing Liquid Areas = 0 pCi/m²-s (based on 2,982 m² area)

Cell 3 - Cover Area = 11.1 pCi/m²-s (based on 82,762 m² area)
- Beach Areas = 44.8 pCi/m²-s (based on 62,761 m² area)
- Standing Liquid Areas = 0 pCi/m²-s (based on 143,335 m² area)

Note: Reference Appendix B of this report for entire summary for individual measurement results and specific sample region maps.

(b) Using the data presented above, we have calculated the total mean radon flux for each pile (cell) as follows:

Cell 2 = 9.5 pCi/m²-s

$$\frac{(6.1)(225,882) + (20.4)(41,761) + (0)(2,982)}{270,625}$$

Cell 3 = 12.9 pCi/m²-s

$$\frac{(11.1)(82,762) + (44.8)(62,761) + (0)(143,335)}{288,858}$$

APPENDIX D

HELP Model

Purpose: To determine the required soil cover thicknesses to minimize surface water infiltration through the White Mesa tailings impoundments so that precipitation will not fully penetrate the soil cover. The White Mesa Mill site is located in Blanding, Utah. The performance of the tailings cover was evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) Model. The HELP model was developed to facilitate rapid, economical estimation of the amounts of surface runoff, subsurface drainage, and leachate that may be expected to result from the operation of a wide variety of possible cover designs.

Method: Determine the soil properties of the cover materials and climatic properties of Blanding, Utah based on existing database values previously collected, and acceptable default parameters. Input parameters into the computer modeling program "HELP" to determine the percolation through the cover materials. A variety of scenarios adjusting cover thicknesses were run to determine the optimum thicknesses of cover materials to eliminate percolation through the bottom cover layer. The modeled tailings cover consists of a compacted clay layer over the tailings, with a random fill soil layer covering the clay.

The model was developed for Cell 3 at the White Mesa Mill since it is the largest of the three cells to be covered (Cells 2, 3, and 4A). Figure 1 shows the location of the cells. The cover requirements determined for Cell 3 will be applied to the remaining cells as well. This is a conservative approach since the remaining cells are smaller in size and require less time and distance for precipitation runoff.

Results: A two-layer uranium mill tailings cover composed of a 2-foot layer of random fill over a 1-foot compacted clay layer will reduce percolation into the tailings material to a negligible quantity (see Appendix A for HELP results). As indicated by the model results, precipitation will either runoff the soil cover or be evaporated.

The cover thicknesses recommended above were also determined to be the minimum thickness requirements for White Mesa tailings covers based on results from radon flux calculations (see "Calculation of Radon Flux from the White Mesa Tailings Cover", 9/11/96). As indicated in the Radon Flux calculation, to restrict radon flux to 20 pCi/m2/sec, (Regulatory Guide 3.64), a cover consisting of 2-feet random fill and 1-foot compacted clay is required.

Parameters: The HELP model requires input of the following parameters for the cover materials:

- Weather Data:
  - Evapotranspiration
  - Precipitation
  - Temperature
  - Solar Radiation

- Soil and Design Data:
  - Landfill area (area of Cell 3)
  - Percent of area where runoff is possible
  - Moisture content initialization

- Cover Layer Data:
  - Layer type
  - Default soil/material texture number
  - Runoff curve number

Weather Data

Evapotranspiration and *solar radiation* data was input using the default parameters from Grand Junction, Colorado. Grand Junction is located north east of Blanding Utah in a similar climate and elevation. The elevation at Grand Junction is 4,600 feet and the elevation at Blanding Utah is 5,600 feet. Figure 1 in Appendix B shows the locations of Blanding and Grand Junction in relation to one another.

Precipitation data from 1988 to 1993 (skipping 1989) was obtained from Utah State University (see Appendix C). Daily precipitation values for the five years were input manually into the HELP model. *Temperature* data was obtained from the Dames & Moore (1978) and is also included in Appendix C. Daily temperature data was not available for manual entry therefore, the computer calculated mean monthly temperatures based on the default location (Grand Junction, Colorado). These values were then edited to match the actual mean monthly temperatures for Blanding, Utah.

Soil and Design Data

The surface area of Cell 3 at the White Mesa Mill, Blanding, Utah was used for the landfill area value. The surface area, as indicated on Figure 1, is 78.7 acres. It was assumed that runoff was possible over 100% of this area and that no rain would sit on the tailings cover.

Cover Layer Data

Layer Thickness:
A two-layer cover over approximately 28 feet of uranium mill tailings was used to run the HELP model. Actual cover thicknesses which would be constructed on site consist of 2-feet of random fill over a 1-foot compacted clay layer. This cover profile was adjusted for modeling purposes to account for freezing and thawing conditions. As indicated in the "Effects of Freezing on Uranium Mill Tailings Covers Calculation Brief" (6/17/96), 6.8 inches of the top random fill cover layer will be effected by freeze/thaw conditions at Blanding, Utah. This suggests that 6.8 inches of the top layer may not contribute to reductions of infiltration into the tailings piles. To conservatively compensate for effects from freezing and thawing, 6.8 inches were subtracted from the top random fill cover layer. Therefore, modeled layer thicknesses consisted of 17.2 inches of random fill over 12 inches of clay.

Layer Type:
The random fill soil layer was classified as a vertical percolation layer. Vertical percolation layers are composed of moderate to high permeability material that drains vertically, primarily as unsaturated flow. The clay layer was classified as a barrier soil liner. This material consists of low permeability soil designed to limit percolation/leakage and drains only vertically as a saturated flow.

Moisture Storage Parameters:
Required moisture storage parameters such as; porosity, field capacity, wilting point, initial soil water content, and permeability, are interrelated with the exception of permeability. The porosity must be greater than zero but less than 1. The field capacity must be between zero and 1 but must be smaller than the porosity. The wilting point must be greater than zero but less than the field capacity, and the initial moisture content must be greater than or equal to the wilting point and less than or equal to the porosity (U.S. EPA, 1994).

Based on these relations, actual measured porosity and permeability values were input for random fill (Chen and Associates, 1987) and clay (Advanced Terra Testing, 1996, sample UT-1). See Appendix D for physical property data. In addition, wilting point data for the layers was set

equal to the long-term moisture content of the materials and the soil water content was adjusted to equal the optimum moisture content. Field capacity values just less than the porosity's were assumed to maintain the interrelationship of the parameters.

Runoff Curve Number
The runoff curve number was calculated by the HELP model based on a minimum surface slope of 0.2%, slope length of 1,200 feet, soil texture of the top layer, and vegetation. A slope length of 1,200 feet was assumed to be the maximum distance which precipitation would travel over the soil cover. The top layer on the tailings cover will be minimum 3" of rock riprap (sandstone) therefore, no vegetation will exist. This top layer, however, was not included in the model to determine percolation quantities.

References:

Advanced Terra Testing, 1996, Physical soil data, White Mesa Project, Blanding Utah, July 25, 1996.

Chen and Associates, 1987. Physical soil data, White Mesa Project, Blanding, Utah.

Dames & Moore, 1978. "Environmental Report, White Mesa Uranium Project, San Juan County Utah", January 20, 1978, revised May 15, 1978.

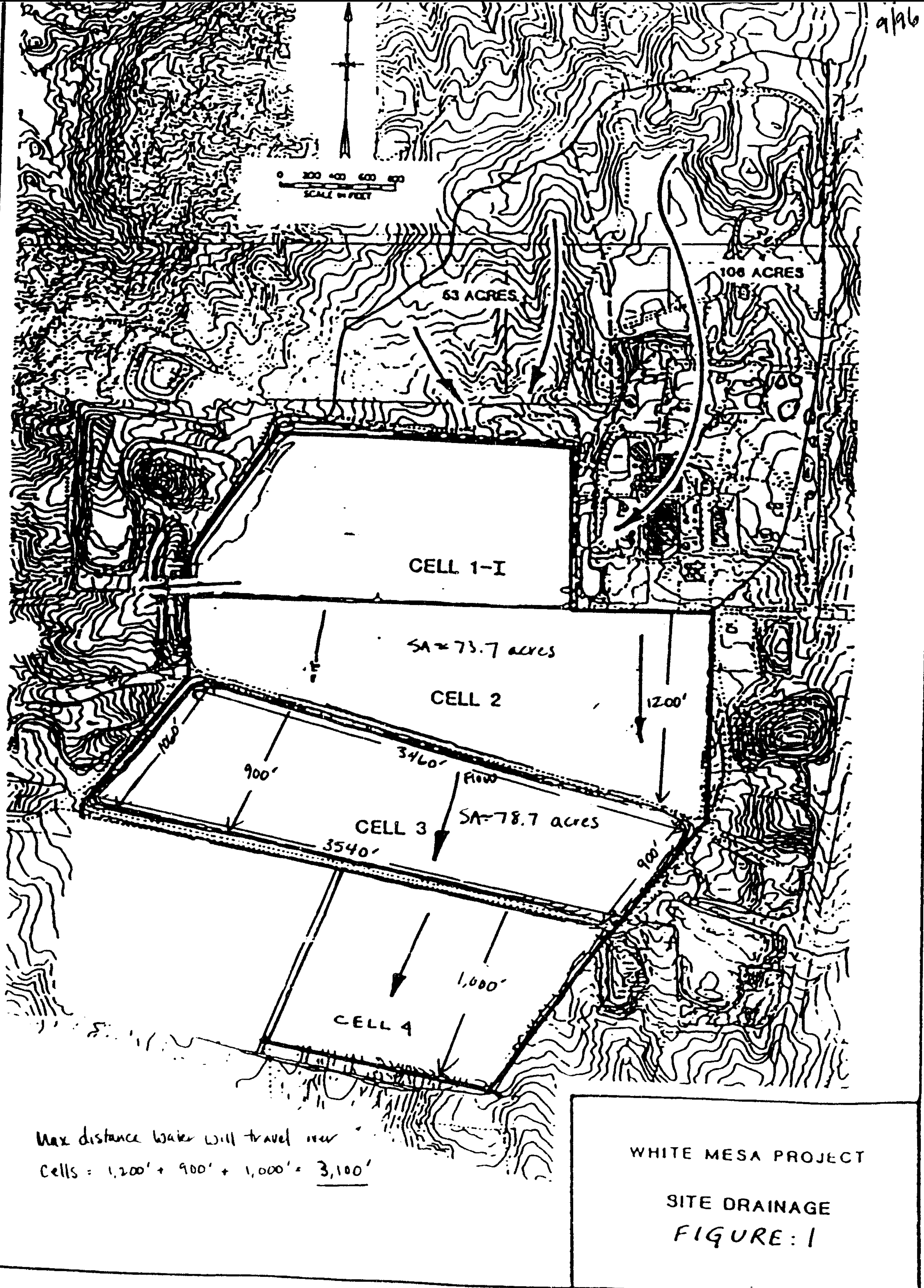
Principles & Practice of Civil Engineering, 2nd Edition, 1996.

U.S. Environmental Protection Agency (EPA), 1994. "The Hydrologic Evaluation of Landfill Performance (HELP) Model", September, 1994.

Utah Climate Center, Utah State University, Daily Precipitation Values, Station #42073807, Blanding, Utah, January 1988 through December 1993.

9/96

5/34



WHITE MESA PROJECT

SITE DRAINAGE

FIGURE: 1

Appendix A

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**              HELP MODEL VERSION 3.01   (14 OCTOBER 1994)                 **
**              DEVELOPED BY ENVIRONMENTAL LABORATORY                       **
**              USAE WATERWAYS EXPERIMENT STATION                           **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************
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7/34

```
PRECIPITATION DATA FILE:     C:\HELP3\PRECIP.D4
TEMPERATURE DATA FILE:       C:\HELP3\TEMP2.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\SOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\EVAP.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\efn-fin2.D10
OUTPUT DATA FILE:            C:\HELP3\efn-fin2.OUT

TIME: 14: 9      DATE:  9/11/1996

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

   TITLE:  EFN - White Mesa

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

    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
           WERE SPECIFIED BY THE USER.

                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  88
          THICKNESS                      =     17.20    INCHES
          POROSITY                       =      0.3150 VOL/VOL
          FIELD CAPACITY                 =      0.3140 VOL/VOL
          WILTING POINT                  =      0.0980 VOL/VOL
          INITIAL SOIL WATER CONTENT     =      0.1180 VOL/VOL
          EFFECTIVE SAT. HYD. COND.      =  0.886999999000E-06 CM/SEC

                                   LAYER  2
```

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 89

THICKNESS	=	12.00	INCHES
POROSITY	=	0.2800	VOL/VOL
FIELD CAPACITY	=	0.2799	VOL/VOL
WILTING POINT	=	0.1410	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.369999995000E-07	CM/SEC

8/34

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #27 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 0.% AND A SLOPE LENGTH OF 1200. FEET.

SCS RUNOFF CURVE NUMBER	=	96.40	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	78.700	ACRES
EVAPORATIVE ZONE DEPTH	=	17.2	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.030	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.418	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.686	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	5.390	INCHES
TOTAL INITIAL WATER	=	5.390	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GRAND JUNCTION COLORADO

MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	109	
END OF GROWING SEASON (JULIAN DATE)	=	293	
AVERAGE ANNUAL WIND SPEED	=	8.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	60.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	36.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	36.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	57.00	%

NOTE: PRECIPITATION DATA FOR BLANDING UTAH WAS ENTERED BY THE USER.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GRAND JUNCTION COLORADO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

9/34

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
27.50	32.90	38.10	47.10	57.40	66.90
73.60	70.90	63.00	51.60	38.50	28.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GRAND JUNCTION COLORADO

STATION LATITUDE = 39.07 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1988 THROUGH 1993

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.10	1.32	0.92	0.46	1.31	0.60
	1.17	1.37	1.16	1.24	1.07	1.18
STD. DEVIATIONS	1.85	1.43	0.72	0.37	0.71	0.62
	0.92	0.43	0.35	0.66	0.51	0.71
RUNOFF						
TOTALS	1.455	0.999	0.542	0.265	0.871	0.389
	0.774	0.885	0.802	0.785	0.713	0.568
STD. DEVIATIONS	1.967	1.206	0.425	0.240	0.472	0.494
	0.691	0.350	0.220	0.495	0.432	0.441
EVAPOTRANSPIRATION						
TOTALS	0.700	0.411	0.331	0.224	0.413	0.231
	0.353	0.490	0.424	0.394	0.402	0.534
STD. DEVIATIONS	0.072	0.246	0.236	0.110	0.296	0.201
	0.243	0.211	0.223	0.235	0.141	0.191
PERCOLATION/LEAKAGE THROUGH LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 2

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1988 THROUGH 1993

	INCHES		CU. FEET	PERCENT
PRECIPITATION	13.90	(2.614)	3971537.7	100.00
RUNOFF	9.048	(2.4802)	2584718.25	65.081
EVAPOTRANSPIRATION	4.908	(0.7521)	1402180.62	35.306
ERCOLATION/LEAKAGE THROUGH FROM LAYER 2	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ACROSS TOP OF LAYER 2	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.054	(0.1827)	-15362.23	-0.387

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PEAK DAILY VALUES FOR YEARS 1988 THROUGH 1993

4/34

	(INCHES)	(CU. FT.)
PRECIPITATION	1.33	379955.719
RUNOFF	1.684	481108.4370
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.000000	0.00000
AVERAGE HEAD ACROSS LAYER 2	0.000	
SNOW WATER	2.96	845040.4370

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.1182
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0962

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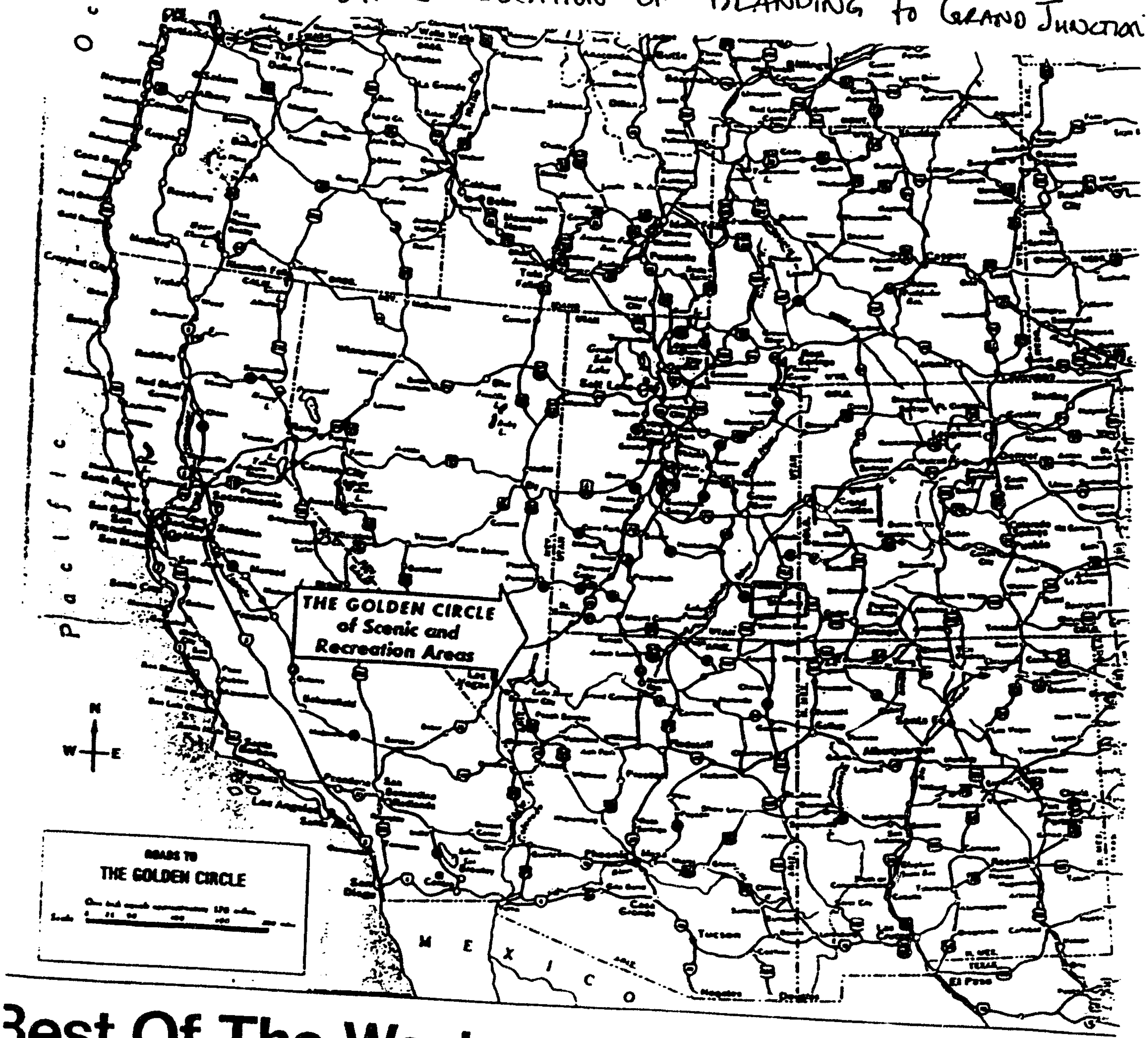
FINAL WATER STORAGE AT END OF YEAR 1993 12/34

LAYER	(INCHES)	(VOL/VOL)
1	1.7607	0.1024
2	3.3600	0.2800
SNOW WATER	0.000	

****
****

Appendix B

FIGURE 1
SHOWS LOCATION OF BLANDING to GRAND JUNCTION



3est Of The West . . .

tah combines the best of the West ʼithin Utah s 85.000 square miles is a ɔncentrated collage of western folk- ɾe scenery and history

ʼeer into Utah and sample some of our ɾe national parks. seven national mon- ... and two national recreation eas. Drive into our 43 state parks or ght national forests. Explore the :untry on this map and you ll soon :ho the statement first made by pio- ɾer settlers to Utah "This Is the Place"

IVE NATIONAL PARKS

Southeastern Utah is the place for the world's greatest—and most concen- trated—repertory of stone arches Arches National Park's trademark is Delicate Arch, although Landscape Arch is a world record-holder with a span of 291 feet

WHITE WATER CANYONS

The Colorado River glides past Arches and churns into Canyonlands National Park 40 miles southwest *National Geo- graphic* labels Canyonlands "the realm of rock and far horizon ...

