9 April 2010 Project No. 073-81694.0022

Mr. Frank Filas, Environmental Manager
Energy Fuels Resources Corporation
44 Union Blvd., Suite 600
Lakewood, Colorado 80228

RE: BORROW SOURCE CHARACTERIZATION ADDENDUM, PIÑON RIDGE PROJECT, MONTROSE COUNTY, COLORADO

Dear Frank:

Golder Associates Inc. (Golder) has prepared this Borrow Source Characterization Addendum (Addendum) for Energy Fuels Resources Corporation (EFRC) for the Piñon Ridge Project located in Montrose County, Colorado. This addendum augments information included in EFRC's Radioactive Material License Application (EFRC, 2009) submitted to the Colorado Department of Public Health and Environment (CDPHE) on the 18th of November 2009. The application was found substantially complete by CDPHE (2009) in mid-December, and CDPHE has begun the technical adequacy review.

A conference call occured on the 4th of January between EFRC and CDPHE to gain preliminary knowledge on anticipated Request for Additional Information (RAI) items, based on the letter titled "*Completeness Determination, Radioactive Materials License Application and Environmental Report, Piñon Ridge Mill Project,*" issued on the 18th of December by CDPHE (2009). On the 26th of February, CDPHE issued their first formal RAI (CDPHE, 2010).

1.0 INTRODUCTION

This Addendum provides responses to a portion of the geotechnical consideration comments, specifically those that relate to borrow source characterization, from CDPHE's RAI (CDPHE, 2010), where CDPHE has reviewed documentation for completeness in accordance with Section 2.0 of NUREG 1620 (NRC 2003) (Geotechnical Stability). The following comments received from CDPHE (2010) are addressed in this report:

> *"For the proposed tailings pond cover, seven different layers are currently planned…The material for several of the layers…has been described as material consisting of "native soil." The capillary break/drainage layer was described as being material that will be imported from off-site. For the other layers…there is no discussion…as to the origin of the material.*
>
> *Besides the location of the material or borrow sources, the engineering properties of each layer must be described and analyzed to assure that there are sufficient quantities of material available for use. This would include site-specific sampling and laboratory testing of each material at appropriate frequencies. Since the Division is unaware of NRC sampling/testing frequency guidance, the use of EPA guidance for generic "waste containment" may be a logical alternative. In particular, Table 2.3 of EPA (1993) lists the recommended minimum testing frequencies for investigation of borrow sources. In an updated version of EPA (1993) guidance, Daniel and Koerner (2007) also recommend the same testing frequencies in their Table 3-3 as those recommended in EPA (1993). If there are technical justifications to vary the sampling and testing frequencies from recommended guidance, then this should be explained. If existing data satisfying these requirements exists, new data collection is not necessary."*

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To demonstrate completeness, the requested information will be reported according to the referenced Acceptance Criteria of NUREG-1620 contained within Section 2.1.3 (NRC, 2003), summarized as follows:

> *"Investigations (including laboratory and field testing) are conducted using appropriate standards published by the American Society for Testing and Materials or the International Society for Rock Mechanics and are sufficient to establish the…engineering parameters of borrow materials…at the site…*
>
> *Parameter values are presented to enable evaluation of…borrow materials…"*

2.0 KEY DOCUMENTS

This Addendum is prepared to provide additional information specifically related to the following reports included in EFRC's Radioactive Material License Application (EFRC, 2009) for the Piñon Ridge Project:

- "*Phase 2 Geotechnical Field and Laboratory Test Program, Piñon Ridge Project, Montrose County, Colorado*" (Golder, 2008a);
- "*Tailings Cell Design Report, Piñon Ridge Project, Montrose County, Colorado*" (Golder, 2008b);
- "*Technical Specifications, Piñon Ridge Project, Montrose County, Colorado*" (Golder, 2008c);
- "*Tailings Cell Closure Design Report, Energy Fuels Resources Corp., Piñon Ridge Project, Montrose County, Colorado*" (Kleinfelder, 2009a);
- "*Piñon Ridge Project – Specifications for Reclamation of Mill Facilities*" (Golder, 2009).

The following documents were used as primary sources of information in preparing this Addendum:

- "*Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites under Title II of the Uranium Mill Tailings Radiation Control Act of 1978*" (NUREG-1620) (NRC, 2003). Referred to in the following sections as NUREG-1620;
- "*Design of Erosion Protection for Long-term Stabilization*" (NUREG-1623) (NRC, 20002). Referred to in the following sections as NUREG-1623; and
- "*Waste Containment Facilities, Guidance for Construction Quality Assurance and Construction Quality Control of Liner and Cover Systems*" (Daniel and Koerner, 2007). Referred to in the following sections as the Waste Containment Guidance.

3.0 BORROW SOURCE CHARACTERIZATION

In principle, determining the suitability of materials for use in construction is required to be performed only once (Daniel and Koerner, 2007). Borrow source characterization programs may be performed either: (1) prior to construction to confirm the suitability and extent or availability of a particular material; or (2) during construction or placement of the materials. However, once construction commences, considerable time and money have generally been invested in a project, and therefore it is appropriate to do at least a certain level of borrow source characterization prior to commencement of the work. Daniel and Koerner (2007) "recommend inspection of the borrow soil prior to (or alternatively, during) excavation."

The Construction Quality Assurance (CQA) Plan for a project is developed to confirm the suitability of the various construction materials during placement, which also may serve to augment the pre-construction (or during construction) borrow source characterization testing frequencies. For the Piñon Ridge Project, the specified minimum testing frequencies for site construction (for operations) is provided as Table 1400.1 in Section 1400.1 (Earthworks Construction Quality Assurance [CQA] Plan) of the Technical Specifications (Golder, 2008c). The Reclamation Specifications (Golder, 2009) for the project provide minimum testing frequencies for closure construction, particularly for construction of the tailings cell closure cover (Kleinfelder, 2009a), as Table 15.1.

Table 1 presents the recommended minimum testing frequency for the investigation of a borrow source (duplicated from Table 3-3 in the Waste Containment Guidance), as referenced by CDPHE.

Table 1

Recommended Minimum Testing Frequencies for Investigation of Borrow Source Materials (From Daniel and Koerner, 2007)

Parameter	Frequency
Water Content	1 test per 2,000 m^3 or Each Change in Material Type
Atterberg Limits	1 test per 5,000 m^3 or Each Change in Material Type
Percentage Fines	1 test per 5,000 m^3 or Each Change in Material Type
Percent Gravel	1 test per 5,000 m^3 or Each Change in Material Type
Compaction Curve	1 test per 5,000 m^3 or Each Change in Material Type
Hydraulic Conductivity	1 test per 10,000 m^3 or Each Change in Material Type

As Table 1 indicates, the frequency of testing is a function of the heterogeneity of the materials, with one of each of the laboratory tests required on each material type.

4.0 ON-SITE CONSTRUCTION BORROW MATERIALS

A site-wide mass balance was performed for the project, included in Appendix K of the Tailings Cell Design Report (Golder, 2008b). The mass balance diagram presented in that report has been duplicated herein, provided as Attachment A. The mass balance diagram, prepared specifically to illustrate the use of on-site borrow materials, shows the material quantity requirements for each of the construction areas (e.g., tailings cells, evaporation ponds, etc.) and phases (e.g., Phase 1, Phase 2, etc.) for operations of the facility, as well as the tailings cell closure cover requirements for the facility. For closure of the facility, on-site materials will be used for construction of the Interim Cover and Radon Barrier layers (Kleinfelder, 2009a). As can be seen by the site mass balance, the majority of the construction materials for initial construction, phased expansion, and closure of the facility is derived from on-site sources. However, off-site borrow sources will be required for some of the layers of the tailings cell closure cover, discussed later in this report.