Eighty percent of Utah's 1.2 million people live along the foothills of the Wasatch Mountains. Salt Lake City is not only the cultural and social hub of Utah, but also the international base for the Mormon Church

The Utah Symphony, Ballet West, Utah Repertory Dance Theater and the Pio- neer Memorial Theater all lend a cos- mopolitan atmosphere to Salt Lake City. Professional sports are represented by the Golden Eagles hockey club and the Salt Lake Gulls baseball team.

Appendix C

Yearly Total (In) →

14/34

Daily Precipitation Values, Station #42073807, Blanding, Utah

January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
11.40		15.39		11.74		15.32		17.66	
1/1/88	0	1/1/90	0	1/1/91	0	1/1/92	0	1/1/93	0
1/2/88	0	1/2/90	0	1/2/91	0	1/2/92	0	1/2/93	0
1/3/88	0	1/3/90	0.2	1/3/91	0.15	1/3/92	0.04	1/3/93	0
1/4/88	0.06	1/4/90	0	1/4/91	0.96	1/4/92	0.31	1/4/93	0
1/5/88	0.19	1/5/90	0	1/5/91	0.08	1/5/92	0.02	1/5/93	0
1/6/88	0.17	1/6/90	0	1/6/91	0	1/6/92	0.42	1/6/93	0.34
1/7/88	0	1/7/90	0	1/7/91	0	1/7/92	0.03	1/7/93	0.36
1/8/88	0.01	1/8/90	0	1/8/91	0	1/8/92	0	1/8/93	1
1/9/88	0	1/9/90	0	1/9/91	0	1/9/92	0	1/9/93	0.01
1/10/88	0	1/10/90	0	1/10/91	0	1/10/92	0	1/10/93	0.51
1/11/88	0	1/11/90	0	1/11/91	0	1/11/92	0	1/11/93	0.41
1/12/88	0	1/12/90	0	1/12/91	0	1/12/92	0	1/12/93	0
1/13/88	0	1/13/90	0.04	1/13/91	0.01	1/13/92	0	1/13/93	0.21
1/14/88	0	1/14/90	0	1/14/91	0	1/14/92	0	1/14/93	0.2
1/15/88	0	1/15/90	0.14	1/15/91	0.02	1/15/92	0	1/15/93	0
1/16/88	0	1/16/90	0.03	1/16/91	0	1/16/92	0	1/16/93	0.49
1/17/88	0.89	1/17/90	0.06	1/17/91	0	1/17/92	0	1/17/93	0.16
1/18/88	0.71	1/18/90	0.29	1/18/91	0	1/18/92	0	1/18/93	0.88
1/19/88	0	1/19/90	0.32	1/19/91	0	1/19/92	0	1/19/93	0.31
1/20/88	0	1/20/90	0	1/20/91	0	1/20/92	0	1/20/93	0
1/21/88	0	1/21/90	0	1/21/91	0	1/21/92	0	1/21/93	0
1/22/88	0	1/22/90	0	1/22/91	0	1/22/92	0	1/22/93	0
1/23/88	0	1/23/90	0	1/23/91	0	1/23/92	0	1/23/93	0
1/24/88	0	1/24/90	0	1/24/91	0	1/24/92	0	1/24/93	0
1/25/88	0	1/25/90	0	1/25/91	0	1/25/92	0	1/25/93	0
1/26/88	0	1/26/90	0	1/26/91	0	1/26/92	0	1/26/93	0
1/27/88	0	1/27/90	0	1/27/91	0	1/27/92	0	1/27/93	0
1/28/88	0	1/28/90	0	1/28/91	0	1/28/92	0	1/28/93	0
1/29/88	0	1/29/90	0	1/29/91	0	1/29/92	0	1/29/93	0
1/30/88	0	1/30/90	0	1/30/91	0	1/30/92	0	1/30/93	0.22
1/31/88	0	1/31/90	0.03	1/31/91	0	1/31/92	0	1/31/93	0.21
2/1/88	0	2/1/90	0.06	2/1/91	0	2/1/92	0	2/1/93	0.16
2/2/88	0.4	2/2/90	0.03	2/2/91	0	2/2/92	0	2/2/93	0
2/3/88	0.06	2/3/90	0	2/3/91	0	2/3/92	0	2/3/93	0
2/4/88	0	2/4/90	0	2/4/91	0	2/4/92	0.01	2/4/93	0
2/5/88	0	2/5/90	0	2/5/91	0	2/5/92	0	2/5/93	0
2/6/88	0	2/6/90	0	2/6/91	0	2/6/92	0	2/6/93	0
2/7/88	0	2/7/90	0	2/7/91	0	2/7/92	0	2/7/93	0
2/8/88	0	2/8/90	0	2/8/91	0	2/8/92	0.02	2/8/93	1.16
2/9/88	0	2/9/90	0	2/9/91	0	2/9/92	0	2/9/93	0.48
2/10/88	0	2/10/90	0	2/10/91	0	2/10/92	0.3	2/10/93	0.02
2/11/88	0	2/11/90	0	2/11/91	0	2/11/92	0.27	2/11/93	0
2/12/88	0	2/12/90	0	2/12/91	0	2/12/92	0.05	2/12/93	0
2/13/88	0	2/13/90	0	2/13/91	0	2/13/92	0.66	2/13/93	0
2/14/88	0	2/14/90	0.16	2/14/91	0	2/14/92	0	2/14/93	0.01
2/15/88	0	2/15/90	0.06	2/15/91	0	2/15/92	0	2/15/93	0.01
2/16/88	0	2/16/90	0	2/16/91	0.03	2/16/92	0.23	2/16/93	0.08
2/17/88	0	2/17/90	0	2/17/91	0.02	2/17/92	0	2/17/93	0
2/18/88	0	2/18/90	0.03	2/18/91	0	2/18/92	0	2/18/93	0.05
2/19/88	0	2/19/90	0.01	2/19/91	0	2/19/92	0	2/19/93	0.62
2/20/88	0	2/20/90	0.03	2/20/91	0	2/20/92	0	2/20/93	0.7
2/21/88	0	2/21/90	0	2/21/91	0	2/21/92	0	2/21/93	0
2/22/88	0	2/22/90	0	2/22/91	0	2/22/92	0	2/22/93	0
2/23/88	0	2/23/90	0	2/23/91	0	2/23/92	0	2/23/93	0
2/24/88	0	2/24/90	0	2/24/91	0	2/24/92	0	2/24/93	0.4
2/25/88	0	2/25/90	0	2/25/91	0	2/25/92	0	2/25/93	0.04
2/26/88	0	2/26/90	0	2/26/91	0	2/26/92	0	2/26/93	0
2/27/88	0.04	2/27/90	0	2/27/91	0	2/27/92	0	2/27/93	0
2/28/88	0	2/28/90	0	2/28/91	0.4	2/28/92	0	2/28/93	0
2/29/88	0					2/29/92	0		
3/1/88	0	3/1/90	0.02	3/1/91	0.9	3/1/92	0	3/1/93	0
3/2/88	0	3/2/90	0	3/2/91	0	3/2/92	0	3/2/93	0
3/3/88	0	3/3/90	0	3/3/91	0	3/3/92	0.34	3/3/93	0
3/4/88	0	3/4/90	0	3/4/91	0			3/4/93	0

TABLE 1

17/34

Daily Precipitation Values, Station #42073807, Blanding, Utah
January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
3/5/88	0	3/5/90	0	3/5/91	0	3/4/92	0	3/5/93	0
3/6/88	0.01	3/6/90	0.01	3/6/91	0	3/5/92	0	3/6/93	0
3/7/88	0	3/7/90	0	3/7/91	0	3/6/92	0	3/7/93	0
3/8/88	0	3/8/90	0	3/8/91	0	3/7/92	0	3/8/93	0
3/9/88	0	3/9/90	0	[illegible]	0	3/8/92	0.25	3/9/93	0
3/10/88	0.01	3/10/90	0.02	3/10/91	0	3/9/92	0.03	3/10/93	0
3/11/88	0	3/11/90	0.15	3/11/91	0	3/10/92	0	3/11/93	0
3/12/88	0	3/12/90	0.23	3/12/91	0	3/11/92	0	3/12/93	0
3/13/88	0	3/13/90	0.06	3/13/91	0	3/12/92	0	3/13/93	0
3/14/88	0	3/14/90	0	3/14/91	0.06	3/13/92	0	3/14/93	0
3/15/88	0	3/15/90	0	3/15/91	0.01	3/14/92	0	3/15/93	0
3/16/88	0.01	3/16/90	0	3/16/91	0	3/15/92	0	3/16/93	0
3/17/88	0	3/17/90	0	3/17/91	0	3/16/92	0	3/17/93	0
3/18/88	0	3/18/90	0	3/18/91	0	3/17/92	0	3/18/93	0.19
3/19/88	0	3/19/90	0	3/19/91	0.03	3/18/92	0	3/19/93	0
3/20/88	0	3/20/90	0	3/20/91	0	3/19/92	0	3/20/93	0
3/21/88	0	3/21/90	0	3/21/91	0.14	3/20/92	0	3/21/93	0
3/22/88	0	3/22/90	0	3/22/91	0	3/21/92	0.03	3/22/93	0
3/23/88	0	3/23/90	0	3/23/91	0	3/22/92	0.02	3/23/93	0
3/24/88	0	3/24/90	0	3/24/91	0	3/23/92	0.05	3/24/93	0
3/25/88	0	3/25/90	0	3/25/91	0	3/24/92	0.02	3/25/93	0
3/26/88	0	3/26/90	0	3/26/91	0.26	3/25/92	0	3/26/93	0.06
3/27/88	0	3/27/90	0	3/27/91	0	3/26/92	0	3/27/93	0.47
3/28/88	0	3/28/90	0	3/28/91	0	3/27/92	0.5	3/28/93	0
3/29/88	0	3/29/90	0	3/29/91	0	3/28/92	0.37	3/29/93	0.01
3/30/88	0	3/30/90	0.08	3/30/91	0	3/29/92	0	3/30/93	0
3/31/88	0	3/31/90	0	3/31/91	0	3/30/92	0.13	3/31/93	0
4/1/88	0	4/1/90	0	4/1/91	0	3/31/92	0.11	4/1/93	0
4/2/88	0	4/2/90	0	4/2/91	0	4/1/92	0.05	4/2/93	0
4/3/88	0	4/3/90	0	4/3/91	0	4/2/92	0	4/3/93	0
4/4/88	0.02	4/4/90	0	4/4/91	0	4/3/92	0	4/4/93	0.03
4/5/88	0	4/5/90	0	4/5/91	0	4/4/92	0	4/5/93	0.04
4/6/88	0	4/6/90	0	4/6/91	0	4/5/92	0	4/6/93	0.5
4/7/88	0	4/7/90	0.06	4/7/91	0	4/6/92	0	4/7/93	0
4/8/88	0	4/8/90	0.11	4/8/91	0	4/7/92	0	4/8/93	0
4/9/88	0	4/9/90	0	4/9/91	0	4/8/92	0	4/9/93	0
4/10/88	0	4/10/90	0	4/10/91	0	4/9/92	0	4/10/93	0
4/11/88	0	4/11/90	0	4/11/91	0	4/10/92	0	4/11/93	0
4/12/88	0	4/12/90	0	4/12/91	0	4/11/92	0	4/12/93	0
4/13/88	0	4/13/90	0	4/13/91	0	4/12/92	0	4/13/93	0
4/14/88	0.06	4/14/90	0	4/14/91	0	4/13/92	0	4/14/93	0
4/15/88	0.2	4/15/90	0	4/15/91	0	4/14/92	0	4/15/93	0
4/16/88	0.16	4/16/90	0	4/16/91	0	4/15/92	0.03	4/16/93	0.02
4/17/88	0.2	4/17/90	0	4/17/91	0	4/16/92	0.03	4/17/93	0
4/18/88	0.02	4/18/90	0	4/18/91	0	4/17/92	0	4/18/93	0
4/19/88	0	4/19/90	0	4/19/91	0	4/18/92	0	4/19/93	0
4/20/88	0	4/20/90	0	4/20/91	0	4/19/92	0	4/20/93	0
4/21/88	0.01	4/21/90	0	4/21/91	0	4/20/92	0	4/21/93	0
4/22/88	0.08	4/22/90	0	4/22/91	0	4/21/92	0	4/22/93	0
4/23/88	0.01	4/23/90	0	4/23/91	0.01	4/22/92	0	4/23/93	0
4/24/88	0.02	4/24/90	0.48	4/24/91	0	4/23/92	0	4/24/93	0
4/25/88	0	4/25/90	0	4/25/91	0	4/24/92	0	4/25/93	0
4/26/88	0	4/26/90	0	4/26/91	0	4/25/92	0	4/26/93	0
4/27/88	0	4/27/90	0	4/27/91	0	4/26/92	0	4/27/93	0
4/28/88	0	4/28/90	0	4/28/91	0	4/27/92	0	4/28/93	0
4/29/88	0	4/29/90	0.09	4/29/91	0	4/28/92	0	4/29/93	0
4/30/88	0	4/30/90	0.06	4/30/91	0	4/29/92	0	4/30/93	0
5/1/88	0	5/1/90	0.83	5/1/91	0	4/30/92	0	5/1/93	0
5/2/88	0	5/2/90	0	5/2/91	0	5/1/92	0	5/2/93	0
5/3/88	0	5/3/90	0	5/3/91	0	5/2/92	0	5/3/93	0
5/4/88	0	5/4/90	0	5/4/91	0	5/3/92	0	5/4/93	0.05
5/5/88	0	5/5/90	0	5/5/91	0	5/4/92	0.07	5/5/93	0.5
5/6/88	0	5/6/90	0	5/6/91	0	5/5/92	0	5/6/93	0
5/7/88	0	5/7/90	0	5/7/91	0	5/6/92	0	5/7/93	0.06

Table 1 (cont)

18/34

Daily Precipitation Values, Station #42073807, Blanding, Utah
January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
5/8/88	0	5/8/90	0	5/8/91	0	5/7/92	0.19	5/8/93	0.15
5/9/88	0	5/9/90	0	5/9/91	0	5/8/92	0	5/9/93	0
5/10/88	0	5/10/90	0	5/10/91	0	5/9/92	0.96	5/10/93	0
5/11/88	0	5/11/90	0	5/11/91	0	5/10/92	0	5/11/93	0
5/12/88	0	5/12/90	0	5/12/91	0	5/11/92	0	5/12/93	0
5/13/88	0	5/13/90	0	5/13/91	0	5/12/92	0	5/13/93	0
5/14/88	0	5/14/90	0	5/14/91	0	5/13/92	0	5/14/93	0
5/15/88	0	5/15/90	0	5/15/91	0.06	5/14/92	0	5/15/93	0.02
5/16/88	0	5/16/90	0	5/16/91	0	5/15/92	0	5/16/93	0.08
5/17/88	0.64	5/17/90	0	5/17/91	0	5/16/92	0	5/17/93	0.35
5/18/88	0.3	5/18/90	0	5/18/91	0	5/17/92	0	5/18/93	0
5/19/88	0.15	5/19/90	0	5/19/91	0	5/18/92	0	5/19/93	0
5/20/88	0	5/20/90	0	5/20/91	0	5/19/92	0.06	5/20/93	0.01
5/21/88	0	5/21/90	0	5/21/91	0	5/20/92	0.05	5/21/93	0
5/22/88	0	5/22/90	0	5/22/91	0	5/21/92	0.06	5/22/93	0
5/23/88	0	5/23/90	0	5/23/91	0	5/22/92	0.36	5/23/93	0
5/24/88	0	5/24/90	0	5/24/91	0	5/23/92	0.02	5/24/93	0
5/25/88	0	5/25/90	0	5/25/91	0	5/24/92	0.2	5/25/93	0.05
5/26/88	0	5/26/90	0	5/26/91	0	5/25/92	0.15	5/26/93	0.11
5/27/88	0	5/27/90	0	5/27/91	0	5/26/92	0.13	5/27/93	0.19
5/28/88	0	5/28/90	0	5/28/91	0	5/27/92	0.05	5/28/93	0.05
5/29/88	0.17	5/29/90	0.02	5/29/91	0	5/28/92	0	5/29/93	0
5/30/88	0.01	5/30/90	0	5/30/91	0	5/29/92	0.03	5/30/93	0
5/31/88	0	5/31/90	0	5/31/91	0.43	5/30/92	0	5/31/93	0
6/1/88	0	6/1/90	0	6/1/91	0	5/31/92	0	6/1/93	0
6/2/88	0	6/2/90	0	6/2/91	0	6/1/92	0	6/2/93	0
6/3/88	0	6/3/90	0	6/3/91	0	6/2/92	0	6/3/93	0
6/4/88	0	6/4/90	0	6/4/91	0	6/3/92	0	6/4/93	0
6/5/88	0	6/5/90	0	6/5/91	0	6/4/92	0.01	6/5/93	0
6/6/88	0	6/6/90	0	6/6/91	0	6/5/92	0.03	6/6/93	0.01
6/7/88	0	6/7/90	0	6/7/91	0	6/6/92	0	6/7/93	0.01
6/8/88	0	6/8/90	0	6/8/91	0	6/7/92	0	6/8/93	0.06
6/9/88	0	6/9/90	0.04	6/9/91	0	6/8/92	0.16	6/9/93	0
6/10/88	0	6/10/90	1.09	6/10/91	0	6/9/92	0	6/10/93	0
6/11/88	0	6/11/90	0	6/11/91	0	6/10/92	0	6/11/93	0
6/12/88	0	6/12/90	0	6/12/91	0	6/11/92	0	6/12/93	0
6/13/88	0	6/13/90	0	6/13/91	0	6/12/92	0	6/13/93	0
6/14/88	0	6/14/90	0	6/14/91	0.05	6/13/92	0	6/14/93	0
6/15/88	0	6/15/90	0	6/15/91	0	6/14/92	0	6/15/93	0
6/16/88	0	6/16/90	0	6/16/91	0	6/15/92	0	6/16/93	0
6/17/88	0	6/17/90	0	6/17/91	0	6/16/92	0	6/17/93	0.04
6/18/88	0	6/18/90	0	6/18/91	0	6/17/92	0	6/18/93	0
6/19/88	0	6/19/90	0	6/19/91	0	6/18/92	0	6/19/93	0
6/20/88	0	6/20/90	0	6/20/91	0	6/19/92	0	6/20/93	0
6/21/88	0	6/21/90	0	6/21/91	0	6/20/92	0	6/21/93	0
6/22/88	0.02	6/22/90	0	6/22/91	0	6/21/92	0	6/22/93	0
6/23/88	0.01	6/23/90	0	6/23/91	0	6/22/92	0	6/23/93	0
6/24/88	0.05	6/24/90	0	6/24/91	0	6/23/92	0	6/24/93	0
6/25/88	0.27	6/25/90	0	6/25/91	0	6/24/92	0	6/25/93	0
6/26/88	0.11	6/26/90	0	6/26/91	0	6/25/92	0.08	6/26/93	0
6/27/88	0.52	6/27/90	0	6/27/91	0	6/26/92	0	6/27/93	0
6/28/88	0.42	6/28/90	0	6/28/91	0	6/27/92	0	6/28/93	0
6/29/88	0	6/29/90	0	6/29/91	0	6/28/92	0.01	6/29/93	0
6/30/88	0	6/30/90	0	6/30/91	0	6/29/92	0	6/30/93	0
7/1/88	0	7/1/90	0	7/1/91	0	6/30/92	0	7/1/93	0
7/2/88	0	7/2/90	0	7/2/91	0	7/1/92	0	7/2/93	0
7/3/88	0	7/3/90	0	7/3/91	0	7/2/92	0	7/3/93	0
7/4/88	0	7/4/90	0	7/4/91	0	7/3/92	0	7/4/93	0
7/5/88	0	7/5/90	0	7/5/91	0	7/4/92	0	7/5/93	0
7/6/88	0	7/6/90	0	7/6/91	0	7/5/92	0	7/6/93	0
7/7/88	0	7/7/90	0.78	7/7/91	0	7/6/92	0	7/7/93	0
7/8/88	0	7/8/90	0.73	7/8/91	0.1	7/7/92	0	7/8/93	0
7/9/88	0	7/9/90	0.02	7/9/91	0.45	7/8/92	0.4	7/9/93	0
7/10/88	0	7/10/90	0	7/10/91	0.01	7/9/92	0	7/10/93	0

PRECIP.XLS/[illegible]

Table 1 (cont)

19/34

Daily Precipitation Values, Station #42073807, Blanding, Utah
January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
7/11/88	0	7/11/90	0	7/11/91	0	7/10/92	0	7/11/93	0
7/12/88	0	7/12/90	0	7/12/91	0	7/11/92	0	7/12/93	0
7/13/88	0	7/13/90	0	7/13/91	0	7/12/92	1.33	7/13/93	0
7/14/88	0	7/14/90	0.05	7/14/91	0	7/13/92	0.02	7/14/93	0
7/15/88	0	7/15/90	0	7/15/91	0	7/14/92	0	7/15/93	0
7/16/88	0	7/16/90	0	7/16/91	0	7/15/92	0	7/16/93	0
7/17/88	0.05	7/17/90	0	7/17/91	0	7/16/92	0	7/17/93	0
7/18/88	0	7/18/90	0.01	7/18/91	0	7/17/92	0	7/18/93	0
7/19/88	0	7/19/90	0	7/19/91	0	7/18/92	0.08	7/19/93	0
7/20/88	0	7/20/90	0	7/20/91	0.28	7/19/92	0	7/20/93	0
7/21/88	0	7/21/90	0.03	7/21/91	0	7/20/92	0	7/21/93	0
7/22/88	0	7/22/90	0	7/22/91	0	7/21/92	0	7/22/93	0
7/23/88	0	7/23/90	0.01	7/23/91	0.04	7/22/92	0.1	7/23/93	0
7/24/88	0	7/24/90	0.02	7/24/91	0.23	7/23/92	0.08	7/24/93	0.01
7/25/88	0	7/25/90	0.05	7/25/91	0.08	7/24/92	0	7/25/93	0
7/26/88	0.16	7/26/90	0	7/26/91	0.01	7/25/92	0.17	7/26/93	0
7/27/88	0	7/27/90	0	7/27/91	0	7/26/92	0	7/27/93	0
7/28/88	0	7/28/90	0.02	7/28/91	0	7/27/92	0	7/28/93	0
7/29/88	0.13	7/29/90	0	7/29/91	0	7/28/92	0.02	7/29/93	0
7/30/88	0.05	7/30/90	0.19	7/30/91	0	7/29/92	0	7/30/93	0
7/31/88	0.12	7/31/90	0	7/31/91	0	7/30/92	0	7/31/93	0
8/1/88	0.13	8/1/90	0	8/1/91	0.03	7/31/92	0	8/1/93	0
8/2/88	0	8/2/90	0.25	8/2/91	0.04	8/1/92	0	8/2/93	0
8/3/88	0	8/3/90	0	8/3/91	0.08	8/2/92	0	8/3/93	0
8/4/88	0	8/4/90	0	8/4/91	0	8/3/92	0	8/4/93	0.01
8/5/88	0.38	8/5/90	0	8/5/91	0.01	8/4/92	0	8/5/93	0
8/6/88	0.02	8/6/90	0	8/6/91	0.56	8/5/92	0.02	8/6/93	0.03
8/7/88	0	8/7/90	0	8/7/91	0	8/6/92	0.01	8/7/93	0.03
8/8/88	0	8/8/90	0	8/8/91	0	8/7/92	[illegible]	8/8/93	0.03
8/9/88	0	8/9/90	0	8/9/91	0	8/8/92	[illegible]	8/9/93	0.03
8/10/88	0	8/10/90	0	8/10/91	0	8/9/92	[illegible]	8/10/93	0.01
8/11/88	0.04	8/11/90	0.04	8/11/91	0	8/10/92	[illegible]	8/11/93	0
8/12/88	0.07	8/12/90	0	8/12/91	0.36	8/11/92	[illegible]	8/12/93	0
8/13/88	0	8/13/90	0.15	8/13/91	0	8/12/92	[illegible]	8/13/93	0
8/14/88	0	8/14/90	0.07	8/14/91	0	8/13/92	0	8/14/93	0
8/15/88	0.09	8/15/90	0.05	8/15/91	0.01	8/14/92	0	8/15/93	0
8/16/88	0.05	8/16/90	0.24	8/16/91	0	8/15/92	0	8/16/93	0
8/17/88	0	8/17/90	0	8/17/91	0	8/16/92	0	8/17/93	0
8/18/88	0	8/18/90	0	8/18/91	0.06	8/17/92	0.19	8/18/93	0
8/19/88	0	8/19/90	0	8/19/91	0	8/18/92	0	8/19/93	0.03
8/20/88	0.24	8/20/90	0	8/20/91	0	8/19/92	0	8/20/93	0
8/21/88	0.15	8/21/90	0	8/21/91	0	8/20/92	0	8/21/93	0.02
8/22/88	0	8/22/90	0	8/22/91	0	8/21/92	0	8/22/93	0
8/23/88	0	8/23/90	0	8/23/91	0	8/22/92	0.37	8/23/93	0
8/24/88	0	8/24/90	0	8/24/91	0	8/23/92	0.16	8/24/93	0
8/25/88	0	8/25/90	0	8/25/91	0	8/24/92	0	8/25/93	0.08
8/26/88	0	8/26/90	0	8/26/91	0	8/25/92	0	8/26/93	0.74
8/27/88	0	8/27/90	0	8/27/91	0.01	8/26/92	0	8/27/93	0
8/28/88	0	8/28/90	0	8/28/91	0	8/27/92	0	8/28/93	0.73
8/29/88	0	8/29/90	0	8/29/91	0	8/28/92	0	8/29/93	0
8/30/88	0.18	8/30/90	0	8/30/91	0	8/29/92	0	8/30/93	0
8/31/88	0.47	8/31/90	0	8/31/91	0.02	8/30/92	0.28	8/31/93	0.05
9/1/88	0.01	9/1/90	0.01	9/1/91	0	8/31/92	0.16	9/1/93	0
9/2/88	0	9/2/90	0.32	9/2/91	0	9/1/92	0	9/2/93	0
9/3/88	0	9/3/90	0.1	9/3/91	0	9/2/92	0	9/3/93	0
9/4/88	0	9/4/90	0	9/4/91	0	9/3/92	0	9/4/93	0
9/5/88	0	9/5/90	0.08	9/5/91	0	9/4/92	0	9/5/93	0
9/6/88	0	9/6/90	0.1	9/6/91	0.93	9/5/92	0	9/6/93	0
9/7/88	0	9/7/90	0	9/7/91	0.25	9/6/92	0	9/7/93	0
9/8/88	0	9/8/90	0	9/8/91	0	9/7/92	0	9/8/93	0
9/9/88	0	9/9/90	0	9/9/91	0	9/8/92	0	9/9/93	0
9/10/88	0.32	9/10/90	0	9/10/91	0	9/9/92	0	9/10/93	0
9/11/88	0.05	9/11/90	0	9/11/91	0.13	9/10/92	0	9/11/93	0
9/12/88	0.58	9/12/90	0	9/12/91	0	9/11/92	0	9/12/93	0.01

Table 1 (cont.)

20/34

Daily Precipitation Values, Station #42073807, Blanding, Utah
January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
9/13/88	0	9/13/90	0	9/13/91	0.01	9/12/92	0	9/13/93	0.6
9/14/88	0	9/14/90	0	9/14/91	0	9/13/92	0	9/14/93	0
9/15/88	0	9/15/90	0	9/15/91	0	9/14/92	0	9/15/93	0
9/16/88	0	9/16/90	0	9/16/91	0	9/15/92	0.13	9/16/93	0
9/17/88	0	9/17/90	0	9/17/91	0	9/16/92	0	9/17/93	0
9/18/88	0	9/18/90	0.63	9/18/91	0	9/17/92	0	9/18/93	0.22
9/19/88	0	9/19/90	0	9/19/91	0	9/18/92	0.22	9/19/93	0
9/20/88	0	9/20/90	0.16	9/20/91	0	9/19/92	0.47	9/20/93	0
9/21/88	0.08	9/21/90	0	9/21/91	0	9/20/92	0.08	9/21/93	0
9/22/88	0	9/22/90	0	9/22/91	0	9/21/92	0	9/22/93	0
9/23/88	0	9/23/90	0.06	9/23/91	0	9/22/92	0	9/23/93	0
9/24/88	0	9/24/90	0	9/24/91	0	9/23/92	0	9/24/93	0
9/25/88	0	9/25/90	0	9/25/91	0	9/24/92	0	9/25/93	0
9/26/88	0	9/26/90	0	9/26/91	0	9/25/92	0	9/26/93	0
9/27/88	0.03	9/27/90	0	9/27/91	0	9/26/92	0	9/27/93	0
9/28/88	0	9/28/90	0.23	9/28/91	0	9/27/92	0	9/28/93	0
9/29/88	0	9/29/90	0	9/29/91	0	9/28/92	0	9/29/93	0
9/30/88	0	9/30/90	0	9/30/91	0	9/29/92	0	9/30/93	0
10/1/88	0	10/1/90	0.01	10/1/91	0	9/30/92	0	10/1/93	0
10/2/88	0	10/2/90	1.1	10/2/91	0	10/1/92	0	10/2/93	0
10/3/88	0	10/3/90	0.02	10/3/91	0	10/2/92	0	10/3/93	0
10/4/88	0	10/4/90	0	10/4/91	0	10/3/92	0	10/4/93	0
10/5/88	0	10/5/90	0	10/5/91	0	10/4/92	0	10/5/93	0
10/6/88	0.02	10/6/90	0	10/6/91	0	10/5/92	0	10/6/93	0.61
10/7/88	0.04	10/7/90	0.1	10/7/91	0	10/6/92	0	10/7/93	0.21
10/8/88	0.02	10/8/90	0	10/8/91	0	10/7/92	0	10/8/93	0.19
10/9/88	0	10/9/90	0	10/9/91	0	10/8/92	0	10/9/93	0
10/10/88	0	10/10/90	0	10/10/91	0	10/9/92	0	10/10/93	0.01
10/11/88	0	10/11/90	0	10/11/91	0	10/10/92	0	10/11/93	0.1
10/12/88	0	10/12/90	0	10/12/91	0	10/11/92	0	10/12/93	0
10/13/88	0	10/13/90	0	10/13/91	0	10/12/92	0	10/13/93	0
10/14/88	0	10/14/90	0	10/14/91	0	10/13/92	0	10/14/93	0
10/15/88	0	10/15/90	0	10/15/91	0	10/14/92	0	10/15/93	0
10/16/88	0	10/16/90	0	10/16/91	0	10/15/92	0	10/16/93	0.09
10/17/88	0	10/17/90	0	10/17/91	0	10/16/92	0	10/17/93	0.2
10/18/88	0	10/18/90	0.2	10/18/91	0	10/17/92	0	10/18/93	0.02
10/19/88	0	10/19/90	0.28	10/19/91	0	10/18/92	0	10/19/93	0
10/20/88	0	10/20/90	0.11	10/20/91	0	10/19/92	0	10/20/93	0
10/21/88	0	10/21/90	0	10/21/91	0	10/20/92	0	10/21/93	0
10/22/88	0	10/22/90	0	10/22/91	0.02	10/21/92	0.11	10/22/93	0
10/23/88	0	10/23/90	0	10/23/91	0	10/22/92	0	10/23/93	0
10/24/88	0	10/24/90	0	10/24/91	0.08	10/23/92	0	10/24/93	0
10/25/88	0	10/25/90	0	10/25/91	0	10/24/92	0.37	10/25/93	0
10/26/88	0	10/26/90	0	10/26/91	0	10/25/92	0.15	10/26/93	0
10/27/88	0	10/27/90	0	10/27/91	0.69	10/26/92	0	10/27/93	0
10/28/88	0	10/28/90	0	10/28/91	0.26	10/27/92	0.04	10/28/93	0
10/29/88	0	10/29/90	0	10/29/91	0.26	10/28/92	0.26	10/29/93	0
10/30/88	0.02	10/30/90	0	10/30/91	0.1	10/29/92	0.12	10/30/93	0
10/31/88	0	10/31/90	0	10/31/91	0	10/30/92	0.22	10/31/93	0
11/1/88	0	11/1/90	0	11/1/91	0	10/31/92	0.19	11/1/93	0
11/2/88	0	11/2/90	0.35	11/2/91	0	11/1/92	0	11/2/93	0
11/3/88	0	11/3/90	0.37	11/3/91	0	11/2/92	0	11/3/93	0
11/4/88	0	11/4/90	0	11/4/91	0	11/3/92	0	11/4/93	0
11/5/88	0	11/5/90	0	11/5/91	0	11/4/92	0	11/5/93	0
11/6/88	0	11/6/90	0.01	11/6/91	0	11/5/92	0	11/6/93	0
11/7/88	0	11/7/90	0.12	11/7/91	0	11/6/92	0	11/7/93	0
11/8/88	0	11/8/90	0	11/8/91	0	11/7/92	0	11/8/93	0
11/9/88	0	11/9/90	0	11/9/91	0	11/8/92	0	11/9/93	0
11/10/88	0	11/10/90	0	11/10/91	0.03	11/9/92	0	11/10/93	0
11/11/88	0.56	11/11/90	0	11/11/91	0	11/10/92	0.14	11/11/93	0.64
11/12/88	0	11/12/90	0	11/12/91	0	11/11/92	0	11/12/93	0.3
11/13/88	0	11/13/90	0	11/13/91	0	11/12/92	0	11/13/93	0.14
11/14/88	0	11/14/90	0	11/14/91	0.49	11/13/92	0	11/14/93	0
11/15/88	0.25	11/15/90	0	11/15/91	0.95	11/14/92	0	11/15/93	0

Table 1 (cont.)

21/34

Daily Precipitation Values, Station #42073807, Blanding, Utah
January, 1988 through February, 1994

Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)	Date	Precipitation (inches)
11/16/88	0	11/16/90	0	11/16/91	0.03	11/15/92	0	11/16/93	0
11/17/88	0.02	11/17/90	0	11/17/91	0	11/16/92	0	11/17/93	0
11/18/88	0	11/18/90	0	11/18/91	0.07	11/17/92	0	11/18/93	0
11/19/88	0	11/19/90	0	11/19/91	0	11/18/92	0.01	11/19/93	0
11/20/88	0	11/20/90	0.09	11/20/91	0	11/19/92	0	11/20/93	0
11/21/88	0	11/21/90	0	11/21/91	0	11/20/92	0.12	11/21/93	0
11/22/88	0	11/22/90	0	11/22/91	0	11/21/92	0	11/22/93	0
11/23/88	0	11/23/90	0	11/23/91	0	11/22/92	0	11/23/93	0
11/24/88	0	11/24/90	0	11/24/91	0	11/23/92	0	11/24/93	0
11/25/88	0.07	11/25/90	0	11/25/91	0	11/24/92	0	11/25/93	0
11/26/88	0.11	11/26/90	0.48	11/26/91	0	11/25/92	0	11/26/93	0
11/27/88	0	11/27/90	0.01	11/27/91	0	11/26/92	0	11/27/93	0
11/28/88	0	11/28/90	0	11/28/91	0	11/27/92	0	11/28/93	0
11/29/88	0	11/29/90	0	11/29/91	0	11/28/92	0	11/29/93	0
11/30/88	0	11/30/90	0	11/30/91	0.01	11/29/92	0	11/30/93	0
12/1/88	0.03	12/1/90	0	12/1/91	0	11/30/92	0	12/1/93	0
12/2/88	0	12/2/90	0	12/2/91	0	12/1/92	0	12/2/93	0
12/3/88	0	12/3/90	0	12/3/91	0	12/2/92	0	12/3/93	0
12/4/88	0	12/4/90	0	12/4/91	0	12/3/92	0	12/4/93	0
12/5/88	0	12/5/90	0	12/5/91	0	12/4/92	0.13	12/5/93	0
12/6/88	0	12/6/90	0	12/6/91	0	12/5/92	0.81	12/6/93	0
12/7/88	0	12/7/90	0	12/7/91	0	12/6/92	0	12/7/93	0
12/8/88	0	12/8/90	0	12/8/91	0	12/7/92	-99999	12/8/93	0
12/9/88	0	12/9/90	0	12/9/91	0	12/8/92	0.28	12/9/93	0
12/10/88	0	12/10/90	0	12/10/91	0.02	12/9/92	0	12/10/93	0
12/11/88	0	12/11/90	0	12/11/91	0.26	12/10/92	0	12/11/93	0
12/12/88	0	12/12/90	0.27	12/12/91	0	12/11/92	0	12/12/93	0.07
12/13/88	0	12/13/90	0.04	12/13/91	0	12/12/92	0.5	12/13/93	0
12/14/88	0	12/14/90	0	12/14/91	0	12/13/92	0	12/14/93	0
12/15/88	0	12/15/90	0.06	12/15/91	0	12/14/92	0	12/15/93	0.07
12/16/88	0	12/16/90	0.11	12/16/91	0	12/15/92	0	12/16/93	0.18
12/17/88	0	12/17/90	0	12/17/91	0	12/16/92	0	12/17/93	0
12/18/88	0	12/18/90	0	12/18/91	0.54	12/17/92	0	12/18/93	0
12/19/88	0	12/19/90	0.06	12/19/91	0.43	12/18/92	0.2	12/19/93	0
12/20/88	0.05	12/20/90	0.36	12/20/91	0	12/19/92	0	12/20/93	0
12/21/88	0.38	12/21/90	0	12/21/91	0	12/20/92	0	12/21/93	0
12/22/88	0	12/22/90	0	12/22/91	0	12/21/92	0	12/22/93	0
12/23/88	0.2	12/23/90	0	12/23/91	0	12/22/92	0	12/23/93	0
12/24/88	0.13	12/24/90	0	12/24/91	0	12/23/92	0	12/24/93	0
12/25/88	0.09	12/25/90	0	12/25/91	0	12/24/92	0	12/25/93	0
12/26/88	0	12/26/90	0	12/26/91	0	12/25/92	0	12/26/93	0
12/27/88	0	12/27/90	0	12/27/91	0	12/26/92	0	12/27/93	0.1
12/28/88	0	12/28/90	0	12/28/91	0	12/27/92	0	12/28/93	0
12/29/88	0	12/29/90	0	12/29/91	0.05	12/28/92	0.3	12/29/93	0
12/30/88	0	12/30/90	0	12/30/91	0.11	12/29/92	0	12/30/93	0
12/31/88	0	12/31/90	0	12/31/91	0.02	12/30/92	0.07	12/31/93	0
						12/31/92	0		

Notes: Source: Utah Climet Center, Utah State University, Logan, UT.

Table 1 (cont.)

APPENDIX E

Freeze/Thaw Evaluation

Purpose: To determine if freeze/thaw conditions will impact the performance of the White Mesa uranium mill tailings cover. This calculation brief predicts the depth of frost which may be anticipated at the mill site. Only frost depth is evaluated since this would have the greatest impact on cover integrity (i.e. increasing permeability or damage by frost heave).

Method: A digital computer program of the modified Berggren equation for calculating the depth of freeze or thaw in a multi-layered soil system was used for purposes presented in this calculation. This method, used for determining the frost depth, is considered adequate for Uranium Mill Tailings Remedial Action (UMTRA) Projects by the U.S. Department of Energy for the following reasons:

- It calculates depth of frost based on a zero degrees Celsius isotherm, whereas the frozen front occurs some distance above this line.
- Extrapolation of current weather records beyond 200 years is not reliable.
- Extreme changes in temperatures for the 1,000 year design life are not anticipated based on geomorphic evidence.

Parameters for the cover materials based on accepted methods and existing database values previously collected, were input into the computer modeling program to determine the depth of frost penetration. A cover thickness of 2 feet random fill over 1 foot of compacted clay (as determined by HELP and RADON computer modeling) was used.

Assumptions: The model assumes:

- One-dimensional heat flow with the entire soil mass at its mean annual temperature prior to the start of the freezing season.
- At the start of the freezing season, the surface temperature changes suddenly from the mean annual temperature to a temperature below freezing and remains at this temperature throughout the entire freezing season.
- The effect of latent heat is considered as a heat sink at the moving frost line.
- Soil freezes at a temperature of 32 degrees Fahrenheit.

Results: The total frost penetration depth is less than 6.8 inches. Therefore, the 2-foot layer of random fill will provide adequate protection to the underlying 1-foot clay layer. See Appendix A for computer modeling results.