4.1 Characterization of On-Site Borrow Materials

Geotechnical field and laboratory test programs were performed to characterize the *in situ* conditions of the site, as well as to characterize future excavated materials for use as borrow. Kleinfelder performed an initial Phase 1 site characterization program, primarily to gain information on the site conditions (e.g., depth to bedrock, presence of groundwater, etc.) and install monitoring wells. Golder (2008a), working with Kleinfelder specifically for the mill area, completed an extensive Phase 2 site characterization program, comprised of test pits, geotechnical boreholes, *in situ* testing (Standard Penetration Tests [SPTs], packer tests), and laboratory testing of disturbed *in situ* and re-compacted samples (i.e. potential borrow materials), including:

- Sieve Analysis – ASTM C117/C136;
- Hydrometer/Sieve/Specific Gravity – ASTM D422;

- Atterberg Limits – ASTM D4318;
- Natural Moisture Content – ASTM D2216;
- Natural Density and Moisture Content – ASTM D2937/D2216;
- Standard Proctor Compaction Testing – ASTM D698;
- Swell / Consolidation Testing – ASTM D4546, modified;
- Constant Head Flexible-Wall Permeability Testing – ASTM D5084;
- Consolidated-Undrained (CU) Triaxial Compression – ASTM D4767;
- Interface Shear Testing (ASTM D5321); and
- Unsaturated Hydraulic Conductivity Testing (ASTM D6836).

Soil samples collected as part of the Phase 2 geotechnical field and laboratory test program (Golder, 2008a) were classified using the Unified Soil Classification System (USCS) (ASTM D2487).

4.2 Comparison of On-Site Borrow Characterization to CDPHE Recommended Frequencies

During the Phase 2 geotechnical field and laboratory test program (Golder, 2008a), seventy-five (75) samples of on-site alluvial materials were tested for Unified Soil Classification System (USCS) parameters of Atterberg limits and grain size distribution. The on-site soil sample USCS characterizations are summarized in Table 2. The majority of the site soils (62% for the Phase 1 program, and 52% for the Phase 2 program) classified as silty sand (SM).

Table 2
On-Site Soil USCS Classification of Samples Collected

USCS Classification	Phase 1 Program*		Phase 2 Program	
	Number of Materials Tested	Relative Percentage of Site Soils	Number of Materials Tested	Relative Percentage of Site Soils
Well-graded silty gravel (GW-GM)	0	0 %	1	1 %
Silty GRAVEL (GM)	1	3 %	0	0 %
Silty SAND (SM)	23	62 %	39	52 %
Clayey SAND (SC)	2	5 %	6	8 %
Clayey and silty SAND (SC-SM)	2	6 %	5	7 %
Well-graded silty SAND (SW-SM)	0	0 %	1	1 %
Poorly-graded silty SAND (SP-SM)	1	3 %	1	1 %
Low plasticity CLAY (CL)	3	8 %	11	15 %
Low plasticity CLAY and SILT (CL-ML)	2	5 %	6	8 %
Low plasticity SILT (ML)	3	8 %	5	7 %
Total Number of Tested Samples:	***37***	***100 %***	***75***	***100 %***

*Estimated based on tabulated laboratory test results for the Phase 1 program received from Kleinfelder.

As demonstrated by the Phase 1 and Phase 2 site characterization programs (summarized in Tables 3 and 4), the excavated site soils will dominantly classify as a SM soil when blended and placed as fill materials. For the purposes of pre-construction borrow source characterization, the testing frequencies performed during the geotechnical field and laboratory programs exceed the recommended minimum testing frequency for this material type presented in Table 1 (Daniel and Koerner, 1997). However, it is important to note that the majority of the borrow source characterization work will occur during construction of the project, in accordance with the CQA Plan included in the project specifications (Golder, 2008c; Golder, 2009). As discussed in Daniel and Koerner (1997), this approach is considered appropriate.

Table 3

On-Site Alluvium Testing Summary, Phase 1 Program

Parameter	Number of Tests Performed	Alluvium Types Tested (USCS Classification)
Water Content	66	SM, SC, CL, SC-SM, ML, CL-ML, SP-SM, GM
Atterberg Limits	54	SM, SC, CL, SC-SM, ML, CL-ML, SP-SM, GM
Percentage Fines	66	SM, SC, CL, SC-SM, ML, CL-ML, SP-SM, GM
Percent Gravel	66	SM, SC, CL, SC-SM, ML, CL-ML, SP-SM, GM
Compaction Curve	N/A	N/A
Hydraulic Conductivity	N/A	N/A

Table 4

On-Site Alluvium Testing Summary, Phase 2 Program

Parameter	Number of Tests Performed	Alluvium Types Tested (USCS Classification)
Water Content	57	SM, SC, CL, SC-SM, ML, CL-ML, SW-SM
Atterberg Limits	77	SM, SC, CL, SC-SM, ML, CL-ML, SW-SM, SP-SM, GW-GM
Percentage Fines	88	SM, SC, CL, SC-SM, ML, CL-ML, SW-SM, SP-SM, GW-GM
Percent Gravel	88	SM, SC, CL, SC-SM, ML, CL-ML, SW-SM, SP-SM, GW-GM
Compaction Curve	8	SM, SC-SM
Hydraulic Conductivity	16	SM, SC, ML

Tables 3 and 4 show that compaction testing and hydraulic conductivity testing were not performed for each and every USCS classification of material encountered. With regard to compaction, testing of the SM material is anticipated to be generally representative of the blended on-site materials which would be used for construction. Additional compaction testing will need to be performed during construction on the blended materials, in accordance with the CQA Plan (Golder, 2008c). This is also true for testing of potential borrow for hydraulic conductivity. However, for the Piñon Ridge Project, testing of potential construction borrow materials for hydraulic conductivity is not considered critical for operations or closure for the following reasons:

- Compacted low permeability soil layers are not included in the liner system design for the tailings cells, evaporation ponds, or ore pads for the project, as use of a manufactured geosynthetic clay liner (GCL) is proposed, which has been shown to meet or exceed the prescriptive regulatory requirements (Golder 2008b); and
- Tailings cell closure cover design does not incorporate compacted low permeability soils. The Radon Barrier, which often is designed with clayey soils to reduce the required thickness, has instead been designed to incorporate on-site silty sand (SM) soils (at an increased thickness), which also limits the potential for desiccation of the layer.

5.0 OFF-SITE CONSTRUCTION BORROW MATERIALS

Although the majority of site construction requires the use of on-site borrow materials, closure construction of the tailings cells will require the use of imported materials for some of the cover layers and erosion protection. This section discusses the availability of off-site materials for construction of the closure cover.

5.1 Tailings Cell Closure Cover Off-Site Material Requirements

The tailings cell closure cover has been designed as an evapotranspiration (ET), or water balance, cover. Refer to Kleinfelder (2009a, 2009b) for details of the closure cover design, and refer to Golder (2009) for specifications of the various closure cover materials. The closure cover is proposed to consist of the following layers (from top to bottom):

- Erosion barrier / vegetative cover, comprised of rock mulch (0.5 ft) overlying native soil (1.5 ft);
- Bio-intrusion layer (1 ft);
- Filter layer (0.5 ft);
- Capillary break / drainage layer (1 ft);
- Radon barrier (ranges from 4.6 to 7 ft); and
- Interim cover (2 ft).

The radon barrier, interim cover, and native soil components of the tailings cell closure cover will be derived from on-site sources, as discussed in Section 4.0. The other cover components require gravels and durable rock, which are available off-site, as discussed in the following sections.