Parameters: The computer program requires input of the following parameters for the soil cover layers:

- freezing index (degree);
- length of season (days);
- mean annual temperature (degrees Fahrenheit);
- n-factor;
- layer thickness' (inches);
- water content (percent);
- dry unit weight (lbs/cubic foot);
- heat capacity (Btu/cubic foot-deg F);
- thermal conductivity (Btu/foot-hour-deg F), and;
- latent heat of fusion (Btu/cubic foot).

Freezing Index/Length of Season/Mean Annual Temperature

Default values from Grand Junction, Colorado were used for the freezing index and length of season. Grand Junction, Colorado was used for default parameters since it is similar in elevation and climate to Blanding Utah. An actual mean annual temperature for Blanding Utah from Dames & Moore (1978) was used for modeling purposes (see Appendix B).

N-factor

A default n-factor of 0.70 for sand and gravel surface type was used as per recommended in the freeze/thaw model guidelines (Aitken and Berg, 1968).

Soil type

Soil type was considered to be fine grained soil for both cover layers. Soil type number is 5.

Layer thickness'

The thickness of the cover materials were determined by infiltration and radon flux modeling programs to be 2 feet of random fill over 1 foot of clay. For this calculation, a single 36-inch layer was used. This was used because the random fill and clay soil have very similar properties.

Moisture Content

Optimum moisture content from Chen and Associates (1987) and Advanced Terra Testing (1996) was used for the random fill and the clay (UT-1) layer respectively. This data is included in Appendix B.

Optimum moisture content:

random fill	=11.8%
clay	=13.9%

A weighted averaged moisture content of 12.5 percent was used for this analysis.

Soil Density

Soil dry density was determined from Chen and Associates (1987) for random fill and Advanced Terra Testing (1996) for clay. The maximum dry density for the random fill was measured to be 120.2 pounds per cubic foot (pcf) and the maximum dry density for the clay was measured to be 113.5 pcf. Assuming the soil will be compacted to 95 percent of the maximum density, the weighted average bulk soil density would be 112 pcf.

Heat Capacity

Based on the nomographs presented in Aitken and Berg (1968) and included herein as Figure 1, using an average soil density of 112 pcf and an average moisture content of 12.5 percent yields a heat capacity of 30 Btu/ft^3 ° F.

Thermal Conductivity

Thermal conductivity of the soil cover was assumed to be similar to that for a dry sand. The thermal conductivity of a dry sand is reported to be 0.19 Btu/ hr. ft °F (Perry, Robert H. et al., 1984) (see Table 1).

Latent Heat

Based on the nomographs presented in Aitken and Berg (1968) and included herein as Figure 1, using an average soil density of 112 pcf and an average moisture content of 12.5 percent yields a Latent Heat of 2000 Btu/ ft^3 .

References:

Advanced Terra Testing, 1996. Physical soil data, White Mesa Project, Blanding Utah, July 25, 1996.

Aitken, George W. and Berg, Richard L., 1968, "Digital Solution of Modified Berggren Equation to Calculate Depths of Freeze or Thaw in Multilayered Systems", October, 1968.

Chen and Associates, 1987. Physical soil data, White Mesa Project Blanding Utah.

Dames & Moore, 1978. "Environmental Report, White Mesa Uranium Project, San Juan County, Utah, January 20, 1978, revised May 15, 1978.

Perry, Robert H. et al., 1984. "Perry's Chemical Engineers' Handbook, Sixth Edition", McGraw Hill Book Company, 1984.

U.S. Department of Energy, 1988, "Effect of Freezing and Thawing on UMTRA Covers" Albuquerque, New Mexico, October 1988.

TABLE 1

5/18

[illegible] Thermal Conductivities of Some Building and Insulating Materials*

k = Btu/(h·ft²)(°F/ft)

Material	Apparent density ρ, lb./cu. ft. at room temperature	t, °C.	k
Aerogel, silica, opacified	8.5	120	0.013
		290	.026
Asbestos-cement boards	120	20	.43
Asbestos sheets	55.5	51	.096
Asbestos slate	112	0	.087
	112	60	.114
Asbestos	29.3	−200	.043
	29.3	0	.090
	36	0	.087
	36	100	.111
	36	200	.120
	36	400	.129
	43.5	−200	.090
	43.5	0	.135
Aluminum foil (7 air spaces per 2.5 in.)	0.2	38	.025
		177	.038
Ashes, wood	......	0–100	.041
Asphalt	132	20	.43
Boiler scale (Note 1)			
Bricks:			
Alumina (92–99% Al_2O_3 by wt.) fused	......	427	1.8
	......	1315	2.7
Alumina (64–65% Al_2O_3 by wt.)	115	800	0.62
(See also Bricks, fire clay)	115	1100	.63
Building brick work	......	20	.4
Carbon	96.7	......	3.0
Chrome brick (32% Cr_2O_3 by wt.)	200	200	.67
	200	650	.85
	200	1315	1.0
Diatomaceous earth, natural, across strata (Note 2)	27.7	204	0.051
	27.7	871	.077
Diatomaceous, natural, parallel to strata (Note 2)	27.7	204	.081
	27.7	871	.106
Diatomaceous earth, molded and fired (Note 2)	38	204	.14
	38	871	.18
Diatomaceous earth and clay, molded and fired (Note 2)	42.3	204	.14
	42.3	871	.19
Diatomaceous earth, high burn, large pores (Note 3)	37	200	.13
	37	1000	.34
Fire clay (Missouri)	......	200	.58
		600	.85
		1000	.95
		1400	1.02
Kaolin insulating brick (Note 3)	27	500	0.15
	27	1150	.26
Kaolin insulating firebrick (Note 4)	19	200	.050
	19	760	.113
Magnesite (86.8% MgO, 6.3% Fe_2O_3, 3% CaO, 2.6% SiO_2 by wt.)	158	204	2.2
	158	650	1.6
	158	1200	1.1
Silicon carbide brick, recrystallized (Note 3)	129	600	10.7
	129	800	9.2
	129	1000	8.0
	129	1200	7.0
	129	1400	6.3
Calcium carbonate, natural	162	30	1.3
White marble	......	......	1.7
Chalk	96	......	0.4
Calcium sulfate (4H_2O), artificial	84.6	40	.22
plaster (artificial)	132	75	.43
(building)	77.9	25	.25
Cambric (varnished)	......	38	.091
Carbon, gas	......	0–100	2.0
Carbon stock	94	−184	0.55
	1	0	3.6
Cardboard, corrugated	......	......	0.037
Celluloid	87.3	30	.12
Charcoal flakes	11.9	80	.043
	15	80	.051
Clinker (granular)	......	0–700	.27
Coke, petroleum	......	100	3.4
		500	2.9
Coke, petroleum (20–100 mesh)	62	400	0.55
Coke (powdered)	......	0–100	.11
Concrete (cinder)	......	......	.20
(stone)	......	......	.54
(1:4 dry)	......	......	.44

Material	Apparent density ρ, lb./cu. ft. at room temperature	t, °C.	k
Cotton wool	5	30	0.024
Cork board	10	30	.025
Cork (regranulated)	8.1	30	.026
(ground)	9.4	30	.025
Diatomaceous earth powder, coarse (Note 2)	20.0	38	.036
	20.0	871	.082
fine (Note 2)	17.2	204	.040
	17.2	871	.074
molded pipe covering (Note 2)	26.0	204	.051
	26.0	871	.088
4 vol. calcined earth and 1 vol. cement, poured and fired (Note 2)	61.8	204	.16
	61.8	871	.23
Dolomite	167	50	1.0
Ebonite	......	......	0.10
Enamel, silicate	38	......	0.5–0.75
Felt, wool	20.6	30	0.03
Fiber insulating board	14.8	21	.028
Fiber, red	80.5	20	.27
(with binder, baked)	......	20–97	.097
Gas carbon	......	0–100	2.0
Glass	......	......	0.2–0.73
Borosilicate type	139	30–75	0.63
Window glass	......	......	0.3–0.61
Soda glass	......	......	0.3–0.44
Granite	......	......	1.0–2.3
Graphite, longitudinal	......	20	95.
powdered, through 100 mesh	30	40	0.104
Gypsum (molded and dry)	78	20	.25
Hair felt (perpendicular to fibers)	17	30	.021
Ice	57.5	0	1.3
Infusorial earth, see diatomaceous earth			
Kapok	0.88	20	0.020
Lampblack	10	40	.038
Lava	......	......	.49
Leather, sole	62.4	......	.092
Limestone (15.3 vol. % H_2O)	103	24	.54
Linen	......	30	.05
Magnesia (powdered)	49.7	47	.35
Magnesia (light carbonate)	13	21	0.034
Magnesium oxide (compressed)	49.9	20	.32
Marble	......	......	1.2–1.7
Mica (perpendicular to planes)	......	50	0.25
Mill shavings	......	......	0.033–0.05
Mineral wool	9.4	30	0.0225
	19.7	30	.024
Paper	......	......	.075
Paraffin wax	......	0	.14
Petroleum coke	......	100	3.4
	......	500	2.9
Porcelain	......	200	0.88
Portland cement, see concrete	......	90	.17
Pumice stone	......	21–66	.14
Pyroxylin plastics	......	......	.075
Rubber (hard)	74.8	0	.087
(para)	......	21	.109
(soft)	......	21	0.075–0.092
Sand (dry)	94.6	20	0.19
Sandstone	140	40	1.08
Sawdust	12	21	0.03
Scale (Note 1)			
Silk	6.3	......	.026
varnished	......	38	.096
Slag, blast furnace	......	24–127	.064
Slag wool	12	30	.022
Slate	......	94	.06
Snow	34.7	0	.27
Sulfur (monoclinic)	......	100	0.09–0.097
(rhombic)	......	21	0.16
Wall board, insulating type	14.8	21	.028
Wall board, stiff paste board	43	30	.04
Wood shavings	8.8	30	.034
Wood (across grain):			
Balsa	7–8	30	0.025–0.03
Oak	51.5	15	0.12
Maple	44.7	50	.11
Pine, white	34.0	15	.087
Teak	40.0	15	.10
White fir	28.1	60	.062
Wood (parallel to grain):			
Pine	34.4	21	.20
Wool, animal	6.9	30	.021

* Marks, "Mechanical Engineers' Handbook," 4th ed., McGraw-Hill, New York, 1941. "International Critical Tables," McGraw-Hill, 1929, and other sources. For additional data, see pp. 458–459.

Note 1: B. Kamp [Z. tech. Physik, 12, 30 (1931)] shows the effect of increased porosity in decreasing thermal conductivity of boiler scale. Partridge [University of Michigan Eng. Research Bull. 15, 1930] has published a 170-page treatise on Formation and Properties of Boiler Scale.

Note 2. Townshend and Williams, Chem. & Met., 39, 219 (1932).

Note 3: Norton, "Refractories," 2d ed., McGraw-Hill, New York, 1942.

Note 4: Norton, private communication.

REF: PERRY'S CHEMICAL ENGINEERS' HANDBOOK, 1984, 6TH EDITION.

TJM
9/11/96

FIGURE 1

6/18

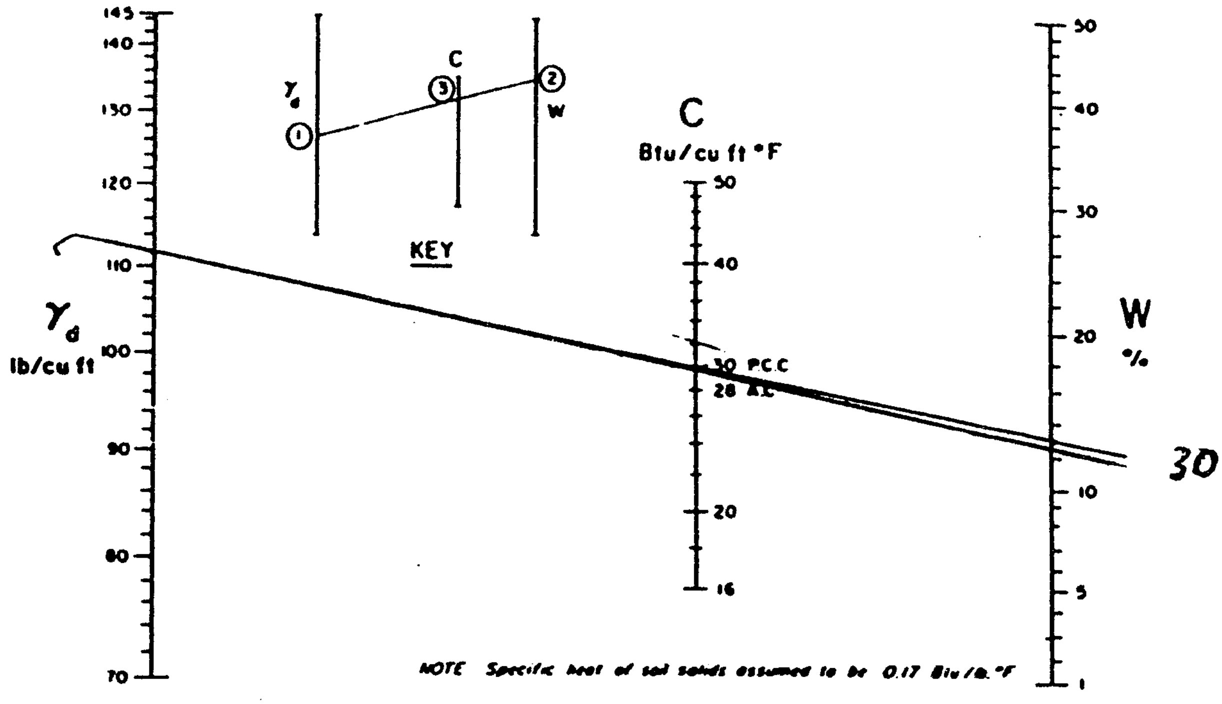


Figure 8. Average volumetric heat capacity for soils (after Aldrich and Paynter, 1953).

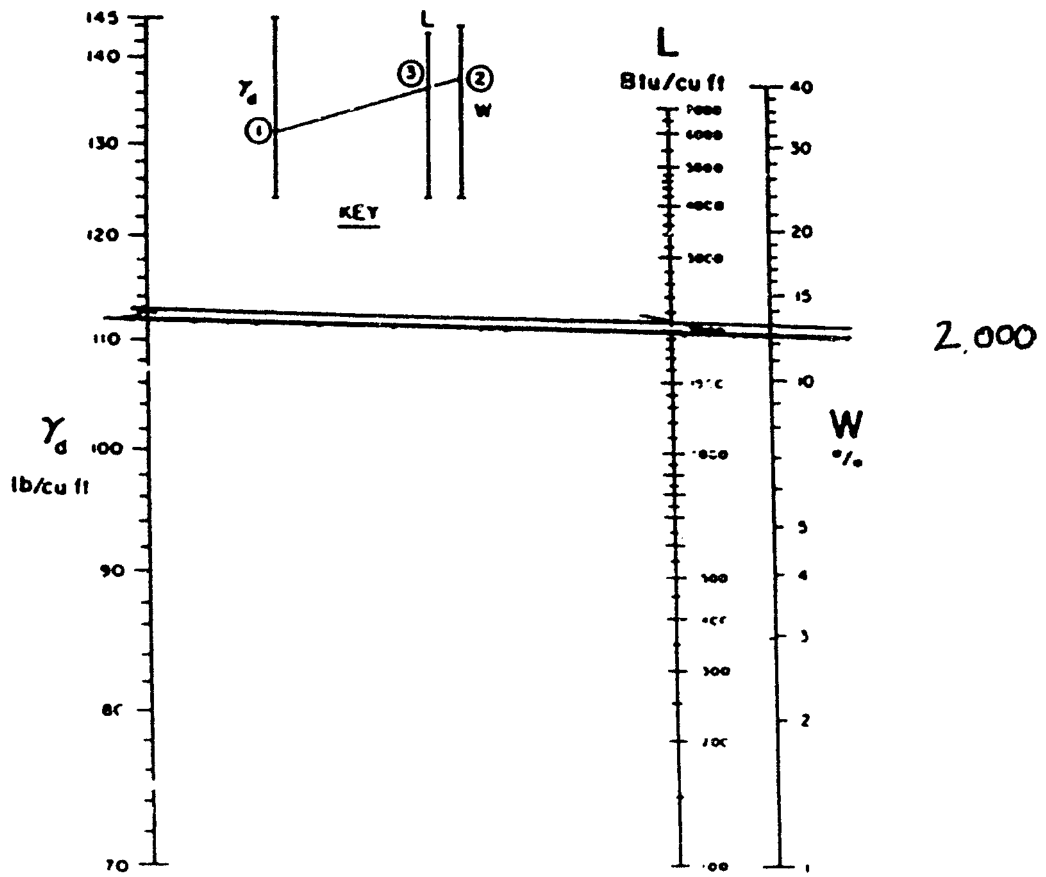


Figure 9. Volumetric latent heat for soils (after Aldrich and Paynter, 1953).

TAM

Appendix A

WEATHER STATIONS in Colorado:

Station Location	Design Freezing Index (°F days)	Mean Annual Temp. (°F)	Length of Freezing Season (days)
1 = Alamosa	2274	41.3	159
2 = Buckley ANGB	577	50.3	88
3 = Colorado Springs	633	48.7	67
4 = Denver	629	50.3	71
5 = Grand Junction	1101	52.6	86
6 = Pueblo	676	52.3	65

Enter the number representing the data you want:
(0 to input your own data):

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9/11/96

9/18

LOCATION and WEATHER DATA

Input weather data for your location in Colorado:

DESIGN AIR FREEZING Index (F-Days): 1101

MEAN ANNUAL TEMPERATURE (F): 49.8

LENGTH of FREEZING SEASON (Days): 86

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9/11/96

CHOOSE an APPROPRIATE N-FACTOR

Surface Type	N-Factor * (Freezing)
1 = Portland Cement (snow-free)	0.75
2 = Asphalt (snow-free)	0.70
3 = Snow	1.00
4 = Sand and Gravel (snow-free)	0.70
5 = Turf (snow-free)	0.50

0 = To input your own N-Factor

Enter your option: 4

* N-Factor varies with lattitude, wind speed, cloud cover, and other climatic conditions.

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INFORMATION for LAYER 1:

Choose the appropriate soil type for this layer —

1 = Portland Cement stabilized layer
2 = Asphalt stabilized layer
3 = Snow
4 = Course-grained soil
5 = Fine-grained soil
6 = Insulating layer
7 = Organic soil

Enter your option: 5

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9/11/96

LAYER PARAMETERS

Parameters for LAYER 1, Fine-grained	Default Values	Values Used
Layer Thickness (inches)	12.0	36.0
Moisture Content (% dry weight)	17.0	12.5
Dry Unit Weight (lbs/cubic foot)	122.0	112.0
Heat Capacity (Btu/cubic foot °F)	* 29.5	30.0
Thermal Conductivity (Btu/foot hour °F)	* 0.90	0.19
Latent Heat of Fusion (Btu/cubic foot)	* 2016.0	2000

* recalculated based upon new MOISTURE CONTENT/WEIGHT value(s).

...<return> for Default Values...

TAM
9/11/94

Summary: MODIFIED BERGGREN SOLUTION

Design Freezing Index (AIR) = 1101 F-days
Design Freezing Index (SURFACE) = 771 F-days
Mean Annual Temperature = 49.8 °F
Length of Freezing Season = 86 Days

LAYER #: Type	LAYER THICKNESS (inches)	FREEZING INDEX DISTRIBUTION Each Layer	Accum	Berggren
1: Fine-grained	< 6.8	145	←	Calculations could not converge Surface DFI

End of Frost Penetration

TOTAL FROST PENETRATION = 6.8 inches

Do you want a hard copy of this data (Y or default N)?

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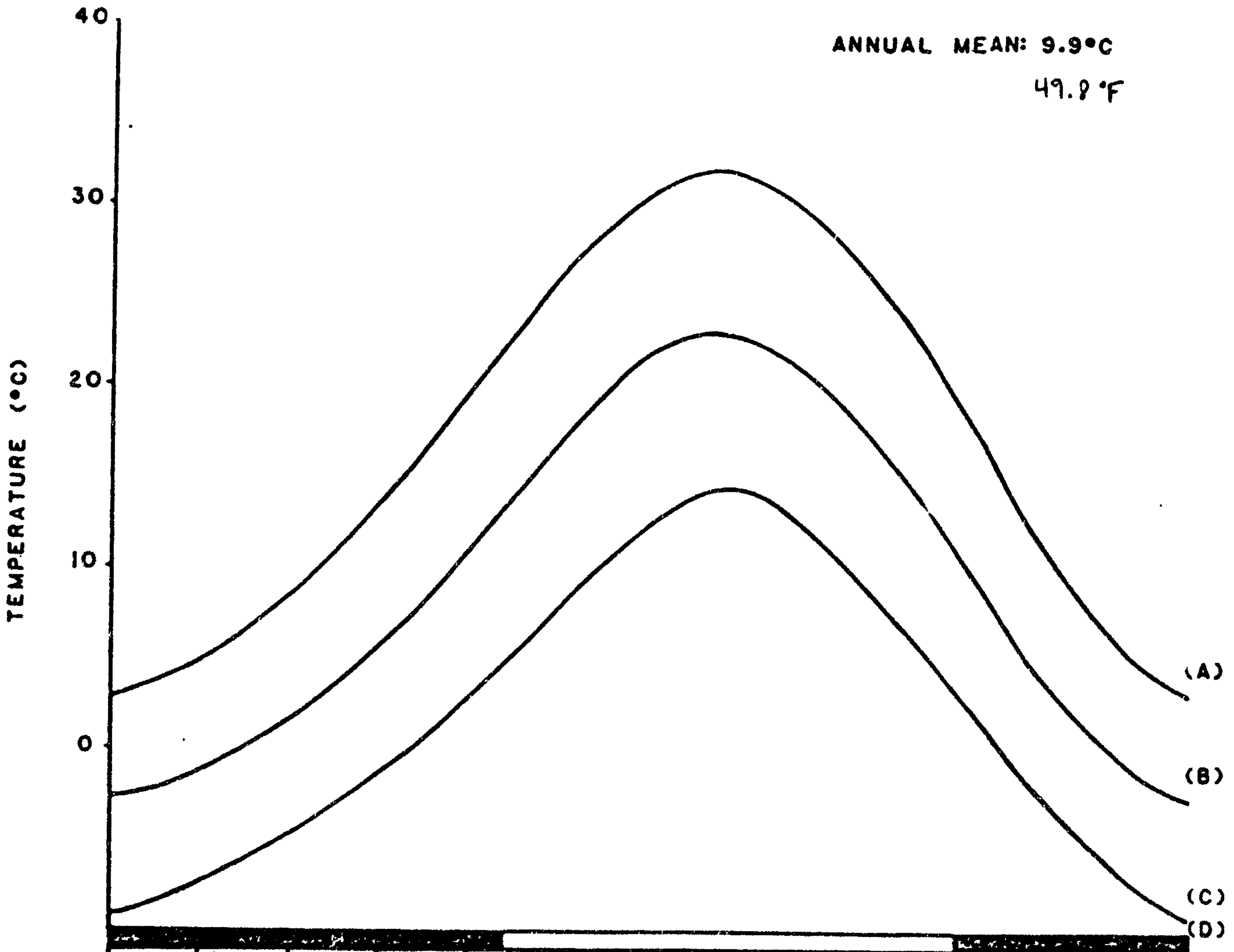
9/11/96

Appendix B

15/18

MONTHLY MEANS AND EXTREMES OF TEMPERATURES BLANDING, UTAH



MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
EXTREME MAX.	16	18	24	27	33	38	38	37	34	29	21	15
MEAN MAX.	3.8	6.9	10.9	16.3	22.8	28.7	31.9	30.2	26.0	18.8	10.2	4.5
MEAN	-2.5	0.5	3.4	8.4	14.1	19.4	23.1	21.6	17.2	10.9	3.6	-1.7
MEAN MIN.	-8.8	-5.9	-3.2	0.4	5.4	10.1	14.2	13.1	8.4	2.9	-3.2	-7.8
EXTREME MIN.	-29	-22	-15	-11	-6	-1	8	3	-5	-12	-19	-22

(A) MEAN DAILY MAXIMUM
(B) MEAN MONTHLY
(C) MEAN DAILY MINIMUM
(D) FREEZE DATES

16/18

TAILINGS AND RANDOM FILL PROPERTIES

Table 3.4-1

Physical Properties of Tailings

and

Proposed Cover Materials

Material Type	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity	% Passing No. 200 Sieve	Maximum Dry Density (pcf)	Optimum Moisture Content
Tailings	28	6	2.85	46	104	18.1
Random Fill	22	7	2.67	48	120.2	11.8
Clay	29	14	2.69	56	121.3	12.1
Clay	36	19	2.75	68	108.7	18.5

Note: Physical Soil Data from Chen and Associates (1987).

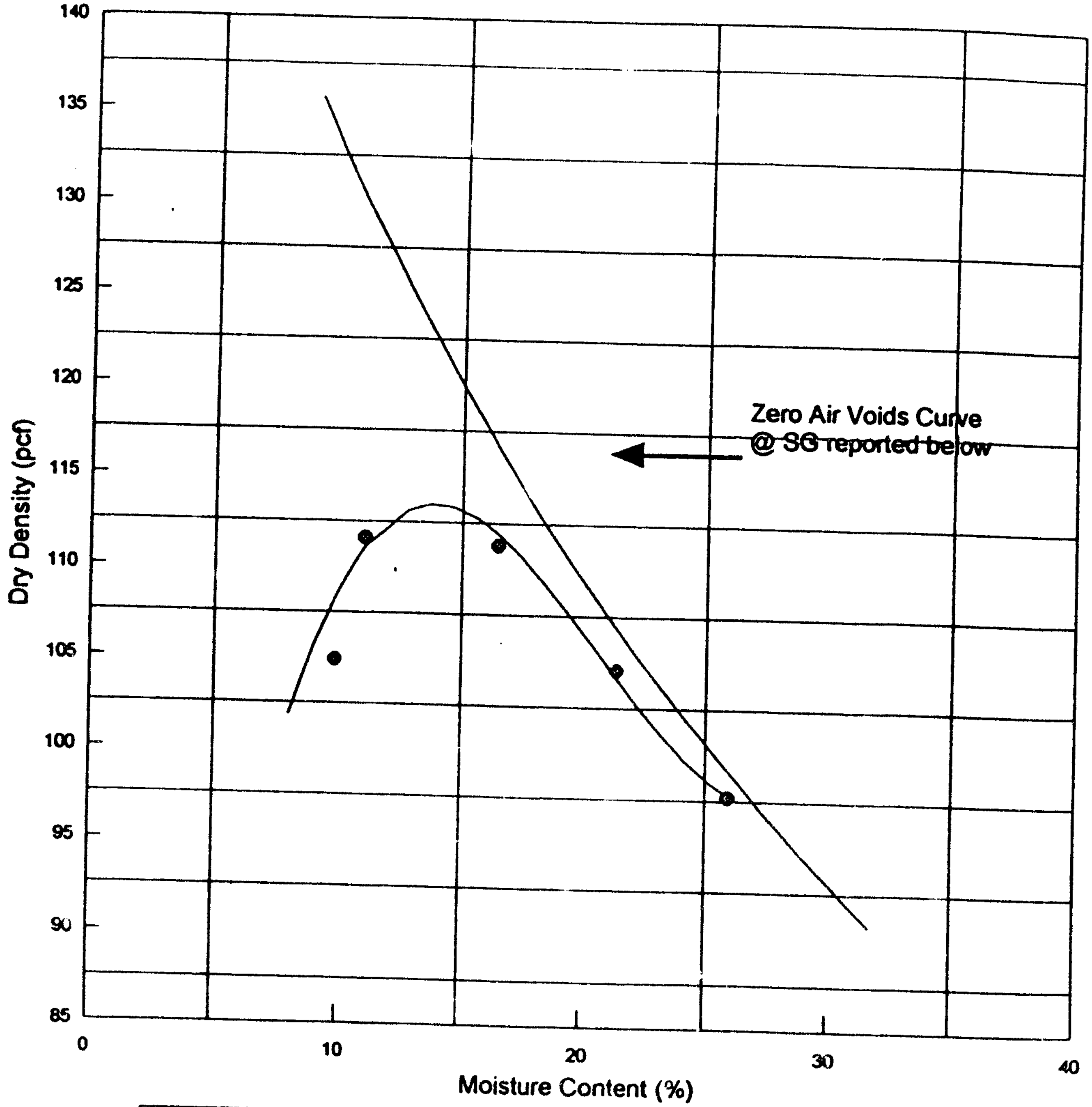
17/18

ADVANCED TERRA TESTING inc

833 Parfet Street
Lakewood, Colorado 80215
(303) 232-8308

Proctor Compaction Test

, , UT-1



- Best Fit Curve
- Actual Data
- Zero Air VoidsCurve @ SG = 2.70

OPTIMUM MOISTURE CONTENT = 13.9 MAXIMUM DRY DENSITY = 113.5
ASTM D 1557 A, Rock correction applied? N

ADVANCED TERRA TESTING, INC.

APPENDIX F

Erosion Protection

PURPOSE:

Design of Erosion Protection layer of Riprap for the Cover of Uranium Tailings

An erosion protection layer of rock riprap is required to protect the soil cover for the uranium mill tailings at Blanding, Utah. The cover is supposed to have a design life of 1000 years according to requirements set by U.S. Nuclear Regulatory Commission [Ref: "Final Staff Technical Position - Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites", 1990; U.S. Nuclear Regulatory Commission (U.S.N.R.C.)]. Hence the erosion protection layer should be designed accordingly. A design for the stone size and overall riprap thickness required for erosion protection is provided in this document.

METHODOLOGY:

The design for rock riprap for protection of top and side slopes of the cover is based on the guidelines provided by the following documents:

a) "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments" (NUREG/CR-4620), 1986; U.S. Nuclear Regulatory Commission

b) "Final Staff Technical Position - Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites", 1990; U.S. Nuclear Regulatory Commission (U.S.N.R.C.)

c) "Development of Riprap Design Criteria by Riprap Testing in Flumes"(NUREG/CR-4651), 1987; U.S. Nuclear Regulatory Commission

The top of the cover and the side slopes will be designed separately as the side slopes are much steeper than the top of the cover. Overland flow calculations will be determined based on the guidelines set by Nuclear Regulatory Commission and the site data. The size of the riprap placed on top of the tailings cover will be determined using the Safety Factor method (NUREG/CR-4651), while the Stephenson method (NUREG/CR-4651) will be applied for those placed along the side slopes.

A: Overland Flow Calculations

The methods for overland flow calculations are same for top and side slopes of the cover. The results have been tabulated under Table 1A and 2A respectively. The formulas, methodologies and equations used for overland flow calculations are discussed in this part of the document. The calculations are based on unit width of drainage area.

Average Slope 'S' and Length of drainage basin 'L': Figure 1 shows the direction of drainage for cells 2, 3 & 4. Table 1A calculates the flow parameters by varying slopes and slope lengths of cells 2, 3 & 4. Runoff and flow calculations have been provided for slopes ranging from 0.001 to 0.008 for cells 2 and 4 and from 0.001 to 0.005 for cell 3. As the slopes are very gentle, for each cell the drainage length varies negligibly and hence has been considered constant for calculation purpose. The drainage lengths have been measured from the site map. For erosion protection design of the side slopes, a side slope of 5H:1V and the maximum value of drainage lengths for cells 2, 3 & 4 have been considered (Table 2A).

Probable Maximum Precipitation (PMP): The 1-hour local storm PMP for White Mesa is 7.76 inches (data from NOAA, 1977).

Time of Concentration of Rainfall, T_c:

$$T_c = 0.00013\frac{L^{0.77}}{S^{0.385}}\text{hours} = 0.00013\frac{L^{0.77}}{S^{0.385}} \times 60\,\text{mins}$$ (Ref: Equation 4.44 in NUREG/CR-4620)

where, S = average slope of drainage basin and L = length of drainage basin in feet
The percentage of 1-hour precipitation is obtained by interpolating from Table 2.1 of NUREG/CR-4620. The minimum value of T_c used in this table is 2.5 minutes.

% PMP: The percentage for 1-hour precipitation (PMP) is obtained by interpolating from table 2.1 of NUREG/CR-4620.

Rainfall Depth:
Precipitation Amount (inches) = % PMP × PMP = % of 1-hour precipitation × PMP (Ref: Eqn. 2.1, NUREG/CR-4620).

Precipitation intensity, 'i':
Precipitation intensity in inches/hour can be computed as (Ref: Eqn. 2.2, NUREG/CR-4620):
i = rainfall depth (inches) × [60 / {rainfall duration T_c (minute)}]

Runoff Coefficient, C: Runoff coefficient depends on climatic conditions, the type of terrain, permeability, and storage potential of the basin. Runoff Coefficient has been assumed to be 0.8 for

the top of cover and the side slopes (Ref: Appendix D, section 2.4 (Example) in "Final Staff Technical Position", U.S.N.R.C.).

Unit Area, A: Area of 1-ft wide drainage basin
$A =$ Length of drainage basin (ft.) × width (ft.) $= L \times 1$ sq. ft. $= [L \times 1/(43560)]$ Acres

Peak discharge per unit width for the drainage basin, q:
By Rational method, $q = CiA$, where C, i & A have their usual meanings [q in cu. ft./sec (cfs), i in inches/hour and A in acres] (Ref: Eqns. 4.42 and 4.43, NUREG/CR-4620).

Flow Concentration Factor:
From section 4.9 of NUREG/CR-4620, "...it is reasonable to assume that values between 2 and 3 are attainable with only a slight evolutionary change in cover." Thus, a flow concentration factor of 3 and 2 have been assumed for top and side slopes respectively (as the top of cover is flatter than the side slopes, it has been assumed that concentration of flow will be higher on the top than along the side slopes).

Concentrated discharge per unit width for the drainage basin, q_c:
q_c (cu. ft./sec) = q × flow concentration factor

Manning's Roughness coefficient, n:
Assumed n = 0.03 for graded loam to cobbles (Ref: table 4.2, NUREG/CR-4620)

Depth of water, D:

Depth of water in ft., $D = \left[\frac{q_c \times n}{1.486\sqrt{S}}\right]^{\frac{3}{5}}$ (Ref: Eqn. 4.46, NUREG/CR-4620), where q_c is in cu. ft./sec

Permissible Velocity:
The cover permissible velocity is between 5 to 6 ft./sec (Ref: section 4.11.3, NUREG/CR-4620)

Flow Velocity, V:
Using continuity equation,
discharge = velocity × cross-sectional area

$\therefore q_c = V \times (D \times \text{unit width}) = V \times D \times 1$

$\therefore V(\text{in ft./sec}) = \frac{q_c}{D \times 1}$

For all the calculations provided in Table 1A and 2A for top of cover and side slopes respectively, $V_{developed} < V_{permissible}$

B: Calculation for Preliminary Size (D_{50}) of Rock Riprap used for Erosion Protection

B.1 Preliminary Size (D_{50}) of Riprap along Top of Cover

According to recommendations by U.S.N.R.C. [Ref: Appendix D, section 2.2 (step 5), "Final Staff Technical Position"], recent studies have indicated that Safety Factor method is more applicable for designing rock for slopes less than 10%. The slopes along top of the cover for all the cells 2, 3 and 4 do not exceed 10%. Hence the Safety Factor method has been adopted to calculate the median diameter D_{50} of the rock particles used for riprap.

According to the Safety Factor method for determination of stone size, if the Safety Factor (S.F.) is greater than unity, the riprap is considered to be safe from failure (Ref: Section 3.4.1,"Development of Riprap Design Criteria by Riprap Testing in Flumes", NUREG/CR-4651). For calculations to determine the riprap size for top of cover, a safety factor of 1.1 has been assumed and the D_{50} corresponding to this safety factor has been computed. Table 1B tabulates the results for the safety factor method.

The equations 3.5 through 3.9 of NUREG/CR-4651 (see appendix) for Safety Factor method are provided below :

$$SF = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta}$$ ....eqn. A_1 (eqn. 3.5 of NUREG/CR-4651)

$$\eta' = \eta\left[\frac{1+\sin(\lambda+\beta)}{2}\right]$$ ....eqn. B_1 (eqn. 3.6 of NUREG/CR-4651)

$$\eta = \frac{21\tau_0}{(G_s - 1)\gamma_w \times D_{50}}$$ ....eqn. C_1 (eqn. 3.7 of NUREG/CR-4651)

$$\tau_0 = \gamma_w DS$$ ....eqn. D_1 (eqn. 3.8 of NUREG/CR-4651)

$$\beta = \tan^{-1}\left[\frac{\cos\lambda}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\lambda}\right]$$ ....eqn. E_1 (eqn 3.9 of NUREG/CR-4651)

where,

λ = angle between a horizontal line and the velocity vector compoment measured in the plane of side slope (refer to fig. 3.1of NUREG/CR-4651)

θ = side slope angle

S = side slope = $\tan\theta$

ϕ = angle of repose (friction angle) of rock

τ_0 = bed shear stress
D_{50} = representative stone size
G_s = Specific gravity or relative density of the rock
D = depth of flow
γ_w = specific weight of the liquid (in this case, water)
η & η' = stability numbers
β = angle between vector component of the weight, Ws, directed down the side slope and the direction of particle movement

For top of the cover, as slopes are very gentle, for all practical purposes, λ can be considered to be equal to zero (Ref: pg 22, NUREG/CR-4651)
Thus for $\lambda = 0$: $\cos\lambda = 1$, $\sin\lambda = 0$.
Hence, equation 3.9 of NUREG/CR-4651 can be reduced to

$$\beta = \tan^{-1}\left[\frac{\eta\tan\phi}{2\sin\theta}\right] \text{.......eqn } E_2 \text{ (eqn 3.10 of NUREG/CR-4651)}$$

Also, equation 3.6 of NUREG/CR-4651 can be reduced to

$$\eta' = \eta\left[\frac{1+\sin\beta}{2}\right] \text{.......eqn. } B_2$$

ϕ = 40° (see Table 3)
G_s = 2.48 (see Table 3)
γ_w = 62.4 lb./ft^3

The values for depth of water 'D' have been computed in Table 1A. Table 1B provides the preliminary D_{50} size for each of cells 2, 3 & 4 by varying the slope and the length of the drainage basin.

D_{50} calculated by CSU method

According to CSU method (Ref: NUREG/CR-4651, Phase-II),
$D_{50} = 5.23 \times (\text{slope})^{0.43} \times (\text{discharge})^{0.56}$
The results of D_{50} computed by CSU method have been included in table 1B (values of discharge have been computed in table 1A to compare with those obtained by Safety Factor method.

B.2 Preliminary Size (D_{50}) of Riprap along Side Slopes

According to recommendations by U.S.N.R.C. (Ref: Appendix D, section 2.2 (step 5), "Final Staff Technical Position"), recent studies have indicated that Stephenson method is more applicable for designing rock for slopes less than 10%. As the side slopes (5H:1V) have a value of S = 1/5 = 0.2 = 20%(>10%), the Stephenson method (Ref: "Development of Riprap Design Criteria by Riprap Testing in Flumes", NUREG/ CR-4651) will be most appropriate.

By **Stephenson method**, the median size for rock, D_{50} is given by the following equation (Ref: eqn. 3.15, NUREG/CR-4651):

$$D_{50} = \left[\frac{q_c (\tan\theta)^{\frac{7}{6}} \times n_p^{\frac{1}{6}}}{C\sqrt{g} \times [(1-n_p)(G_s - 1)(\cos\theta)(\tan\phi - \tan\theta)]^{\frac{5}{3}}} \right]^{\frac{2}{3}}$$

where, q_c = Concentrated discharge in cu. ft./sec
θ = Slope angle = $\tan^{-1}(S) = \tan^{-1}(0.2) = 11.31°$
ϕ = Friction angle of the rock = 40° (see Table 3)
G_s = Relative Density of the rock = 2.48 (see Table 3)
g = Acceleration due to gravity = 32.2 ft./sec^2
n_p = Porosity of the rock = 0.30 (for sandstone) [Ref: (a) "Origin of Sedimentary Rocks" and (b) Table 3
C = Empirical factor [0.22 for gravel/pebble and 0.27 for crushed granite]
Also, K = Oliver's constant [1.2 for gravel and 1.8 for crushed rock]

The results for q_c from table 2A have been substituted into the above equation and the solution tabulated in table 2B. The value of D_{50} has been multiplied by the Oliver's constant K to insure stability.