5.2 Off-Site Borrow Quantity Development

Quantities of rock required for construction of the tailings cell closure cover were developed by EFRC personnel using the information provided in Kleinfelder (2009a, 2009b) and Golder (2009), and associated *AutoCAD* files. The types and quantities of rock are summarized by tailings cell, included in

Table B-1 (Attachment B). A breakdown of the calculations and areas requiring rock are also presented in Attachment B.

Although the quantities have been broken down by tailings cell, they are not representative of the quantities required to reclaim a single cell without constructing other cells. For example, if Tailings Cell A were to be reclaimed without the construction of Tailings Cell B, the material required to construct the north (i.e., downgradient) slope of the reclaimed cell would be more than what is indicated for Tailings Cell A in this estimate because Tailing Cell B is assumed to be in that location. Additionally, the materials included in this estimate for constructing the slope and rundown channels in between cells A and B would not be required if Cell B were not constructed.

5.3 Rock Durability

Rock used for construction at the project will be tested for durability in accordance with the project specifications. The reclamation specifications (Golder, 2009) specify that rock used for construction of the tailings cell closure cover and closure drainage controls consist of durable rock meeting the durability scoring criteria in Appendix D of NUREG-1623. Laboratory testing and a durability rating will be performed for each rock borrow prior to use in construction.

The durability of rock borrow materials available in relatively close proximity to the Piñon Ridge Project were assessed, and are considered representative of material that would be available during the time of site reclamation. The following sources of information were used:

- "*1997 Durita Site Reclamation and Construction Verification Report*," (Hecla, 1998a);
- "*1998 Durita Site Reclamation and Construction Verification Report*," (Hecla, 1998b);
- "*1999 Durita Site Reclamation and Construction Verification Report*," (Hecla, 1999); and
- "*Summary of Test Results for the Cotter Pit*," (Sundale Associates, 2002).

The rock used at the Durita Uranium Tailings Site came from the Reams Quarry in Naturita, Colorado (1.8/2.0" spec, 3.6" spec, and 8.2" spec) and Cotter's Papoose Pit in La Sal, Utah (12.0" spec). These are the same sources that EFRC proposes to use for reclamation of the Piñon Ridge Project. The Papoose Pit has supplied rock to several other uranium tailings reclamation sites, including the Monticello, Utah UMTRA site; the Rio Algom Lisbon Mine and Mill Site; and the VCA Mill Site.

A summary of the durability results are presented in Table C-1 in Attachment C. The summary tables for durability ratings from the referenced reports are also included in Attachment C. The ratings on these tables were verified by EFRC personnel, and, in the case of the 12.0 inch specification material, were found to be incorrect. The values included in the Durita Site Report summary table were the calculated rating for igneous rock; however, this rock consists fully of limestone. The values presented in Table C-1 have been corrected for this discrepancy.

U.S. Nuclear Regulatory Commission's (NRC) NUREG-1623, "*Design of Erosion Protection for Long-term Stabilization*," lists five tests (bulk specific gravity, absorption, sodium sulfate loss, LA abrasion and Schmidt hammer rebound hardness) available to determine a rock durability rating. The Durita Site material durability ratings performed for the as-built reports were based on three tests: bulk specific gravity, absorption, and sodium sulfate loss. The Sundale Associates (2002) analysis included all five tests, plus tensile strength. NUREG-1623 allows for the use of additional tests.

The Piñon Ridge Mill Tailings Cell Closure Design Report (Kleinfelder, 2009a) and NUREG-1623 indicate that durability ratings of 50 or more are suitable for non-critical areas, ratings of 65 or more are suitable for critical areas, and rock with ratings less than 80 require over-sizing. Based on the available information, all of the durability ratings were greater than 80 indicating that rock from these sources would be adequate for reclamation usage at the Piñon Ridge Mill without the need for over-sizing.

A petrographic analysis (Gianniny, 2002) for the Cotter Papoose Pit rock is included in Attachment D.

5.4 Availability

Because sand and gravel (including bedding material) is available at nearly any quarry, its availability was not specifically evaluated. Rather, the availability of rock with size specifications of 0.5-inch and larger was confirmed.

EFRC personnel visited the nearby Reams Quarry and spoke with the pit operator, John Reams. Mr. Reams did not have an estimation of the available reserves, but indicated that there was enough to satisfy the required 0.5-inch to 9.0-inch specification material required for reclamation of the tailings cells (Golder, 2009), a total of approximately 270,000 tons. Reams Quarry obtains their rock from river deposits.

Locally, river rock deposits are available in several areas along and near the San Miguel River and Naturita Creek. EFRC identified five additional active gravel mining operations in the area (refer to Figure 1). It is reasonable to assume that rock from these operations is similar to the rock at Reams Quarry because they consist of similar river deposits. Several of the sites were observed by EFRC personnel, and the material visually appears to be similar to the Reams Quarry rock. Another deposit was also identified as a potential source by EFRC personnel. This deposit (referred to the Richards Deposit) was observed to be similar to the Reams Quarry deposit. The active gravel quarries and the Richards Deposit are summarized in Table 5, along with the distance from the mill site and permitted acreages.

Table 5

Identified Rock Quarries Proximal to the Piñon Ridge Site

Permittee	Quarry Name	Distance from Mill Site (miles)	Permitted Acreage
Reams Construction	Reams Quarry (Tomcat)	16	9.1
Not Applicable (not permitted)	Richards Deposit	14	120*
Sutherland Brothers, Inc.	Weimer No. 2	16	9.9
West End Gravel Company	West End Gravel Pit #1	20	39.4
Redvale Sand and Gravel Co.	Cadgene Pit #2	23	160
Louisiana Land and Gravel Co.	Angie Pit	27	154
Sky Ute Sand and Gravel, LLC	Allen Pit	27	51.5

*Acreage of Richards Deposit estimated from aerial photo, not a permitted acreage.

6.0 CONCLUSIONS

Golder and EFRC personnel have developed this Borrow Source Characterization Addendum in response to CDPHE's RAI requesting additional information on on-site and off-site borrow characterization.

For operational phased construction and closure of the proposed mill, the majority of the construction borrow will be derived from on-site excavations. The geotechnical field and laboratory test program provides sufficient information for initial characterization of the material, in accordance with the guidance presented in Daniel and Koerner (1997). However, additional testing performed during placement of materials, in accordance with the CQA Plan (Golder, 2008c; Golder, 2009), will confirm suitability of materials for use as structural fill. As discussed in Daniel and Koerner (1997), this approach is considered appropriate for borrow source characterization.

Reclamation of the mill, in particular construction of the tailings cell closure covers, will require use of off-site gravel and rock materials. EFRC personnel have reviewed the availability and durability of nearby rock sources, and found that sufficient quantities of suitable material are anticipated to be available at the time of site reclamation. Laboratory testing and a durability rating will be performed for each rock borrow source prior to use in reclamation construction, in accordance with the project specifications (Golder, 2009).

7.0 CLOSING

Golder appreciates the opportunity to provide continued engineering services to EFRC for the Piñon Ridge Project. If you have any questions or comments regarding the contents of this letter, please contact the undersigned via phone at 303-980-0540, or via e-mail at kmorrison@golder.com.

Sincerely,

GOLDER ASSOCIATES INC.

Kimberly Finke Morrison, P.E., R.G.
Associate – Senior Project Manager

for James M. Johnson, P.E.
Principal

cc: Bob Monok, Zach Rogers

ATTACHMENTS

Figure 1	Local Gravel Quarries
Attachment A	Mass Balance Diagram
Attachment B	Tailings Cell Closure Construction Quantities
Attachment C	Rock Durability Results
Attachment D	Petrographic Analysis of Cotter Papoose Pit Rock

KFM/JMJ/kag

8.0 REFERENCES

Colorado Department of Public Health and Environment (CDPHE). 2009. "*Completeness Determination, Radioactive Materials License Application and Environmental Report, Piñon Ridge Mill Project*," 18 December 2009.