<u>D_{50} calculated by CSU method</u>

According to CSU method (Ref: NUREG/CR-4651, Phase-II),
$D_{50} = 5.23 \times (\text{slope})^{0.43} \times (\text{discharge})^{0.56}$

The results of D_{50} computed by CSU method have been included in table 2B to compare with those obtained by Stephenson method.

C: Oversizing of Riprap based on durability and Overall Riprap Thickness

C.1 Modification of Size (D_{50}) of Riprap based on Durability

Tables 3 and 4 include the properties of the rock to be used as protective cover material. Based on these values and according to the scoring criteria set by U.S.N.R.C. (Ref: Appendix D, sections 6.2, 6.2.1,6.2.2 and table D-1 in "Final Staff Technical Position"), a rock rating analysis has been provided in Table 4. The results show a rock rating of 55.74%, which according to U.S.N.R.C. can be used for non critical areas like top slopes and side slopes.

Thus the oversizing required = 80-55.74 = 24.26%
[ref: (a) Appendix D, section 6.2.2B, "Final Staff Technical Position"; U.S.N.R.C. (oversizing required based on a 80-rating), (b) Appendix D, section 6.4 (example), "Final Staff Technical Position" and (c) Table 4.
However a oversizing factor of 25 % has been used. Thus the nominal diameter D_{50} obtained in tables 1B and 2B has been multiplied with 1.25 to obtain a modified rock size D_{50} (tables 1C and 2C).

C.2 Overall Riprap Thickness

According to the Safety Factor method, it is recommended that the riprap thickness be at least 1.5 times the D_{50} value whereas according to the Stephenson method the riprap thickness should be at least 2 times the D_{50} value. The results based on the above recommendations are shown in tables 1C and 2C respectively.

RESULTS:

Results of the calculations have been tabulated under tables 1A, 1B, 1C, 2A, 2B, 2C respectively.

REFERENCE:

a) "Final Staff Technical Position - Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites", 1990; U.S. Nuclear Regulatory Commission (U.S.N.R.C.)

b) Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments" (NUREG/CR-4620), 1986; U.S. Nuclear Regulatory Commission

c) "Development of Riprap Design Criteria by Riprap Testing in Flumes" (NUREG/CR-4651), 1987; U.S. Nuclear Regulatory Commission

d) National Oceanic and Atmospheric Administration (NOAA), 1977. Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages. Hydrometeorological Report (HMR) No. 49.

e) "Origin of Sedimentary Rocks", second edition; Harvey Blatt, Gerard Middleton and Raymond Murray

TABLES

TITAN ENVIRONMENTAL

Project # 8111-001
Client: EFN, White Mesa
Location: Blanding, Utah

Date: June 1996
Prepared by: KG
Checked by:

Overland Flow Calculations for Top Portion of the Cover

Table 1A Calculation for Runoff and Flow parameters

Cell No	Maximum Length "L" of Drainage Basin (appx.)	Average Slope "S"	Drainage Area per ft. run A = L x 1 ft.		Manning's Roughness Coefficient n	1-hour precipitation amount	Design Storm	Time of Concentration, Tc: Calculated value (using Eqn. 4.44, NUREG 4620)	Time of Concentration, Tc: Minimum value, based on table 2.1, NUREG 4620	Time of Concentration, Tc: Value used	%PMP = % of 1-hour precipitation (Table 2.1, NUREG 4620)	Rainfall Depth	Precipitation Intensity "I"	Runoff Coefficient "C"	Flow Concentration Factor	Peak Discharge per unit ft. width q = CIA	Concentrated Discharge per unit ft. width q_c	Depth of water "D" (eqn. 4.48, NUREG 4620)	Flow Velocity, V = Discharge / c.s. Area	Permissible Velocity
	ft.	ft./ft.	sq. ft.	Acres		inches		minutes	minutes	minutes		inches	inches/hr.			cu.ft./sec.	cu.ft./sec.	ft.	ft./sec	ft./sec.
2	1350	0.0080	1350	0.0310	0.03	7.76	PMP	12.86	2.5	12.86	68.80	5.36	24.92	0.8	3	0.62	1.86	0.593	3.13	5 - 6
	1350	0.0072	1350	0.0310	0.03	7.76	PMP	13.41	2.5	13.41	70.18	5.46	24.37	0.8	3	0.60	1.81	0.604	3.00	
	1350	0.0070	1350	0.0310	0.03	7.76	PMP	13.86	2.5	13.86	70.63	5.47	24.23	0.8	3	0.60	1.80	0.607	2.97	
	1350	0.0060	1350	0.0310	0.03	7.76	PMP	14.38	2.5	14.38	72.82	5.63	23.48	0.8	3	0.58	1.75	0.624	2.80	
	1350	0.0050	1350	0.0310	0.03	7.76	PMP	15.43	2.5	15.43	74.69	5.80	22.54	0.8	3	0.56	1.68	0.643	2.61	
	1350	0.0040	1350	0.0310	0.03	7.76	PMP	16.81	2.5	16.81	76.90	5.97	21.30	0.8	3	0.53	1.58	0.664	2.38	
	1350	0.0030	1350	0.0310	0.03	7.76	PMP	18.78	2.5	18.78	80.08	6.21	19.84	0.8	3	0.49	1.48	0.694	2.13	
	1350	0.0020	1350	0.0310	0.03	7.76	PMP	21.96	2.5	21.96	83.37	6.47	17.68	0.8	3	0.44	1.31	0.731	1.80	
	1350	0.0010	1350	0.0310	0.03	7.76	PMP	28.67	2.5	28.67	88.07	6.83	14.30	0.8	3	0.36	1.06	0.793	1.34	
3	1100	0.0050	1100	0.0253	0.03	7.76	PMP	13.18	2.5	13.18	69.63	5.40	24.60	0.8	3	0.50	1.49	0.569	2.49	
	1100	0.0040	1100	0.0253	0.03	7.76	PMP	14.36	2.5	14.36	72.47	5.62	23.40	0.8	3	0.47	1.42	0.623	2.29	
	1100	0.0030	1100	0.0253	0.03	7.76	PMP	16.04	2.5	16.04	76.67	5.87	21.88	0.8	3	0.44	1.33	0.652	2.04	
	1100	0.0020	1100	0.0253	0.03	7.76	PMP	18.76	2.5	18.76	80.00	6.21	19.85	0.8	3	0.40	1.20	0.694	1.74	
	1100	0.0013	1100	0.0253	0.03	7.76	PMP	22.14	2.5	22.14	83.80	6.48	17.56	0.8	3	0.35	1.06	0.733	1.45	
	1100	0.0010	1100	0.0253	0.03	7.76	PMP	24.49	2.5	24.49	86.14	6.61	16.19	0.8	3	0.33	0.98	0.756	1.30	
4	1250	0.0080	1250	0.0287	0.03	7.76	PMP	12.13	2.5	12.13	67.12	5.21	25.78	0.8	3	0.59	1.77	0.577	3.07	
	1250	0.0070	1250	0.0287	0.03	7.76	PMP	12.77	2.5	12.77	68.66	5.33	25.02	0.8	3	0.57	1.72	0.591	2.92	
	1250	0.0060	1250	0.0287	0.03	7.76	PMP	13.86	2.5	13.86	70.63	5.47	24.23	0.8	3	0.56	1.67	0.607	2.75	
	1250	0.0057	1250	0.0287	0.03	7.76	PMP	13.83	2.5	13.63	71.18	5.52	23.97	0.8	3	0.55	1.65	0.612	2.70	
	1250	0.0050	1250	0.0287	0.03	7.76	PMP	14.64	2.5	14.54	72.80	5.65	23.34	0.8	3	0.54	1.61	0.627	2.57	
	1250	0.0040	1250	0.0287	0.03	7.76	PMP	15.86	2.5	15.85	75.35	5.85	22.14	0.8	3	0.51	1.52	0.649	2.35	
	1250	0.0030	1250	0.0287	0.03	7.76	PMP	17.70	2.5	17.70	78.32	6.08	20.60	0.8	3	0.47	1.42	0.678	2.09	
	1250	0.0020	1250	0.0287	0.03	7.76	PMP	20.69	2.5	20.69	82.48	6.40	18.56	0.8	3	0.43	1.28	0.718	1.78	
	1250	0.0010	1250	0.0287	0.03	7.76	PMP	27.02	2.5	27.02	86.82	6.74	14.96	0.8	3	0.34	1.03	0.778	1.33	

Rainfall Duration (min.)	% of 1-hr. precipitation
2.5	27.5
5	45
10	62
15	74
20	82
30	89
45	95
60	100

Table 2.1 of NUREG 4620

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TITAN ENVIRONMENTAL

Project #: 6111-001
Client: EFN, White Mesa
Location: Blanding, Utah

Date: June 1996
Prepared by: KG
Checked by:

Riprap Design for Top portion of the Cover

Table 1B: Calculation for preliminary sizing of riprap, D50

Cell No.	Slope of Channel S (ft./ft.)	Slope of Channel θ (degrees)	Depth of flow, D (ft.)	Specific Weight of water γ_w (lb/cu. ft)	Bed Shear Stress $\tau_0 = \gamma_w DS$ (lb/sq. ft)	Rock Specific Gravity G_s	Angle of Motion φ (degrees)	λ (degrees)	cos θ	sin θ	cos λ	sin λ	tan φ
2	0.0080	0.458	0.583	62.4	0.290	2.40	40	0	1.000	0.008	1.000	0.000	0.839
	0.0072	0.413	0.604	62.4	0.271	2.40	40	0	1.000	0.007	1.000	0.000	0.839
	0.0070	0.401	0.607	62.4	0.265	2.40	40	0	1.000	0.007	1.000	0.000	0.839
	0.0060	0.344	0.624	62.4	0.233	2.40	40	0	1.000	0.006	1.000	0.000	0.839
	0.0050	0.286	0.643	62.4	0.201	2.40	40	0	1.000	0.005	1.000	0.000	0.839
	0.0040	0.229	0.664	62.4	0.166	2.40	40	0	1.000	0.004	1.000	0.000	0.839
	0.0030	0.172	0.694	62.4	0.130	2.40	40	0	1.000	0.003	1.000	0.000	0.839
	0.0020	0.115	0.731	62.4	0.091	2.40	40	0	1.000	0.002	1.000	0.000	0.839
	0.0010	0.057	0.793	62.4	0.049	2.40	40	0	1.000	0.001	1.000	0.000	0.839
3	0.0050	0.286	0.600	62.4	0.187	2.40	40	0	1.000	0.005	1.000	0.000	0.839
	0.0040	0.229	0.623	62.4	0.166	2.40	40	0	1.000	0.004	1.000	0.000	0.839
	0.0030	0.172	0.652	62.4	0.122	2.40	40	0	1.000	0.003	1.000	0.000	0.839
	0.0020	0.115	0.694	62.4	0.087	2.40	40	0	1.000	0.002	1.000	0.000	0.839
	0.0013	0.074	0.733	62.4	0.060	2.40	40	0	1.000	0.001	1.000	0.000	0.839
	0.0010	0.057	0.786	62.4	0.047	2.40	40	0	1.000	0.001	1.000	0.000	0.839
4	0.0080	0.458	0.577	62.4	0.288	2.40	40	0	1.000	0.008	1.000	0.000	0.839
	0.0070	0.401	0.601	62.4	0.260	2.40	40	0	1.000	0.007	1.000	0.000	0.839
	0.0060	0.344	0.607	62.4	0.227	2.40	40	0	1.000	0.006	1.000	0.000	0.839
	0.0057	0.327	0.612	62.4	0.218	2.40	40	0	1.000	0.006	1.000	0.000	0.839
	0.0050	0.286	0.627	62.4	0.196	2.40	40	0	1.000	0.005	1.000	0.000	0.839
	0.0040	0.229	0.640	62.4	0.162	2.40	40	0	1.000	0.004	1.000	0.000	0.839
	0.0030	0.172	0.670	62.4	0.127	2.40	40	0	1.000	0.003	1.000	0.000	0.839
	0.0020	0.115	0.710	62.4	0.089	2.40	40	0	1.000	0.002	1.000	0.000	0.839
	0.0010	0.057	0.779	62.4	0.049	2.40	40	0	1.000	0.001	1.000	0.000	0.839

Cell No.	D50 by Safety Factor method (inches)	D50 by Safety Factor method (ft.)	η	tan β	β (degrees)	cos β	η'	Safety Factor	D50 by CSU method (inches)
2	0.89	0.074	0.007	47.582	88.796	0.021	0.007	1.10	0.93
	0.82	0.068	0.009	62.830	89.017	0.019	0.009	1.10	0.97
	0.80	0.066	0.010	64.830	89.040	0.016	0.010	1.10	0.86
	0.70	0.058	0.010	63.824	89.160	0.016	0.010	1.10	0.79
	0.60	0.050	0.012	78.619	89.261	0.013	0.012	1.10	0.72
	0.50	0.041	0.012	86.861	89.401	0.010	0.012	1.10	0.63
	0.39	0.033	0.009	127.130	89.540	0.008	3.009	1.10	0.53
	0.29	0.023	0.009	180.875	89.686	0.005	0.009	1.10	0.42
	0.16	0.013	0.012	302.675	89.800	0.003	0.012	1.10	0.30
3	0.56	0.047	0.011	78.416	89.269	0.013	0.011	1.10	0.67
	0.47	0.039	0.013	86.721	89.401	0.010	0.013	1.10	0.60
	0.37	0.030	0.013	127.801	89.551	0.008	0.013	1.10	0.56
	0.26	0.022	0.009	180.807	89.690	0.006	0.009	1.10	0.40
	0.18	0.015	0.012	304.196	89.805	0.003	0.012	1.10	0.31
	0.14	0.012	0.009	370.044	89.849	0.003	0.009	1.10	0.27
4	0.87	0.072	0.009	47.288	88.796	0.021	0.009	1.10	0.90
	0.79	0.066	0.009	64.466	89.048	0.016	0.009	1.10	0.84
	0.69	0.057	0.012	63.742	89.101	0.016	0.012	1.10	0.77
	0.66	0.054	0.007	66.776	89.142	0.015	0.007	1.10	0.75
	0.59	0.049	0.012	78.831	89.261	0.013	0.012	1.10	0.70
	0.49	0.040	0.012	86.824	89.401	0.010	0.012	1.10	0.62
	0.38	0.032	0.011	127.413	89.550	0.008	0.011	1.10	0.52
	0.27	0.023	0.007	190.227	89.699	0.005	0.007	1.10	0.41
	0.15	0.012	0.009	300.702	89.809	0.003	0.009	1.10	0.27

Table 1C: Diameter of Riprap modified based on durability, and Overall Riprap Thickness

Cell No.	Slope of channel S (ft./ft.)	D50 based on Safety Factor Method (inches)	Oversizing Factor based on Rock Quality (from previous report)	Modified D50 after oversizing (inches)	Thickness of Riprap layer =1.5xD50 (inches)	Overall Riprap Thickness suggested (inches)
2	0.0080	0.89	1.25	1.11	1.67	3
	0.0072	0.82	1.25	1.02	1.53	
	0.0070	0.80	1.25	0.99	1.49	
	0.0060	0.70	1.25	0.88	1.31	
	0.0050	0.60	1.25	0.75	1.13	
	0.0040	0.50	1.25	0.62	0.93	
	0.0030	0.39	1.25	0.49	0.73	
	0.0020	0.29	1.25	0.34	0.52	
	0.0010	0.16	1.25	0.19	0.29	
3	0.0050	0.56	1.25	0.70	1.05	
	0.0040	0.47	1.25	0.59	0.87	
	0.0030	0.37	1.25	0.46	0.69	
	0.0020	0.26	1.25	0.33	0.49	
	0.0013	0.18	1.25	0.22	0.33	
	0.0010	0.14	1.25	0.18	0.27	
4	0.0080	0.87	1.25	1.09	1.63	
	0.0070	0.78	1.25	0.97	1.46	
	0.0060	0.69	1.25	0.86	1.29	
	0.0057	0.66	1.25	0.82	1.23	
	0.0050	0.58	1.25	0.73	1.10	
	0.0040	0.49	1.25	0.61	0.91	
	0.0030	0.38	1.25	0.48	0.71	
	0.0020	0.27	1.25	0.34	0.51	
	0.0010	0.15	1.25	0.19	0.27	

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TITAN ENVIRONMENTAL

Project - 6111-001
Client: EFN, White Mesa
Location: Blanding, Utah

Date: June 1996
Prepared by: KG
Checked by:

Overland Flow Calculations for Side Slopes of the Cover

Table 2A. Calculation for Runoff and Flow parameters

Maximum Length, "L" of Drainage Basin (appx)	Average Slope "S"	Drainage Area per ft. run A = L x 1 ft.		Manning's Roughness Coefficient n	1-hour precipitation amount	Design storm	Time of Concentration, Tc			% PMP % of 1-hour precipitation (Table 2.1, NUREG 4620	Precipitation Amount	Precipitation intensity "I"	Runoff Coefficient "C"	Flow Concentration Factor	Peak Discharge per unit ft. width q = CiA	Concentrated Discharge per unit ft. width q_c	Depth of water, "D" (eqn. 4.46, NUREG 4620)	Flow Velocity, V = Discharge / c.c. Area	Permissible Velocity (sec. 4.11.3 of (NUREG 4620)
							Calculated value (using Eqn.4.44, NUREG 4620)	Minimum value based on table 2.1, NUREG 4620	Value used										
ft.	ft./ft.	sq. ft.	Acres		inches		minutes	minutes	minutes		inches	inches/hr			cu.ft./sec.	cu.ft./sec.	ft.	ft./sec.	ft./sec.
275	0.2000	275	0.0063	0.03	7.76	PMP	1.10	2.5	2.5	27.5	2.13	51.22	0.8	2	0.26	0.52	0.105	4.93	5 - 6

Rainfall Duration (min.)	% of 1-hr. precipitation
2.5	27.5
5	45
10	62
15	74
20	82
30	89
45	95
60	100

TITAN ENVIRONMENTAL

Project #: 6111-001
Client: EFN, White Mesa
Location: Blanding, Utah

Date: June 1996
Prepared by: KG
Checked by:

Riprap Design for Side Slopes of the Cover

Table 2B: Calculation for preliminary sizing of riprap, D_{50}

Slope of Channel S	Slope of Channel θ	Angle of friction for rock ϕ	Concentrated discharge per unit ft. width, q_d	Relative density of Rock G_s	Porosity n_p	Type of Riprap	Stephenson Constant C	tan θ	cos θ	tan ϕ	D_{50} by Stephenson Method (Eqn. 4.28 of NUREG 4620)		Oliver's Constant K	Modified D_{50}	D_{50} based on CSU method
ft./ft.	degrees	degrees	cu. ft./sec								ft.	inches		inches	ft.
0.200	11.310	40	0.52	2.48	0.3	gravel/pebbles	0.22	0.200	0.981	0.839	0.22	2.70	1.2	3.235	1.81
0.200	11.310	40	0.52	2.48	0.3	crushed granite	0.27	0.200	0.981	0.839	0.20	2.35	1.8	4.234	1.81

Table 2C: Diameter of Riprap modified based on durability, and Overall Riprap Thickness

Slope of channel S	D_{50} based on Stephenson Method	Oversizing Factor based on Rock Quality (from previous report)	Modified D_{50} after oversizing	Thickness of Riprap layer = 2 x D_{50}	Overall Riprap Thickness suggested	Type of Riprap
ft./ft.	inches		inches	inches	inches	
0.200	3.235	1.25	4.04	8.09	12	gravel/pebbles
0.200	4.234	1.25	5.29	10.58	12	crushed granite

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TABLE 3

WHITE MESA CHANNEL A ROCK APRON
RIPRAP SIZING – STEPHENSON'S METHOD

	ENTER		WITH 24% OVERSIZE
UNIT FLOW RATE "q"	4.27	CFS/FT	
ROCKFILL POROSITY – n	0.3		
SLOPE ANGLE	11.3	DEGREES	
FRICTION ANGLE	40	DEGREES	
SPECIFIC GRAVITY OF ROCK	2.48		
D–100 (BASED ON 1.25xD50)	12.00	INCHES	14.88"
D–50	9.60	INCHES	12.6"

WHITE MESA CHANNEL B ROCK APRON
RIPRAP SIZING – STEPHENSON'S METHOD

	ENTER		
UNIT FLOW RATE "q"	3.26	CFS/FT	
ROCKFILL POROSITY – n	0.3		
SLOPE ANGLE	11.3	DEGREES	
FRICTION ANGLE	40	DEGREES	
SPECIFIC GRAVITY OF ROCK	2.48		
D–100 (BASED ON 1.5xD50)	12.03	INCHES	14.9"
D–50	8.02	INCHES	9.94"

TABLE 4

NRC SCORING CRITERIA FOR DETERMINING ROCK QUALITY
WHITE MESA ROCK PROTECTION

ROCK TYPE: 2

Limestone = 1
Sandstone = 2
Igneous = 3

LABORATORY TEST	TEST RESULT	SCORE	WEIGHT	SCORE * WEIGHT	MAX. SCORE
Specific Gravity	2.48	4.60	6	27.60	60.00
Absorption, %	1.75	3.50	5	17.50	50.00
Sodium Sulfate, %	0.60	10.00	3	30.00	30.00
L/A Abrasion (100 revs), %	8.40	5.94	8	47.53	80.00
Schmidt Hammer	0.00	0.00	13	0.00	0.00
Tensile Strength, psi	0.00	0.00	4	0.00	0.00

ROCK RATING, %: 55.74

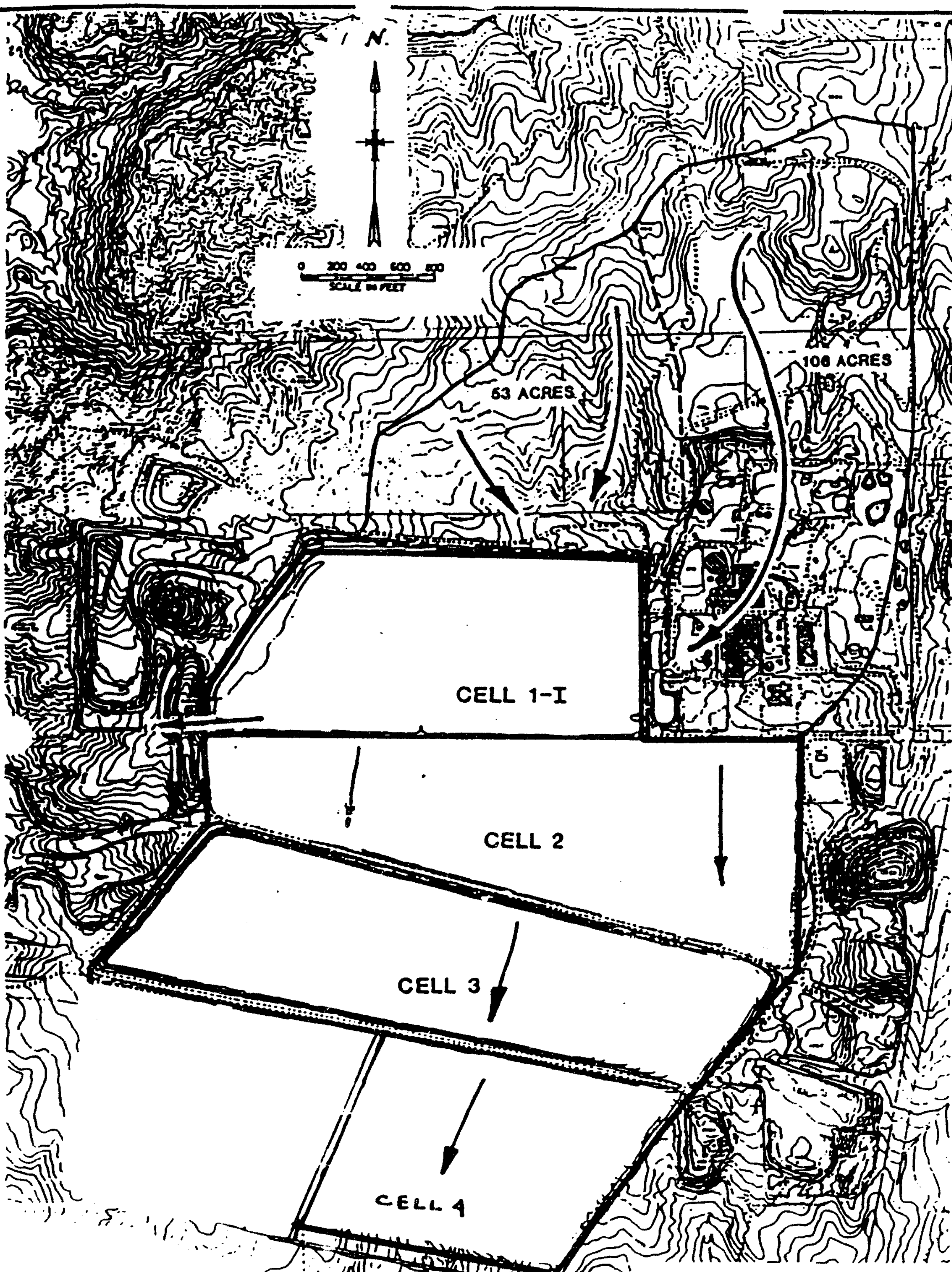
RATING ANALYSIS:

Critical Areas – REJECTED
Oversizing, % =

Non-Critical Areas – OVERSIZING REQUIRED
Oversizing, % = 24

FIGURE

PHA 7/96



WHITE MESA PROJECT

SITE DRAINAGE

FIGURE: 1

APPENDIX

FINAL

STAFF TECHNICAL POSITION

DESIGN OF EROSION PROTECTION COVERS FOR

STABILIZATION OF URANIUM MILL TAILINGS SITES

U. S. Nuclear Regulatory Commission

August 1990

FINAL
STAFF TECHNICAL POSITION
DESIGN OF EROSION PROTECTION COVERS FOR
STABILIZATION OF URANIUM MILL TAILINGS SITES

1. INTRODUCTION

Criteria and standards for environmental protection may be found in the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (PL 95-604) (see Ref. 1) and 10 CFR Section 20.106, "Radioactivity in Effluents to Unrestricted Areas." In 1983, the U. S. Environmental Protection Agency (EPA) established standards (40 CFR Part 192) for the final stabilization of uranium mill tailings for inactive (Title I) and active (Title II) sites. In 1980, the United States Nuclear Regulatory Commission (NRC) promulgated regulations (10 CFR Part 40, Appendix A) for active sites and later revised Appendix A to conform to the standards in 40 CFR Part 192. These standards and regulations establish the criteria to be met in providing long-term stabilization.

These regulations also prescribe criteria for control of tailings. For the purpose of this staff technical position (STP), control of tailings is defined as providing an adequate cover to protect against exposure or erosion of the tailings. To help licensees and applicants meet Federal guidelines, this STP describes design practices the NRC staff has found acceptable for providing such protection for 200 to 1000 years and focuses principally on the design of tailings covers to provide that protection.

Presently, very little information exists on designing covers to remain effective for 1000 years. Numerous examples can be cited where covers for protection of tailings embankments and other applications have experienced significant erosion over relatively short periods (less than 50 years). Experience with reclamation of coal-mining projects, for example, indicates that it is usually necessary to provide relatively flat slopes to maintain overall site stability (Wells and Jercinovic, 1983, see Ref. 2).

Because of the basic lack of design experience and technical information in this area, this position attempts to adapt standard hydraulic design methods and empirical data to the design of erosion protection covers. The design methods discussed here are based either on: (1) the use of documented hydraulic procedures that are generally applicable in any area of hydraulic design; or (2) the use of procedures developed by technical assistance contractors specifically for long-term stability applications.

It should be emphasized that a standard industry practice for stabilizing tailings for 1000 years does not currently exist. However, standard practice does exist for providing stable channel sections. This practice is widely used to design drainage channels that do not erode when subjected to design flood flows. Since an embankment slope can be treated as a wide channel, the staff concludes that the hydraulic design principles and practice associated with

2.1.2 Long-Term Stability

As required by 40 CFR 192.02 and 10 CFR Part 40, Appendix A, Criterion 6, stabilization designs must provide reasonable assurance of control of radiological hazards for a 1000-year period, to the extent practicable, but in any case, for a minimum 200-year period. The NRC staff has concluded that the risks from tailings could be accommodated by a design standard that requires that there be reasonable assurance that the tailings remain stable for a period of 1000 (or at least 200) years, preferably with reliance placed on passive controls (such as earth and rock covers), rather than routine maintenance.

2.1.3 Design for Minimal Maintenance

Criteria for tailings stabilization, with minimal reliance placed on active maintenance, are established in 40 CFR Part 192 and 10 CFR Part 40, Appendix A, Criteria 1 and 12. Criterion 1 of 10 CFR Part 40, Appendix A specifically states that: "Tailings should be disposed of in a manner [such] that no active maintenance is required to preserve conditions of the site." Criterion 12 states that: "The final disposition of tailings or wastes at milling sites should be such that ongoing active maintenance is not necessary to preserve isolation."

It is evident that remedial action designs are intended to last for a long time, without the need for active maintenance. Therefore, in accordance with regulatory requirements, the NRC staff has concluded that the goal of any design for long-term stabilization to meet applicable design criteria should be to provide overall site stability for very long time periods, with no reliance placed on active maintenance.

For the purposes of this STP, active maintenance is defined as any maintenance that is needed to assure that the design will meet specified longevity requirements. Such maintenance includes even minor maintenance, such as the addition of soil to small rills and gullies. The question that must be answered is whether longevity is dependent on the maintenance. If it is necessary to repair gullies, for example, to prevent their growth and ultimate erosion into tailings, then that maintenance is considered to be active maintenance.

2.1.4 Radon Release Limits

Titles 40 CFR 192.02 and 10 CFR Part 40, Appendix A require that earthen covers be placed over tailings at the end of milling operations to limit releases of radon-222 to not more than an average of 20 picocuries per square meter per second (pCi/m^2s), when averaged over the entire surface of the disposal site and over at least a one-year period, for the control period of 200 to 1000 years. Before placement of the cover, radon release rates are calculated in designing the protective covers and barriers for uranium mill tailings. Additionally, recent regulations promulgated under the Clean Air Act

design follows the procedure for a soil cover, because the layer is predominantly soil, rather than rock.

2.2 Design Procedures

A step-by-step procedure for designing riprap for the top and side slopes of a reclaimed pile is presented below:

Step 1. Determine the drainage areas for both the top slope and the side slope. These drainage areas are normally computed on a unit-width basis.

Step 2. Determine time of concentration (tc).

The tc is usually a difficult parameter to estimate in the design of a rock layer. Based on a review of the various methods for calculating tc, the NRC staff concludes that a method such as the Kirpich method, as discussed by Nelson, et al. (1986, see Ref. 02), should be used. The tc may be calculated using the formula:

$$tc = (11.9L^3/H)^{.385}$$, where L = drainage length (in miles)

H = elevation difference (in feet)

Step 3. Determine Probable Maximum Flood (PMF) and Probable Maximum Precipitation (PMP).

Techniques for PMP determinations have been developed for the entire United States, primarily by the National Oceanographic and Atmospheric Administration, in the form of hydrometeorological reports for specific regions. These techniques are commonly accepted and provide straightforward procedures for assessing rainfall potential, with minimal variability. Acceptable methods for

determining the total magnitude of the PMP and various PMP intensities for specific times of concentration are given by Nelson, et al. (1986, see Ref. D2, Section 2.1).

Step 4. Calculate peak flow rate.

The Rational Formula, as discussed by Nelson et al. (1986, see Ref. D2), may be used to calculate peak flow rates for these small drainage areas. Other methods that are more precise are also acceptable; the Rational Formula was chosen for its simplicity and ease of computation.

Step 5. Determine rock size.

Using the peak flow rate calculated in Step 4, the required D_{50} may be determined. Recent studies performed for the NRC staff (Abt, et al., 1988, see Ref. D3) have indicated that the Safety Factors Method is more applicable for designing rock for slopes less than 10 percent and that the Stephenson Method is more applicable for slopes greater than 10 percent. Other methods may also be used, if properly justified.

2.3 Recommendations

Since it is unlikely that clogging of the riprap voids will not occur over a long period of time, it is suggested that no credit be taken for flow through the riprap voids. Even if the voids become clogged, it is unlikely that stability will be affected, as indicated by tests performed for the NRC staff by Abt, et al. (1987, see Ref. D4).

If rounded rather than angular rock is used, some increase in the average rock size may be necessary, since the rock will not be as stable. Computational models, such as the Safety Factors Method, provide stability

coefficients for different angles of repose of the material. The need for oversizing of rounded rock is further discussed by Abt, et al. (1987, see Ref. D4).

2.4 Example of Procedure Application

Determine the riprap requirements for a tailings pile top slope with a length of 1000 feet and a slope of 0.02 and for the side slope with an additional length of 250 feet and a slope of 0.2 (20 percent).

Step 1. The drainage areas for the top slope (A1) and the side slope (A2) on a unit-width basis are computed as follows:

$$A1 = (1000)\ (1)\ /\ 43560 = 0.023 \text{ acres}$$

$$A2 = (1000 + 250)\ (1)\ /\ 43560 = 0.029 \text{ acres.}$$

Step 2. The tcs are individually computed for the top and side slopes, using the Kirpich Method, as discussed by Nelson, et al. (1986, see Ref. D2).

$$tc = [(11.9)(L)^3/H]^{.385}$$

For L = 1000 feet and H = 20 feet,

tc = 0.12 hours = 7.2 minutes for the top slope

For L = 250 feet and H = 50 feet,

tc = 1.0 minute for the side slope.

Therefore, the total tc for the side slope is equal to 7.2 + 1.0, or 8.2 minutes.

Step 3. The rainfall intensity is determined using procedures discussed by Nelson, et al. (1986, see Ref. D2), based on a 7.2-minute PMP of 4.2 inches for the top slope and an 8.2-minute PMP of approximately 4.5 inches for the side slope. These incremental PMPs are based on a one-hour PMP of 8.0 inches for northwestern New Mexico and were derived using procedures discussed by Nelson, et al. (1986, see Ref. D2).

Rainfall intensities, for use in the Rational Formula, are computed as follows:

$i_1 = (60)(4.2)/7.2 = 35$ inches/hr for the top slope

$i_2 = (60)(4.5)/8.2 = 33$ inches/hr for the side slope.

Step 4. Assuming a runoff coefficient (C) of 0.8, the peak flow rates are calculated using the Rational Formula, as follows:

$Q1 = (0.8)\ (35)\ (0.023) = 0.64$ cfs/ft, for the top slope, and

$Q2 = (0.8)\ (33)\ (0.029) = 0.77$ cfs/ft, for the side slope.

Step 5. Using the Safety Factors Method, the required rock size for the pile top slope is calculated to be:

$D_{50} = 0.6$ inches.

Using the Stephenson Method, the required rock size for the side slopes is calculated to be:

D_{50} = 3.1 inches.

2.5 Limitations

The use of the aforementioned procedures is widely applicable. The Stephenson Method is an empirical approach and is not applicable to gentle slopes. The Safety Factors Method is conservative for steep slopes. Other methods may also be used, if properly justified.

3. RIPRAP DESIGN FOR DIVERSION CHANNELS

3.1 Technical Basis

The Safety Factors Method or other shear stress methods are generally accepted as reliable methods for determining riprap requirements for channels. These methods are based on a comparison of the stresses exerted by the flood flows with the allowable stress permitted by the rock. Documented methods are readily available for determining flow depths and Manning "n" values.

3.2 Design Procedures

3.2.1 Normal Channel Designs

In designing the riprap for a diversion channel where there are no particularly difficult erosion considerations, the design of the erosion protection is relatively straightforward.

1. The Safety Factors Method or other shear stress methods may be used to determine the riprap requirements.

2. The peak shear stress should be used for design purposes and can be determined ty substituting the value of the depth of flow (y) in the shear

6. OVERSIZING OF MARGINAL-QUALITY EROSION ROTECTION

6.1 Technical Basis

The ability of some rock to survive without significant degradation for long time periods is well-documented by archaeological and historic evidence (Lindsey, et al., 1982, see Ref. D13). However, very little information is available to quantitatively assess the quality of rock needed to survive for long periods, based on its physical properties.

In assessing the long-term durability of erosion protection materials, the NRC staff has relied principally on the results of durability tests at several sites and on information, analyses, and methodology presented in NUREG/CR-4620 (Nelson, et al., see Ref. D2). This document provides a quantitative method for determining the oversizing requirements for a particular rock type to be placed at specific locations on or near a remediated uranium mill tailings pile.

Staff review of actual field data from several tailings sites has indicated that the methodology may not be sufficiently flexible to allow the use of "borderline" quality rock, where a particular type of rock fails to meet minimum qualifications for placement in a specific zone, but fails to qualify by only a small amount. This may be very important, since the selection of a particular rock type and rock size depends on its quality and where it will be placed on the embankment.

Based on NRC staff review of the actual field data, the methodology previously derived has been modified to incorporate additional flexibility. These revisions include modifications to the quality ratings required for use in a particular placement zone, re-classification of the placement zones, reassessment of weighting factors based on the rock type, and more detailed procedures for computing rock quality and the amount of oversizing required.

Based on an examination of the actual field performance of various types and quality of rock (Esmiol, 1967, see Ref. D14), the NRC staff considers it important to determine rock properties with a petrographic examination. The case history data indicated that the singlemost important factor in rock deterioration was the presence of smectites and expanding lattice clay minerals. Therefore, if a petrographic examination indicates the presence of such minerals, the rock will not be suitable for long-term applications.

6.2 Design Procedures

Design procedures and criteria have been developed by the NRC staff for use in selecting and evaluating rock for use as riprap to survive long time periods. The methods are considered to be flexible enough to accommodate a wide range of rock types and a wide range of rock quality for use in various long-term stability applications.

The first step in the design process is to determine the quality of the rock, based on its physical properties. The second step is to determine the amount of oversizing needed, if the rock is not of good quality. Various combinations of good-quality rock and oversized marginal-quality rock may also be considered in the design, if necessary.

6.2.1 Procedures for Assessing Rock Quality

The suitability of rock to be used as a protective cover should be assessed by laboratory tests to determine the physical characteristics of the rocks. Several durability tests should be performed to classify the rock as being of poor, fair (intermediate), or good quality. For each rock source under consideration, the quality ratings should be based on the results of about three to four different durability test methods for initial screening and about six test methods for final sizing of the rock(s) selected for inclusion in the design. Procedures for determining the rock quality and determining a rock quality "score" are developed in Table D1.

6.2.2 Oversizing Criteria

Oversizing criteria vary, depending on the location where the rock will be placed. Areas that are frequently saturated are generally more vulnerable to weathering than occasionally-saturated areas where freeze/thaw and wet/dry cycles occur less frequently. The amount of oversizing to be applied will also depend on where the rock will be placed and its importance to the overall performance of the reclamation design. For the purposes of rock oversizing, the following criteria have been developed:

A. Critical Areas. These areas include, as a minimum, frequently-saturated areas, all channels, poorly-drained toes and aprons, control structures, and energy dissipation areas.

Rating

80-100 - No Oversizing Needed

65-80 - Oversize using factor of (80-Rating), expressed as the percent increase in rock diameter. For example, a rock with a rating of 70 will require oversizing of 10 percent. (See example of procedure application, given in Section 6.4, p. D-28)

Less than 65 - Reject

B. Non-Critical Areas. These areas include occasionally-saturated areas, top slopes, side slopes, and well-drained toes and aprons.

Rating

80-100 - No Oversizing Needed

50-80 - Oversize using factor of (80-Rating), expressed as the percent increase in rock diameter

Less than 50 - Reject

TABLE D1

Scoring Criteria for Determining Rock Quality

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9 Good	8	7	6 Fair	5	4	3 Poor	2	1	0
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3..
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	?	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642 - "Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review," 1982 (see Ref. D13).

2. Weighting Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G. W. DuPuy, Engineering Geology, July, 1965 (see Ref. D15). Weighting factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighting factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.

3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR-2642 (see Ref. D13), so that proper correlations can be made. This is particularly important for the tensile strength test, where several methods may be used; the method discussed by Nilsson (1962, see Ref. D16) for tensile strength was used in the scoring procedure.

6.3 Recommendations

Based on the performance histories of various rock types and the overall intent of achieving long-term stability, the following recommendations should be considered in assessing rock quality and determining riprap requirements for a particular design.