Colorado Department of Public Health and Environment (CDPHE), 2010, "*Request for Additional Information*," 26 February 2010.

Energy Fuels Resources Corporation (EFRC). 2009. "*Radioactive Material License Application,*" submitted to the Colorado Department of Public Health and Environment, 18 November 2009.

Gianniny, G. 2002. "*Petrographic Analysis: Limestone Suitability for Riprap Material.*" Prepared for Sundale Associates. 23 February 2002.

Golder Associates Inc. (Golder). 2008a. "*Phase 2 Geotechnical Field and Laboratory Test Program, Piñon Ridge Project, Montrose County, Colorado.*" September.

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Golder Associates Inc. (Golder). 2009. "*Specifications for Closure and Reclamation of Mill Facilities, Piñon Ridge Project, Montrose County, Colorado.*" October.

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Hecla Mining Company (Hecla). 1998b. "*1998 Durita Site Reclamation and Construction Verification Report.*" 21 September 1998.

Hecla Mining Company (Hecla). 1999. "*1999 Durita Site Reclamation and Construction Verification Report.*" 9 June 1999.

Kleinfelder. 2009a. "*Tailings Cell Closure Design Report, Energy Fuels Resources Corp., Piñon Ridge Project, Montrose County, Colorado.*" Revision 0. 13 February 2009.

Kleinfelder. 2009b. "*Tailings Cell Cover and Site Closure Grading Plans, Piñon Ridge Project, Montrose County, Colorado.*" 13 February 2009.

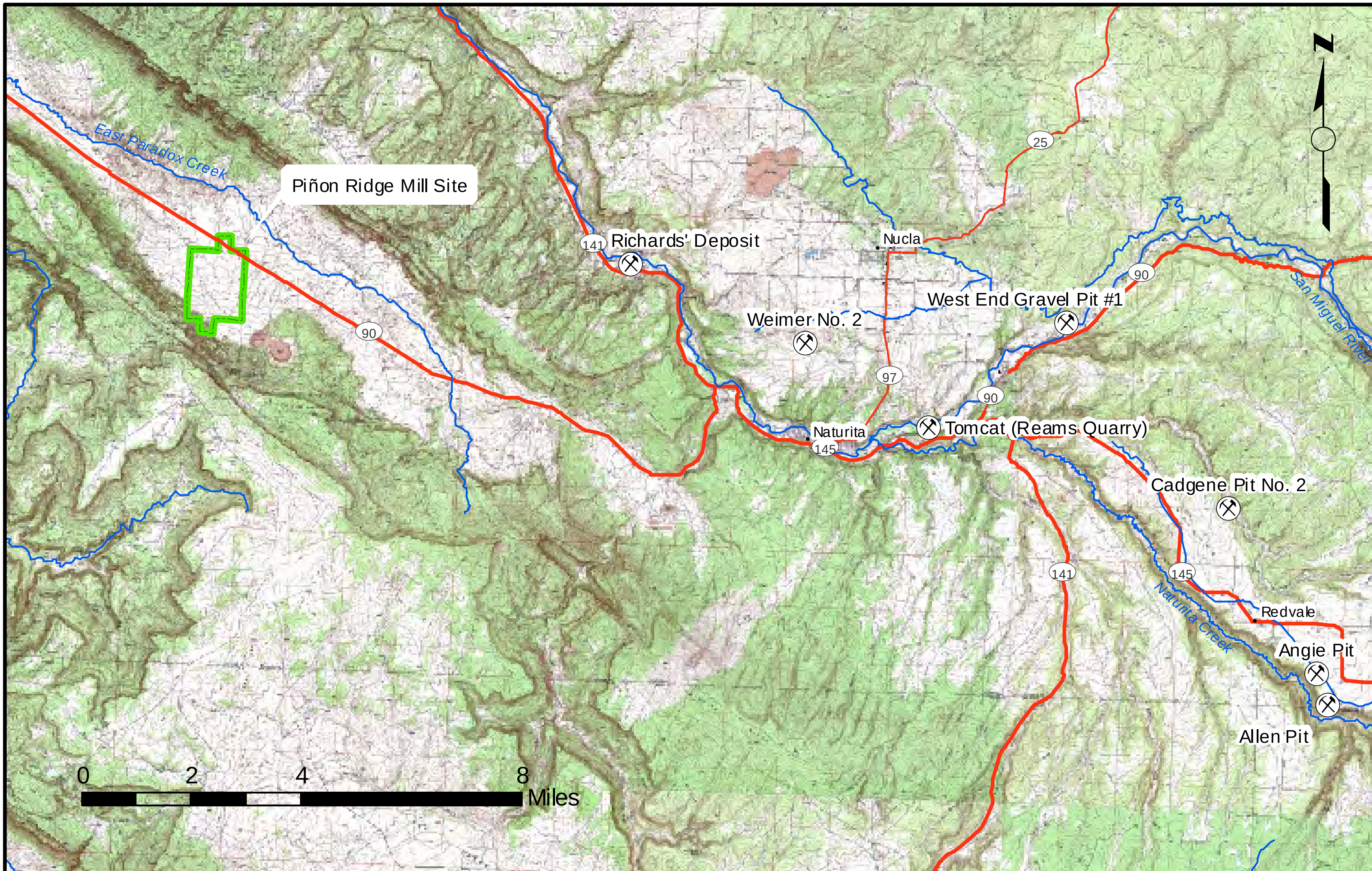
Sundale Associates. 2002. "*Summary of Test Results for the Cotter Pit.*" 28 February 2002.

U.S. Nuclear Regulatory Commission (NRC). 2002. NUREG-1623, "*Design of Erosion Protection for Long-term Stabilization.*"

U.S. Nuclear Regulatory Commission (NRC). 2003. NUREG-1620, "*Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites under Title II of the Uranium Mill Tailings Radiation Control Act of 1978,*" Revision 1.

FIGURE 1

LOCAL GRAVEL QUARRIES



Energy Fuels Resources Corporation

PROJECT	Pinon Ridge
DRAWN:	4/5/10
DRAWN BY:	Z Rogers
CHECKED BY:	
FILE NAME:	GravelPits_040510.mxd