1. The rock that is to be used should first be qualitatively rated at least "fair" in a petrographic examination conducted by a geologist or engineer experienced in petrographic analysis. See NUREG/CR-4620, Table 6.4 (see Ref. D2), for general guidance on qualitative petrographic ratings. In addition, if a rock contains smectites or expanding lattice clay minerals, it will not be acceptable.

2. An occasionally-saturated area is defined as an area with underlying filter blankets and slopes that provide good drainage and are steep enough to preclude ponding, considering differential settlement, and are located well above normal groundwater levels; otherwise, the area is classified as frequently-saturated. Natural channels and relatively flat man-made diversion channels should be classified as frequently-saturated. Generally, any toe or apron located below grade should be classified as frequently-saturated; such toes and aprons are considered to be poorly-drained in most cases.

3. Using the scoring criteria given in Table D1, the results of a durability test determines the score; this score is then multiplied by the weighting factor for the particular rock type. The final rating should be calculated as the percentage of the maximum possible score for all durability tests that were performed. See example of procedure application for additional guidance on determining final rating.

4. For final selection and oversizing, the rating may be based on the durability tests indicated in the scoring criteria. Other tests may also

be substituted or added, as appropriate, depending on rock type and site-specific factors. The durability tests given in Table D1 are not intended to be all-inclusive. They represent some of the more commonly-used tests or tests where data may be published or readily-available. Designers may wish to use other tests than those presented; such an approach is acceptable. Scoring criteria may be developed for other tests, using procedures and references recommended in Table D1. Further, if a rock type barely fails to meet minimum criteria for placement in a particular area, with proper justification and documentation, it may be feasible to throw out the results of a test that may not be particularly applicable and substitute one or more tests with higher weighting factors, depending on the rock type or site location. In such cases, consideration should be given to performing several additional tests. The additional tests should be those that are among the most applicable tests for a specific rock type, as indicated by the highest weighting factors given in the scoring criteria for that rock type.

5. The percentage increase of oversizing should be applied to the diameter of the rock.

6. The oversizing calculations represent minimum increases. Rock sizes as large as practicable should be provided. (It is assumed, for example, that a 12-inch layer of 4-inch rock costs the same as a 12-inch layer of 6-inch rock.) The thickness of the rock layer should be based on the constructability of the layer, but should be at least 1.5 x D_{50}. Thicknesses of less than 6 inches may be difficult to construct, unless the rock size is relatively small.

6.4 Example of Procedure Application

It is proposed that a sandstone rock source will be used. The rock has been rated "fair" in a petrographic examination. Representative test results are given. Compute the amount of oversizing necessary.

Using the scoring criteria in Table D1, the following ratings are computed:

Lab Test	Result	Score	Weight	Score x Weight	Max. Score
Sp. Gr.	2.61	7	6	42	60
Absorp., %	1.22	4	5	20	50
Sod. Sulf., %	6.90	6	3	18	30
L.A. Abr., %	8.70	5	8	40	80
Sch. Ham.	51	6	13	78	130
Tens. Str., psi	670	6	4	24	40
Totals				222	390

The final rating is computed to be 222/390 or 57 percent. As discussed in Section 6.2, the rock is not suitable for use in frequently-saturated areas, but is suitable for use in occasionally-saturated areas, if oversized. The oversizing needed is equal to (80 - 57), or a 23 percent increase in rock diameter.

6.5 Limitations

The procedure previously presented is intended to provide an approximate quantitative method of assessing rock quality and rock durability. Although the procedure should provide rock of reasonable quality, additional data and studies are needed to establish performance histories of rock types that have a score of a specific magnitude. It should be emphasized that the procedure is only a more quantitative estimate of rock quality, based on USBR classification standards.

It should also be recognized that durability tests are not generally intended to determine if rock will actually deteriorate enough to adversely affect the stability of a reclaimed tailings pile for a design life of 200 to 1000 years. These tests are primarily intended to determine acceptability of rock for various construction purposes for design lifetimes much shorter than 1000 years. Therefore, although higher scores give a higher degree of confidence that significant deterioration will not occur, there is not complete assurance that deterioration will not occur. Further, typical construction projects rely on planned maintenance to correct deficiencies. It follows, then, that there is also less assurance that the oversizing methodology will actually result in rock that will only deteriorate a given amount in a specified time period. The amount of oversizing resulting from these calculations is based on the engineering judgment of the NRC staff, with the assistance of contractors. However, in keeping with the Management Position (USNRC, 1989, see Ref. D17), the staff considers that this methodology will provide reasonable assurance of the effectiveness of the rock over the design lifetime of the project.

7. REFERENCES

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Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments

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The rainfall depth for a specific site is estimated by determining the rainfall duration and/or appropriate time of concentration. The resulting rainfall depth in inches, is

$$\text{PMP rainfall depth} = (\%\ \text{PMP}) \times (\text{PMP}) \tag{2.1}$$

where the percent PMP is obtained from Table 2.1 and the PMP is obtained from the appropriate PMP design storm presented in Section 2.1.1.

The rainfall intensity, i, in inches per hour can be computed as

$$i = \text{rainfall depth (inches)} \times \frac{60}{\text{rainfall duration (minutes)}} \tag{2.2}$$

The rainfall intensity determined from Equation 2.2 is generally a conservative value and represents the peak rainfall intensity of the design storm.

To compute the rainfall intensity for any rainfall duration, it is recommended that a rainfall intensity versus rainfall duration curve be plotted on semilogarithmic paper. Because of the extremely conservative rainfall intensity values obtained for short durations, it is recommended that the minimum rainfall duration be 2.5 minutes. Rainfall depths should be extracted from the appropriate Hydrometeorological Report.

2.2 PMP COMPARISON STORMS

A comparison of estimates of the PMP with greatest observed rainfall and estimates of the 100-year events for areas both east and west of the 105° meridian was prepared (NWS, 1980). Information from 6500 precipitation reporting stations in the eastern U.S. and about 2100 stations in the west was used. Including storm durations of 6 to 72 hours, the study indicated that 177 separate storm events have been recorded in which the rainfall was greater than or equal to 50 percent of the PMP for stations east of the 105° meridian. Only 66 separate storm events were recorded west of the 105° meridian where rainfalls were greater than or equal to 50 percent of the PMP.

The National Weather Service also reported the number of storm events which met or exceeded the 100-year rainfall values and compared them with the regional PMP values (NWS, 1980). Table 2.2 summarizes these rainfall events for 6 and 24-hour storms occurring over a 10 square mile area. It is interesting to note that a storm has not been officially recorded west of the Continental Divide that exceeds 90% of the PMP value. However, it is evident that a number of storms approach the PMP values, thereby substantiating that the prescribed PMP values are not extremely conservative.

4.1.5.6 Gully Width

The width of the gully across the top of the gully at the point of maximum depth can be estimated from Figure 4.5. Having computed the maximum depth, D_{max}, and knowing the uniformity coefficient, C_u, the top width is estimated to be approximately 5.6 feet. However, the gully width will widen over time to where the gully side wall stands at an angle less than the angle of repose of the cover material.

4.2 EMBANKMENT AND SLOPE STABILIZATION USING RIPRAP

Rock riprap is one of the most econo[illegible] [illegible]aterials that is commonly used to provide for cover and slope protec[illegible] Factors to consider when designing rock riprap are: (1) rock durability, density, size, shape, angularity, and angle of repose; (2) water velocity, depth, shear stress, and flow direction near the riprap; and (3) the slope of the embankment or cover to be protected. Through the proper sizing and placement of riprap on any impoundment cover, rill and gully erosion can be minimized to ensure long term stabilization.

The primary failure mechanism of concern is the removal of material from the impoundment due to shear forces developed by water flowing parallel and/or adjacent to the cover as described by Nelson et al. (1983). One purpose of the cover is to expedite the removal of precipitation and tributary waters away from the cover to minimize seepage and percolation. However, when surface waters are not properly managed, extreme erosion may result and endanger the impoundment stability. For example, slopes are often designed and constructed to develop sheet flow conditions. After many years of exposure, sheet and rill erosion, and localized settlement, the hydraulic conditions have significantly altered causing flows to merge or concentrate into drainage channels. The greater the concentration of flow into the drainage channels, the greater the erosion potential.

4.2.1 Zone Protection

The design requirements for placing riprap rock on a cover vary depending upon cover location. It is suggested that four areas exist on the cover in which different failure mechanisms can result from tributary drainage. The four areas or zones of concern are presented in Figure 4.6 and include:

1. Zone I: This zone is considered the toe-of-the-slope of the reclaimed impoundment. The riprap protecting the slope toe must be sized to stabilize the slope due to flooding in the major watersheds and dissipate energy as the flow transitions from the impoundment slope into the natural terrain. Zone I is considered a zone of frequent saturation.

2. Zone II: This is the area along the side slope which remains in the major watershed flood plain (PMF). The rock protection must resist not only the flow off the cover, but also floods. The

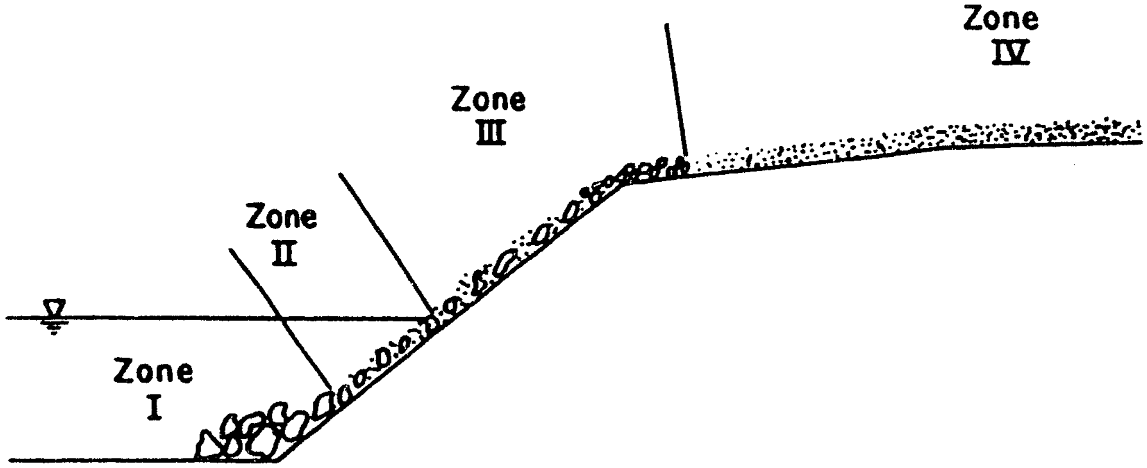

Fig. 4.6. Zones of a reclaimed impoundment requiring riprap protection.

riprap must serve as embankment protection similar to river and canal banks. Zone II is considered a zone of occasional saturation.

3. Zone III: Riprap should be designed to protect steep slopes and embankments from potential high overtopping velocities and excessive erosion. Flows in Zone III are derived from tributary drainage and direct runoff from the reclaimed site. Zone III is considered a seldom saturated zone.

4. Zone IV: Rock protection for Zone IV is generally designed for flows from mild slopes. Zone IV will usually be characterized by sheet flow with low flow velocities. Zone IV is considered a zone of seldom saturation.

Since the rock protection requirements are significantly different on various locations on the cover, it should be apparent that each riprap design procedure available was formulated to address a specific application. Since a single riprap design procedure does not necessarily meet all of the cover protection requirements, recommendations will be made indicating which zone(s) each riprap design procedure best addresses.

Because the frequency of wetting or saturation varies by zone, the durability requirements of the riprap may vary by zone. The concept of durability and oversizing will be addressed in Chapter 6 of this report.

4.2.2 Design Procedures

Presently, several methods are available to assist the designer in determining the appropriate rock size for protection of impoundment covers, embankments and unprotected slopes from the impact of drainage waters. Alternative riprap design methods summarized herein are

1. Safety Factors Method
2. The Stephenson Method
3. Corps of Engineers Method
4. The U.S. Bureau of Reclamation Method

These riprap design procedures are but examples of the many methods available.

4.2.2.1 Safety Factors Method

The Safety Factors Method (Richardson et al., 1975) for sizing rock riprap is quite versatile in that it allows the designer to evaluate rock stability from flow parallel to the cover and adjacent to the cover. The Safety Factors Method can be used by assuming a rock size and then calculating the safety factor (S.F.) or allowing the designer to determine a S.F. and then computing the corresponding rock size. If the S.F. is greater than unity, the riprap is considered safe from failure; if the S.F. is unity, the rock is at the condition of incipient motion; and if S.F. is less than unity, the riprap will fail.

where d_{50} is the mean rock size in feet. A graphical representation for determining n is presented in Figures 4.12 and 4.13. However, these values were developed for uniform flow condition over submerged riprap. When overtopping flows on steep slopes begin to cascade, n values will increase and may range from 0.07 to 0.09 or higher. (Abt and Ruff, 1985 and COE, 1970).

Table 4.2. Manning Coefficient, n.

Channel Material	Manning Coefficient, n
Fine sand, colloidal	0.020
Sandy loam, non-colloidal	0.020
Silt loam, non-colloidal	0.020
Alluvial silts, non-colloidal	0.020
Ordinary firm loam	0.020
Volcanic ash	0.020
Stiff clay, very colloidal	0.025
Alluvial silts, colloidal	0.025
Shales and hardpans	0.025
Fine gravel	0.020
Graded loam to cobbles, non-colloidal	0.030
Graded silts to cobbles, colloidal	0.030
Coarse gravel, non-colloidal	0.025
Cobbles and shingles	0.035

Source: Morris and Wiggert, 1972.

4.8 COVER EROSION RESISTANCE EVALUATION

The cover design should be evaluated to determine if the unprotected slopes(s) can withstand overland or sheet flow with a minimum of erosion. Based upon the site-specific cover and precipitation parameters, the design sheet flow velocity should be estimated. A comparison of the design flow velocity with the cover permissible flow velocity can be performed. Furthermore, the design velocity can be used to determine the sediment discharge using the Universal Soil Loss Equation (Chapter 5) and for sizing stone protection (Section 4.2).

The design velocity will usually be determined from the peak discharge generated from the Probable Maximum Flood (PMF). The PMF can be estimated by

(a) Using computer models, i.e., HEC-1 (COE, 1974), that are widely accepted by the engineering profession.

(b) Applying the Rational Method for tributary areas that are less than approximately one square mile in area.

The Rational formula is commonly expressed as

$$Q = CiA \tag{4.42}$$

where Q is the maximum or design discharge in cfs, C is a runoff coefficient dependent upon the characterization of the drainage basin, i is the rainfall intensity expressed in inches per hour and A is the tributary area expressed in acres. When a unit width approach is taken, the area A_w is the slope(s) length times the unit width. Therefore, Equation 4.42 would be presented as

$$q = CiA_w \tag{4.43}$$

for a unit width analysis.

4.8.1 Runoff Coefficient

The runoff coefficient, C, is related to the climatic conditions and type of terrain characteristic of the watershed including soil materials, permeability and storage potential. Values of the coefficient C are presented in Table 4.4 (Lindsley et al., 1958), Table 4.5 (Chow, 1964), and Table 4.6 (ASCE, 1970 and Seelye, 1960).

Table 4.4. Values of Coefficient C.

Type Area	Value of C
Flat cultivated land, open sandy soil	0.20
Rolli cultivated land, clay-loam soil	0.50
Hill land, forested, clay loam soil	0.50
Steep, impervious slope	0.95

Source: Lindsley, et al, 1958.

The selection of a coefficient value requires considerable judgment as it is a tangible aspect of using the rational formula. It is recommended

that a conservative value of C be applied for PMF estimation since infiltration and storage comprise a low percentage of the runoff. Furthermore, the C values presented were derived for storms of 5-100 year frequencies. Therefore, less frequent, higher intensity storms will require the use of a higher C value (Chow, 1964). It is recommended that a runoff coefficient of 1.0 be used for PMF applications in very small watersheds since the effects of localized storage and infiltration will be small.

Table 4.5. Values of C for Use in Rational Formula.

Soil Type	Watershed Cover		
	Cultivated	Pasture	Woodlands
With above-average infiltration rates; usually sandy or gravelly	0.20	0.15	0.10
With average infiltration rates; no clay pans; loams and similar soils	0.40	0.35	0.30
With below-average infiltration rates; heavy clay soils or soils with a clay pan near the surface; shallow soils above impervious rock	0.50	0.45	0.40

Source: Chow, 1964.

4.8.2 Rainfall Intensity

In order to determine the rainfall intensity, i, the time of concentration, t_c must be estimated. The time of concentration can be approximated by:

(a) Applying one of the many accepted empirical formulae such as

$$t_c = 0.00013 \frac{L^{0.77}}{S^{0.385}} \tag{4.44}$$

where L is the length of the basin in feet measured along the watercourse from the upper end of the watercourse to the drainage basin outlet and S is the average slope of the basin. Time of concentration is expressed in hours. This procedure is not applicable to rock covered slopes. This expression was

Table 4.6. Values of runoff coefficient C.

Character of Surface	Runoff Coefficients	
	Range	Recommended
Pavement--asphalt or concrete	0.70-0.95	0.90
Gravel, from clean and loose to clayey and compact	0.25-0.70	0.50
Roofs	0.70-0.95	0.90
Lawns (irrigated) sandy soil		
Flat, 2 percent	0.05-0.15	0.10
Average, 2 to 7 percent	0.15-0.20	0.17
Steep, 7 percent or more	0.20-0.30	0.25
Lawns (irrigated) heavy soil		
Flat, 2 percent	0.13-0.17	0.15
Average, 2 to 7 percent	0.18-0.22	0.20
Steep, 7 percent	0.25-0.35	0.30
Pasture and non-irrigated lawns		
Sand		
Bare	0.15-0.50	0.30
Light vegetation	0.10-0.40	0.25
Loam		
Bare	0.20-0.60	0.40
Light vegetation	0.10-0.45	0.30
Clay		
Bare	0.30-0.75	0.50
Light vegetation	0.20-0.60	0.40
Composite areas		
Urban		
Single-family, 4-6 units/acre	0.25-0.50	0.40
Multi-family, >6 units/acre	0.50-0.75	0.60
Rural (mostly non-irrigated lawn area)		
<1/2 acre - 1 acre	0.20-0.50	0.35
1 acre - 3 acres	0.15-0.50	0.30
Industrial		
Light	0.50-0.80	0.65
Heavy	0.60-0.90	0.75
Business		
Downtown	0.70-0.95	0.85
Neighborhood	0.50-0.70	0.60
Parks	0.10-0.40	0.20

Source: ASCE, 1970 and Seelye, 1960.

designed for and applicable to small drainage basins (Kirpich, 1940).

(b) Using the Soil Conservation Service (SCS) Triangular Hydrograph Theory (DOI, 1977), the time of concentration is

$$t_c = \left(\frac{11.9\ L^3}{H}\right)^{0.385} \qquad (4.45)$$

See USNRC (pg D-3) "Final Staff Technical Position Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites" (1990)

where L is the length (miles) of the longest watercourse from the point of interest to the tributary divide, H is the difference in elevation (feet) between the point of interest and the tributary divide. The time of concentration will be expressed in hours. The SCS procedure is most applicable to drainage basins of at least 10 square miles.

Once the rainfall duration or time of concentration is determined, the rainfall depth can be computed based on the PMP intensity values estimated in Section 2.1.2.

4.8.3 Tributary Area

The tributary area may be expressed in a unit width format for design of rock protection on an embankment. Therefore, the area is the length of the longest expected or measured water course multiplied by the unit width. This procedure is primarily applicable to Zones I, II, and III and is not applicable for drainage ditch design. It should be noted that a unit width approach to drainage and diversion ditch design is not effective. Ditch design requires an entire basin analysis in which a composite inflow hydrograph is determined and is routed along the channel. From the inflow hydrograph, water surface profiles (i.e., HEC-2) can be estimated to determine flow depth and velocities for riprap design (COE, 1982).

4.8.4 Sheet Flow Velocity

The design velocity for sheet flow on an embankment slope can be estimated by solving the Manning formula presented in Equation 4.39. It is assumed that the hydraulic radius, R, is approximately equal to the flow depth, y, and that the design discharge is equal to that estimated by the Rational Method. Therefore, the depth of flow is

$$y = \left[\frac{Qn}{1.486\ S^{1/2}}\right]^{3/5} \qquad (4.46)$$

where Q is the discharge, S is the slope, and n is the Manning coefficient.