Local Gravel Quarries

ENERGY FUELS RESOURCES
PIÑON RIDGE MILL SITE
MONTROSE COUNTY, COLORADO

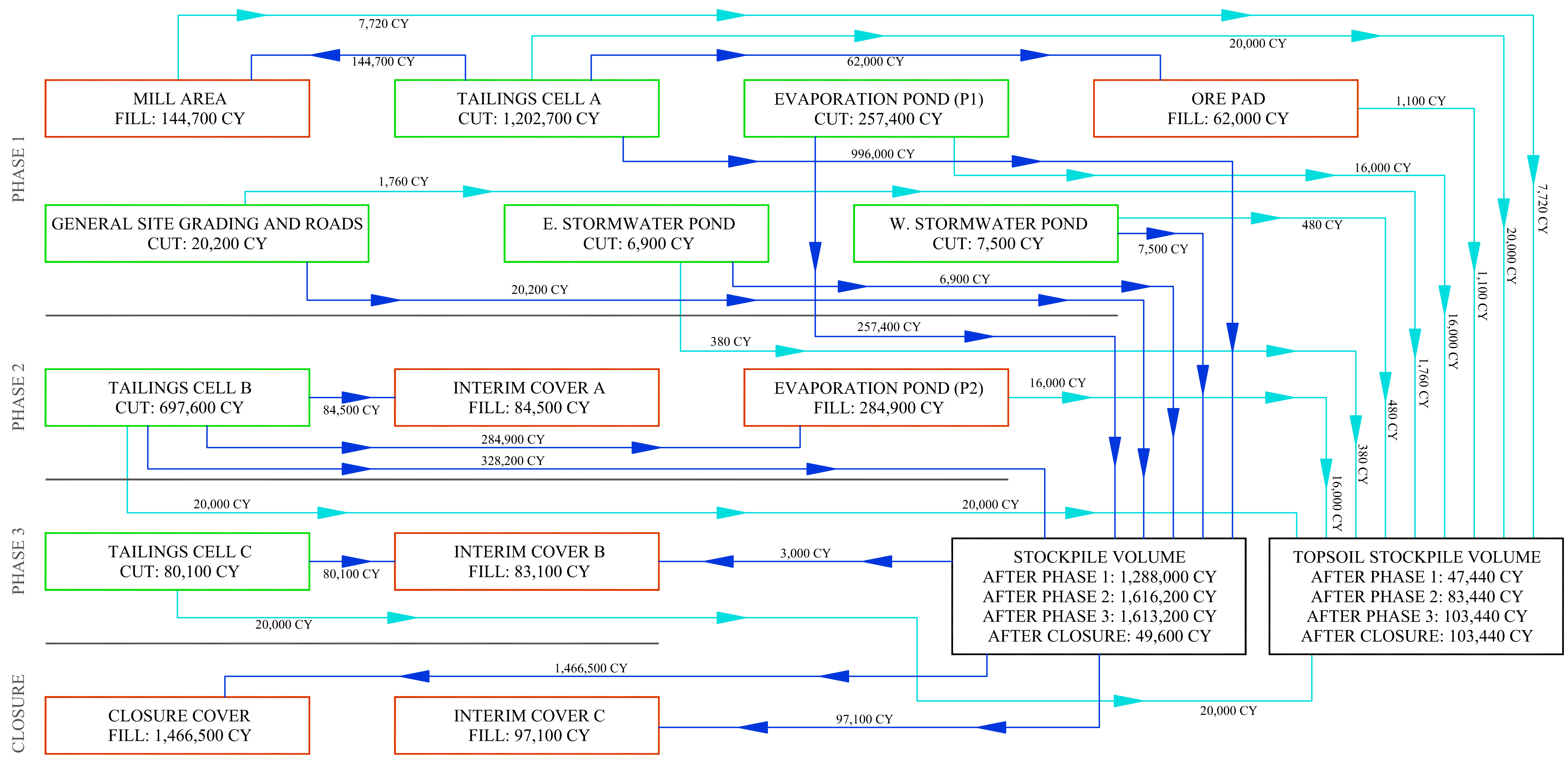
ORIGINATOR: Z Rogers

APPROVED BY:

FIGURE

1

ATTACHMENT A
MASS BALANCE DIAGRAM



LEGEND

- EXCESS CUT AVAILABLE
- FILL REQUIRED
- FLOW LINE (CUT TO FILL)
- FLOW LINE (TOPSOIL)
- PHASE DIVISION

NOTES

1. ALL QUANTITIES SHOWN HAVE BEEN ADJUSTED TO THE EQUIVALENT COMPACTED VOLUMES, ASSUMING NATIVE MATERIAL WITH A DENSITY OF 100 PCF AND COMPACTED MATERIAL WITH A DENSITY OF 112 PCF. INTERIM COVER FILL IS ASSUMED TO BE PLACED AT 100 PCF.
2. MASS BALANCE DEVELOPED ONLY FOR USE OF ON-SITE SOIL SOURCE MATERIALS. IMPORTED MATERIALS ARE EXCLUDED.
3. MATERIAL PROVIDED THROUGH REGRADING OF MILL AND ORE PAD AREAS AT CLOSURE HAS NOT BEEN ACCOUNTED FOR.
4. TOPSOIL MATERIAL FLOWS HAVE BEEN INCLUDED AND ASSUME IN-SITU (100 PCF) DENSITY. TOPSOIL MATERIAL VOLUMES ARE NOT INCLUDED IN THE CUT/FILL VOLUMES LISTED FOR EACH FACILITY.

REV	DATE	DES	REVISION DESCRIPTION	CADD	CHK	RVW
A	10/08	JDE	ISSUED FOR CLIENT REVIEW	JDE	KFM	JMJ

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT
MONTROSE COUNTY, COLORADO

TITLE

SITE-WIDE MASS BALANCE DIAGRAM

Golder Associates
DENVER, COLORADO

PROJECT No.	073-81694	FILE No.	FLOW DIAGRAM	
DESIGN	JDE	7/08	SCALE NTS	REV. A
CADD	JDE	8/08		
CHECK	KFM	8/08		
REVIEW	JMJ	8/08		

FIGURE K-1

Plot Time: 09/26/08 16:32

ATTACHMENT B

TAILINGS CELL CLOSURE CONSTRUCTION QUANTITIES

Table B-1

Summary of Required Materials and Quantities for Reclamation of the Piñon Ridge Mill Tailing Cells

Area	Sand		Sand and Gravel		Cobbles, 3"		CDOT Class 1 Bedding		CDOT Class 2 Bedding	
	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)
Cell A	31,000	26,000	95,000	65,000	31,000	24,000	1,030	720	1,140	800
Cell B	30,000	25,000	94,000	65,000	31,000	24,000	290	200	440	310
Cell C	30,000	25,000	122,000	84,000	31,000	24,000	-	-	-	-
Total	**91,000**	**76,000**	**311,000**	**214,000**	**93,000**	**72,000**	**1,300**	**900**	**1,600**	**1,100**

Area	Rock, d_{50}=0.5		Rock, d_{50}=2.5		Rock, d_{50}=3.5		Rock, d_{50}=8.0		Rock, d_{50}=9.0		Rock, d_{50}=18	
	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)	(ton)	(loose CY)
Cell A	31,000	23,000	24,000	18,000	8,000	6,000	5,800	4,500	3,400	2,600	1,800	1,400
Cell B	31,000	23,000	24,000	18,000	10,000	8,000	2,500	1,900	-	-	2,500	1,900
Cell C	31,000	23,000	80,000	62,000	-	-	7,100	5,500	-	-	-	-
Total	**93,000**	**69,000**	**128,000**	**98,000**	**18,000**	**14,000**	**15,000**	**12,000**	**3,400**	**2,600**	**4,300**	**3,300**

Note:

1. Information developed by EFRC personnel.

Table B-2
Tailings Cell Reclamation Material Quantity Calculations

Area	Layer	Type	D_{50} (in)	Durability	Thickness (ft)	Area (SF)	Volume (CY)	Loose Density (lb/CY)	Bank Density (lb/CY)	Load Factor	Compacted Density (lb/CY)	Density/Loading Reference	Weight (ton)	Loose Volume (CY)
Cell A	Capillary Break	Sand and Gravel		none	1.0	1,417,135	52,486	2,900	3,250	0.89	2,900	CAT-S&G, dry	76,000	52,000
	Filter Layer	Sand		none	0.5	1,373,548	25,436	2,400	2,700	0.89	2,400	CAT-Sand, dry, loose	31,000	26,000
	Biointrusion Layer	Cobbles, 3"		none	1.0	1,351,962	25,036	2,550	2,850	0.89	2,500	CAT-Gravel, dry	31,000	24,000
	Top Erosion Barrier	Rock mulch	0.5	none	0.5	1,247,779	23,107	2,700	4,500	0.60	2,700	CAT-Stone, crushed	31,000	23,000
	10:1 Slope Erosion Barrier	Rock blanket	2.5	non-crit	1.0	505,042	18,705	2,600	4,400	0.59	2,600	CAT-Limestone, broken	24,000	18,000
	10:1 Slope EB filter layer	Sand and Gravel		none	0.5	505,042	9,353	2,900	3,250	0.89	2,900	CAT-S&G, dry	13,600	9,400
	5:1 Slope Erosion Barrier	Rock blanket	3.5	non-crit	1.0	156,716	5,804	2,600	4,400	0.59	2,600	CAT-Limestone, broken	8,000	6,000
	5:1 Slope EB filter layer	Sand and Gravel		none	0.5	156,716	2,902	2,900	3,250	0.89	2,900	CAT-S&G, dry	4,200	2,900
	Rip Rap Rundown channels	Rock	18	critical	3.0	12,730	1,414	2,600	4,400	0.59	2,600	CAT-Limestone, broken	1,800	1,400
	RD Channel filter layer	CDOT Class 1 over		critical	0.33	12,730	156	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	220	150
		CDOT Class 2		critical	0.5	12,730	236	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	330	230
	Cell berm toe protection	Rock	8.0	non-crit	2.0	60,198	4,459	2,600	4,400	0.59	2,600	CAT-Limestone, broken	5,800	4,500
	CBTP filter layer	Sand and Gravel		none	0.5	60,198	1,115	2,900	3,250	0.89	2,900	CAT-S&G, dry	1,600	1,100
	Diversion Berm	Rock	9.0	critical	1.5	47,265	2,626	2,600	4,400	0.59	2,600	CAT-Limestone, broken	3,400	2,600
	DB filter layer, geotextile fabric or	CDOT Class 1 over		critical	0.33	47,265	578	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	810	570
		CDOT Class 2		critical	0.33	47,265	578	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	810	570
Cell B	Capillary Break	Sand and Gravel		none	1.0	1,400,580	51,873	2,900	3,250	0.89	2,900	CAT-S&G, dry	75,000	52,000
	Filter Layer	Sand		none	0.5	1,357,310	25,135	2,400	2,700	0.89	2,400	CAT-Sand, dry, loose	30,000	25,000
	Biointrusion Layer	Cobbles, 3"		none	1.0	1,335,882	24,739	2,550	2,850	0.89	2,500	CAT-Gravel, dry	31,000	24,000
	Top Erosion Barrier	Rock mulch	0.5	none	0.5	1,232,478	22,824	2,700	4,500	0.60	2,700	CAT-Stone, crushed	31,000	23,000
	10:1 Slope Erosion Barrier	Rock blanket	2.5	non-crit	1.0	493,021	18,260	2,600	4,400	0.59	2,600	CAT-Limestone, broken	24,000	18,000
	10:1 Slope EB filter layer	Sand and Gravel		none	0.5	493,021	9,130	2,900	3,250	0.89	2,900	CAT-S&G, dry	13,200	9,100
	5:1 Slope Erosion Barrier	Rock blanket	3.5	non-crit	1.0	199,549	7,391	2,600	4,400	0.59	2,600	CAT-Limestone, broken	10,000	8,000
	5:1 Slope EB filter layer	Sand and Gravel		none	0.5	199,549	3,695	2,900	3,250	0.89	2,900	CAT-S&G, dry	5,000	3,400
	Rip Rap Rundown channels	Rock	18	critical	3.0	17,032	1,892	2,600	4,400	0.59	2,600	CAT-Limestone, broken	2,500	1,900
	RD Channel filter layer	CDOT Class 1 over		critical	0.33	17,032	208	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	290	200
		CDOT Class 2		critical	0.5	17,032	315	2,850	3,200	0.89	2,800	CAT-Gravel, dry, 1/4"-2"	440	310
	Cell berm toe protection	Rock	8.0	non-crit	2.0	26,334	1,951	2,600	4,400	0.59	2,600	CAT-Limestone, broken	2,500	1,900
	CBTP filter layer	Sand and Gravel		none	0.5	26,334	488	2,900	3,250	0.89	2,900	CAT-S&G, dry	710	490
Cell C	Capillary Break	Sand and Gravel		none	1.0	1,400,580	51,873	2,900	3,250	0.89	2,900	CAT-S&G, dry	75,000	52,000
	Filter Layer	Sand		none	0.5	1,357,310	25,135	2,400	2,700	0.89	2,400	CAT-Sand, dry, loose	30,000	25,000
	Biointrusion Layer	Cobbles, 3"		none	1.0	1,335,882	24,739	2,550	2,850	0.89	2,500	CAT-Gravel, dry	31,000	24,000
	Top Erosion Barrier	Rock mulch	0.5	none	0.5	1,232,478	22,824	2,700	4,500	0.60	2,700	CAT-Stone, crushed	31,000	23,000
	10:1 Slope Erosion Barrier	Rock blanket	2.5	non-crit	1.0	1,671,539	61,909	2,600	4,400	0.59	2,600	CAT-Limestone, broken	80,000	62,000
	10:1 Slope EB filter layer	Sand and Gravel		none	0.5	1,671,539	30,954	2,900	3,250	0.89	2,900	CAT-S&G, dry	45,000	31,000
	Cell berm toe protection	Rock	8.0	non-crit	2.0	73,533	5,447	2,600	4,400	0.59	2,600	CAT-Limestone, broken	7,100	5,500
	CBTP filter layer	Sand and Gravel		none	0.5	73,533	1,362	2,900	3,250	0.89	2,900	CAT-S&G, dry	2,000	1,400

Note:

1. Information developed by EFRC personnel.

ATTACHMENT C
ROCK DURABILITY RESULTS

Table C-1

Rock Durability Results Summary for Sources near the Piñon Ridge Mill

Reams Quarry, Naturita, CO

Sample ID	*Date*	*Rating*	*Ref*	*Notes*
1.8/2.0" Spec. Material - Durita Site				
SV0819	6/19/05	83.0	1	
SV0822	6/19/05	81.6	1	
SV0826	6/19/05	86.7	1	
SV0829	6/19/05	81.5	1	
SV0915	6/19/05	85.4	1	
SV0925	6/19/05	87.9	1	
SV1014	6/19/05	86.4	1	
SV1023	6/19/05	85.1	1	
	Average	**84.7**		
3.6" Spec. Material - Durita Site				
SV0130	6/20/05	88.3	2	
8.2" Spec. Material - Durita Site				
SV0605	6/20/05	84.6	2	
SV0609	6/20/05	83.9	2	
	Average	**85.3**		

Cotter Material, Papoose Pit, La Sal, UT

Sample ID	*Date*	*Rating*	*Ref*	*Notes*
12.0" Spec. Material - Durita Site				
SV0219	6/21/05	94.5	3	Summary shows 96.0 - Used igneous, not limestone value
SV0428	6/21/05	93.3	3	Summary shows 95.3 - Used igneous, not limestone value
	Average	**88.3**		
Size not specified				
Trial No. 1	12/20/01	85.0	4	
Trial No. 2	12/20/01	86.1	4	
Trial No. 3	12/20/01	88.0	4	
	Average	**89.2**		

References

1 - Hecla Mining Co., 1997 Durita Site Reclamation and Construction Verification Report, 2/20/98
1 - Hecla Mining Co., 1998 Durita Site Reclamation and Construction Verification Report, 9/21/98
3 - Hecla Mining Co., 1999 Durita Site Reclamation and Construction Verification Report, 6/9/99
4 - Sundale Associates, Summary of Test Results for the Cotter Pit, 2/28/02

Note: 1. Information developed by EFRC personnel.

Table 3
Summary of Erosion Protection Gradation and Durability Tests - 1997

Sample ID	D_{100}	D_{50}	D_{25}	D_{15}	D_0	Bulk Specific Gravity SSD (g/cc)	Absorption (%)	Sodium Sulfate Loss (%)	Rating[1]
2" Spec.	**2.5 - 3.4**	**2.0 - 2.3**	**1.4 - 1.8**	**>1.0**	**<1.0**	NA	NA	NA	>80
1.8" Spec.	**2.3 - 3.1**	**1.8 - 2.0**	**1.3 - 1.6**	**>0.8**	**<0.8**				
SV0819	3.0	1.9	1.5	1.3	<0.8	2.610	1.27	0.80	83.0
SV0822	3.0	2.0	1.5	1.3	<1.0	2.591	1.19	0.07	81.6
SV0826	3.0	1.9	1.5	1.3	<0.8	2.649	1.03	0.06	86.7
SV0829	3.0	2.0	1.5	1.3	<1.0	2.604	1.75	0.20	81.5
SV0902	2.9	2.0	1.5	1.3	<1.0	NA[2]			
SV0915	2.9	1.8	1.4	1.2	<0.8	2.620	0.82	0.05	85.4
SV0925	3.0	1.9	1.4	1.2	<0.8	2.652	0.84	0.08	87.9
SV1014	3.2	2.1	1.6	1.4	<1.0	2.650	1.21	0.02	86.4
SV1023	3.1	2.2	1.7	1.5	<1.0	2.627	0.97	0.09	85.1

1 - Average percentage of rock types in samples was 97% Igneous, 1.5% limestone, 1.5% sandstone.
2 - Only 8 durability tests were required as only 8,000 cy of rock was produced.

Table 1
Summary of Erosion Protection Gradation and Durability Tests - 1998

Sample ID	D_{100}	D_{50}	D_{25}	D_{15}	D_{0}	Bulk Specific Gravity (SSD) (g/cc)	Absorption (%)	Sodium Sulfate Loss (%)	Rating[1]
3.6" spec.[2]	4.5 - 6.2	3.6 - 4.1	2.5 - 3.2	>1.7	<1.7	NA	NA	NA	NA
SV0130	6.1	3.7	2.9	2.3	1.5	2.669	1.01	0.19	88.3
8.2" spec.[3]	10.3 - 14.0	8.2 - 9.3	5.7 - 7.3	>4.0	<4.0	NA	NA	NA	NA
SV0605	13.5	8.3	6.5	>4.0	<4.0	2.627	1.15	0.12	84.6
SV0609	13.8	8.6	6.9	>4.0	<4.0	2.598	0.77	0.08	83.9

1 - Average percentage of rock types in samples was 97% igneous, 1.5% limestone, 1.5% sandstone.
2 - Approximately 820 cubic yards produced, delivered, and placed during 1998.
3 - Approximately 1257 cubic yards produced, delivered, and placed during 1998.

Table 1
Summary of Erosion Protection Gradation and Durability Tests - 1999

Sample ID	D_{100}	D_{50}	D_{25}	D_{15}	D_{0}	Bulk Specific Gravity (SSD) (g/cc)	Absorption (%)	Sodium Sulfate Loss (%)	Rating[1]
8.2" spec.[2]	10.3 - 1420	8.2 - 9.3	5.7 - 7.3	>4.0	<4.0	NA	NA	NA	NA
12.0" spec.[3]	15.1 - 20.5	12.0 - 13.7	8.4 - 10.8	>6.0	<6.0	NA	NA	NA	NA
SV0219	20.0	12.4	10.3	>6.0	<6.0	2.705	0.18	0.29	96.0
SV0428	18.0	12.1	8.8	>6.0	<6.0	2.699	0.21	0.10	95.3

1 - Average percentage of rock types in the 8.2 inch materials was 97% igneous, 1.5% limestone, 1.5% sandstone. All 12 inch rock was 100% limestone.

2 - Approximately 200 cubic yards of rock stockpiled during 1998 were delivered and placed during 1999. Sufficient gradation and durability tests were conducted on this material during the 1998 construction season (see 1998 Construction Verification Report, MEI, 1998a) to verify rock delivered during 1999.

3 - Approximately 2,818 cubic yards were produced, delivered, and placed during 1999.

ROCK QUALITY SCORING

Durability Sample from Cotter's Papoose Pit, Lasal, Utah: 12" rock

LAMBERT: 7308

Sample Number	Rock Type (1 = igneous) (2 = limestone) (3 = sandstone)	Weighting Factor/Test Value/Score	Specific Gravity (SSD) (g/cc)	Absorption (%)	Sulfate Soundness (% loss)	LA Abrasion (% loss)	Schmidt Hammer (SRU)	Tensile Strength (psi)	Totals	Composite Rating For Sample (%)
7308	1	Weighting Factor =	9	2	11					
		Test Value =	2.705	0.18	0.29					
		Score =	9.1	9.6	10.0					
		Rating =	81.9	19.20	110.0				211.1	96.0
		Max. Possible =	90	20	110				220	
	2	Weighting Factor =	12	13	4					
		Test Value =	2.705	0.18	0.29					
		Score =	9.1	9.60	10					
		Rating =	109.2	124.8	40.0				274.0	94.5
		Max. Possible =	120	130	40				290	
	3	Weighting Factor =	6	5	3					
		Test Value =	2.705	0.18	0.29					
		Score =	9.1	9.60	10					
		Rating =	54.6	48.0	30.0				132.6	94.7
		Max. Possible =	60	50	30				140	

Sample is 100% limestone

Lambert 7308 estimated average = 94.5

Required percent increase over design sizes = -14.5

LAMBERT1.WB2

ROCK QUALITY SCORING

Durability Sample from Cotter's Papoose Pit, Lasal, Utah: 12" rock

LAMBERT: 7369

Sample Number	Rock Type (1 = igneous) (2 = limestone) (3 = sandstone)	Weighting Factor/Test Value/Score	Specific Gravity (SSD) (g/cc)	Absorption (%)	Sulfate Soundness (% loss)	LA Abrasion (% loss)	Schmidt Hammer (SRU)	Tensile Strength (psi)	Totals	Composite Rating For Sample (%)
7369	1	Weighting Factor =	9	2	11					
		Test Value =	2.699	0.21	0.10					
		Score =	8.98	9.5	10.0					
		Rating =	80.82	18.90	110.0				209.7	95.3
		Max. Possible =	90	20	110				220	
	2	Weighting Factor =	12	13	4					
		Test Value =	2.699	0.21	0.10					
		Score =	8.98	9.45	10					
		Rating =	107.8	122.9	40.0				270.6	93.3
		Max. Possible =	120	130	40				290	
	3	Weighting Factor =	6	5	3					
		Test Value =	2.699	0.21	0.10					
		Score =	8.98	9.45	10					
		Rating =	53.9	47.3	30.0				131.1	93.7
		Max. Possible =	60	50	30				140	

Sample is 100% limestone

Lambert 7369 estimated average = 93.3

Required percent increase over design sizes = -13.3

LAMBERT1.WB2

Sundale Associates, Inc.

Engineering & Testing

Client: I. T. Group
Attn: Don Janz

Project: Cotter Pit
Project Job Number: 918090
WBS# 09000820

Sundale Project Number: 01110
Date: February 28, 2002

Summary of Test Results for the Cotter Pit

SODIUM SULFATE SOUNDNESS TEST (ASTM C 88)

Trial No.	Percent Loss
1	2.4%
2	2.3%
3	2.4%

L.A. ABRASION (ASTM C 535)

Trial No.	Percent Loss
1 - After 100 Revolutions	4.2%
2 - After 100 Revolutions	4.2%
3 - After 100 Revolutions	4.3%

SPECIFIC GRAVITY, BULK (ASTM C 127) and
ABSORPTION (ASTM C127)

Trial No.	Bulk Specific Gravity	Absorption
1	2.7	0.05%
2	2.7	0.05%
3	2.7	0.05%

649 College Drive
Durango, Colorado 81301
Email: sundale@outerbounds.net
(970) 259-4192 Fax (970) 247-8803 (800) 638-5862

SCHMIDT REBOUND HARDNESS (ISRM)

Trial No.	Average
1	51
2	50
3	53

SPLITTING TENSILE STRENGTH (ASTM D 3967)

Trial NO. 1 Average of 11 samples: 890 psi with the low test being 760 psi and the high test being 1150 psi

Trial NO. 2 Average of 10 samples: 1050 psi with the low test being 870 psi and the high test being 1350 psi

Trial NO. 3 Average of 10 samples: 1250 psi with the low test being 730 psi and the high test being 1660 psi

Monticello Remedial Action Project (918090)

Rock Quality Score – Cotter RIP RAP Durability Testing First Sample

Assumptions:

Material Taken from stockpiles at the source
Sundale Associates, Inc Engineering & Testing Project # 01110
December 20, 2001

	Average Value	Rx Type Weight	CRQS	Weighted Score
Specific Gravity	2.70	12	9	108
Absorption	0.05	13	10	130
Sodium Sulfate	2.4	4	9.25	37
LA Abrasion	4.2	1	8.5	8.5
Schmidt Rebound	50	11	6.5	71.5
Tensile Strength	890	5	7.2	36
Totals		46		391.0

Possible Score (46 * 10) = 460

Rock Quality Score = Weighted Score/Possible Score X 100
= 391.0 / 460 X 100
= 85.0

Date: 3/5/01

Calculated By: Don R. Janz

Checked By:

Monticello Remedial Action Project (918090)

Rock Quality Score – Cotter RIP RAP Durability Testing Second Sample

Assumptions:

Material Taken from stockpiles at the source
Sundale Associates, Inc Engineering & Testing Project # 01110
December 20, 2001

	Average Value	Rx Type Weight	CRQS	Weighted Score
Specific Gravity	2.70	12	9	108
Absorption	0.05	13	10	130
Sodium Sulfate	2.3	4	9.35	37.4
LA Abrasion	4.2	1	8.5	8.5
Schmidt Rebound	50	11	6.5	71.5
Tensile Strength	1050	5	8.1	40.5
Totals		46		395.9

Possible Score (46 * 10) = 460

Rock Quality Score = Weighted Score/Possible Score X 100
= 395.9 / 460 X 100
= 86.1

Date: 3/05/02

Calculated By: Don R. Janz

Checked By:

Monticello Remedial Action Project (918090)

Rock Quality Score – Cotter RIP RAP Durability Testing Third Sample

Assumptions:

Material Taken from stockpiles at the source
Sundale Associates, Inc Engineering & Testing Project # 01110
December 20, 2001

	Average Value	Rx Type Weight	CRQS	Weighted Score
Specific Gravity	2.70	12	9	108
Absorption	0.05	13	10	130
Sodium Sulfate	2.4	4	9.25	37
LA Abrasion	4.3	1	8.4	8.4
Schmidt Rebound	53	11	6.9	75.9
Tensile Strength	1250	5	9.1	45.5
Totals		46		404.80

Possible Score (46 * 10) = 460

Rock Quality Score = Weighted Score/Possible Score X 100
= 404.8 / 460 X 100
= 88.0

Date: 3/05/02

Calculated By: Don R. Janz

Checked By:

ATTACHMENT D

PETROGRAPHIC ANALYSIS OF COTTER PAPOOSE PIT ROCK

Petrographic Analysis :

Limestone Suitability for Riprap Material

Dr. Gary Gianniny, Assistant Professor
Department of Geosciences
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For

Sundale Associates
605 E 7th Ave
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February 23, 2002

This brief report contains a petrographic (microscopic and megascopic) analysis of four samples of limestone delivered to me by Sundale Engineering of Durango Colorado that are intended to be used as riprap material. It is my understanding that these samples are from near Lisbon Valley, Utah. Below I summarize the results for detailed petrographic descriptions of the four samples appear on the following pages.

Gary L. Gianniny

Findings:

Two of the four samples (SE-03 and SE-04) appear to be very well suited for a riprap application as they are well cemented and lack any zones of potential weakness (i.e. siliciclastic-rich layers). Samples SE-01 contains only one thin lamination and material of this type may also be suitable for a riprap application. Sample SE-02 is contains multiple zones with insoluble residua and may have siliciclastic clays that often impart zones of weakness and more rapid mechanical and chemical weathering. This sample is the lowest quality for this application of the four samples provided. None of the rock samples studied contained sulfides or sulfates.

Recommendations:

Limestones of this age (Pennsylvanian) in the Paradox basin (including the Lisbon Valley area are known for their lateral continuity within layers and their vertical variation in rock type. Careful selection and attention by the operators of the quarry is recommended to maintain rock quality. If the rock quality is of critical importance, a geologist familiar with the variation in these units should map or in otherways identify the material with the desired qualities at the quarry.

SAMPLE DESCRIPTIONS:

Sample descriptions from microscopic (thin section) and megascopic petrography:

SE-01 Limestone. Rock name after Dunham (1963): *Ostracode mudstone.*

This sample has a clotted micritic texture with less than 10% fossils. Fossil fragments are composed primarily of recrystallized brachiopods (replaced by blocky calcite) , and trilobites. Entire microfossils include ostracodes, trochospiral and encrusting benthic foraminifera.

Non-soluble residua (that may include minor siliciclastic clays) are concentrated in one 1.0-0.3 mm thick band presumed to be related to compaction and point dissolution during burial.

Sulfide and sulfate minerals where not observed in microscopic or megascopic petrographic analysis of this sample.

SE-02 Limestone. Rock name after Dunham (1963): *Fossiliferous packstone.*

This sample has a compacted peloidal texture with less than 40% fossils. The large skeletal grain is a mollusk, most likely a peleycepod with characteristic laminated shell construction. The large prismatic crystals of the shell have replaced by secondary calcite. Most skeletal fragments are derived, from ostracodes, crinoids, encrusting bryozoa and ramose bryozoa.

Non-soluble residua (that may include minor siliciclastic clays) are concentrated multiple 0.4 – 0.9 mm laminae and in a distinct fossil and residual-rich zone with a thickness of 2mm near the base of the thin section. These bands are presumed to be related to compaction and point dissolution during burial. The composition of the residua has not been identified but they lack the concentration of siliciclastic silt that is often associated with siliciclastic clay minerals. Two possible grains of hematite where observed in the 2mm thick residual layer.

Sulfide and sulfate minerals where not observed in microscopic or megascopic petrographic analysis of this sample.

SE-03 Limestone. Rock name after Dunham (1963): *Recrystallized peloidal grainstone.*

Most of the rock is composed of recrystallized peloids with micritic rims and blocky calcite replacing original texture. Brachiopod fragments are also completely replaced by blocky calcite. Minor fossils (<15%) include echinoderm fragments (spines and crinoid fragments), rare bryozoa, and brachiopod fragments are completely replaced by blocky calcite.

Non-soluble residua (that may include minor siliciclastic clays), and sulfide minerals where not observed in microscopic or megascopic petrographic analysis of this sample.

SE-04 Limestone. Rock name after Dunham (1963): *Mud-rich, recrystallized packstone.*

This sample is heavily recrystallized texture that originally had approximately 40% fossil/skeletal grains. Micritic encrusting foraminifera outline the boundaries of skeletal fragments (? Brachiopods, bryozoa) that have been completely replaced by blocky calcite spar. Fossil fragments include crinoid fragments, echinoid spines, and recrystallized brachiopods (replaced by blocky calcite). Entire microfossils include trochospiral and encrusting benthic foraminifera.

Non-soluble residua (that may include minor siliciclastic clays), and sulfide minerals where not observed in microscopic or megascopic petrographic analysis of this sample.