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MEMORANDUM

To: Mr. Fermin Samorano
Mr. Jeff Cornoyer

From: Mr. David Nicholas, P.E.
Mr. Larry Standridge
Mr. Robert Pratt, P.E.

Date: 20 July 2012

Subject: Slope Angle for the Planned Rosemont Open-Pit Mine South Wall Tertiary Gravel Slope

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1.0 INTRODUCTION

This memorandum presents an update to slope angle recommendations for the Tertiary gravels in the south wall of the planned Rosemont open-pit mine (Figure 1) that incorporates a revision to the geologic interpretation, recent hydrogeologic data, a revised pit design, and CNI's re-interpretation of the rock-mass strength.

1.1 Geotechnical Feasibility Study

Slope angle recommendation from Call &Nicholas, Inc.'s (CNI) 2008 geotechnical feasibility study (report: *Feasibility Level Geotechnical Study of the Rosemont Deposit,* February 2008), for the 715-foot south wall Tertiary gravel slope was a 31-degree overall slope angle for fully depressurized conditions or a 28-degree overall angle if depressurization could not be achieved.

2.0 CONCLUSIONS AND RECOMMENDATIONS

1. For the Tertiary gravel slope height of approximately 600 feet in the final pit, with limited or no depressurization, a 35-degree slope angle is recommended and single benching (50-foot benches).
2. Pump tests performed on the Tertiary gravels and Willow Canyon arkose result in hydraulic conductivity values less than 10^{-5} centimeters/second. Based on these values, it is unlikely that depressurization would be successful. It is anticipated that conductivities of 10^{-4} centimeters/second or greater will be needed for successful depressurization. Hydrogeologic modeling and additional study of the hydraulic conductivity is recommended to evaluate the potential for dewatering.

3.0 SLOPE STABILITY ANALYSIS

The following sections discuss the input parameters and results of slope stability analyses of the south wall Tertiary gravels.

3.1 Pit Design

Figure 1 presents geology projected onto the planned Rosemont final pit design. This design is the P627 final pit provided to CNI by Moose Mountain Consultants in June 2012.

3.2 Geology

A revision to the geologic model provided by Moose Mountain Consultants to CNI in March 2012 resulted in a significant change to the geometry of the south wall Tertiary gravels. Figure 2, cross section NS, shows the differences in the geologic models. The thickness of the Tertiary gravels was reduced, resulting in the maximum slope height changing from over 700 feet to slightly over 600 feet in the current model.

3.3 Hydrogeologic Data

Since the 2008 geotechnical feasibility study, Montgomery & Associates and Engineering Analytics, Inc. have performed pump tests in the Tertiary gravels and the Willow Canyon arkose. Hydraulic conductivity values determined from these pump tests are presented in Table 1. The hydraulic conductivities shown in this table are very low making groundwater depressurization difficult.

CNI recommends groundwater modeling to determine the anticipated horizontal drain spacing for dewatering approximately 100 to 200 feet behind the slope face. Because of the low conductivity values, a relatively tight spacing will be required resulting in a high cost to depressurize the slope.

The phreatic surface is interpreted to be at the 5100 foot elevation. For the analysis CNI has assumed that the phreatic surface will be 0.3 times the height of the saturated slope behind the pit wall due to resulting from the open pit.

3.4 <u>Rock-Mass Shear Strength</u>

The Tertiary gravels' rock-mass shear strength was determined with the use of CNI's method of calculating rock mass shear strength (Karzulovic, Antonio. 2009. "Rock Mass Model." In Guidelines for Open Pit Slope Design, edited by John Read and Peter Stacey, 130-132. Australia: CSIRO Publishing). This method derives estimates of the rock-mass strength with the use of intact and fracture shear strengths as determined with the use of laboratory testing data. The intact and fracture shear strengths are combined, based on the degree of fracturing as indicated by the RQD, to determine the rock-mass shear strength.

3.4.1 Laboratory Testing

All of the samples tested for the Tertiary gravels came from drill hole AR-2050. Laboratory testing was performed as part of the geotechnical feasibility study.

With the use of the residual direct-shear test results, the fracture shear strength was computed as shown on Figure 3. The triaxial compression, uniaxial compression, and disc tension test results were utilized to determine the intact shear strength of the Tertiary gravels as shown on Figure 4.

3.4.2 Rock-Mass Shear Strength

In addition to the intact and fracture shear strengths mentioned previously, an average RQD for the Tertiary gravels of 55 percent was utilized (Figure 5) for the rock-mass shear strength calculation. The average RQD was determined with the use of data from 546 feet of drilling data obtained from 6 core holes. Figure 6 presents the Tertiary gravels' rock-mass shear strength calculation sheet.

3.5 Stability Analysis

Slope stability analyses were conducted with the use of the SLOPE/W© limiting-equilibrium computer program. Stability of the final pit was analyzed (615-foot maximum slope height) to determine the appropriate slope angle with the use of section NS as shown on Figure 2. The location of this section is shown on Figure 1. A phreatic surface elevation of 5100 feet was utilized based on a phreatic surface map provided by Montgomery & Associates. Because of the low hydraulic conductivities determined from pump tests mentioned previously, CNI did not consider a reduction in the phreatic surface level with the use of depressurization from vertical pumping wells.

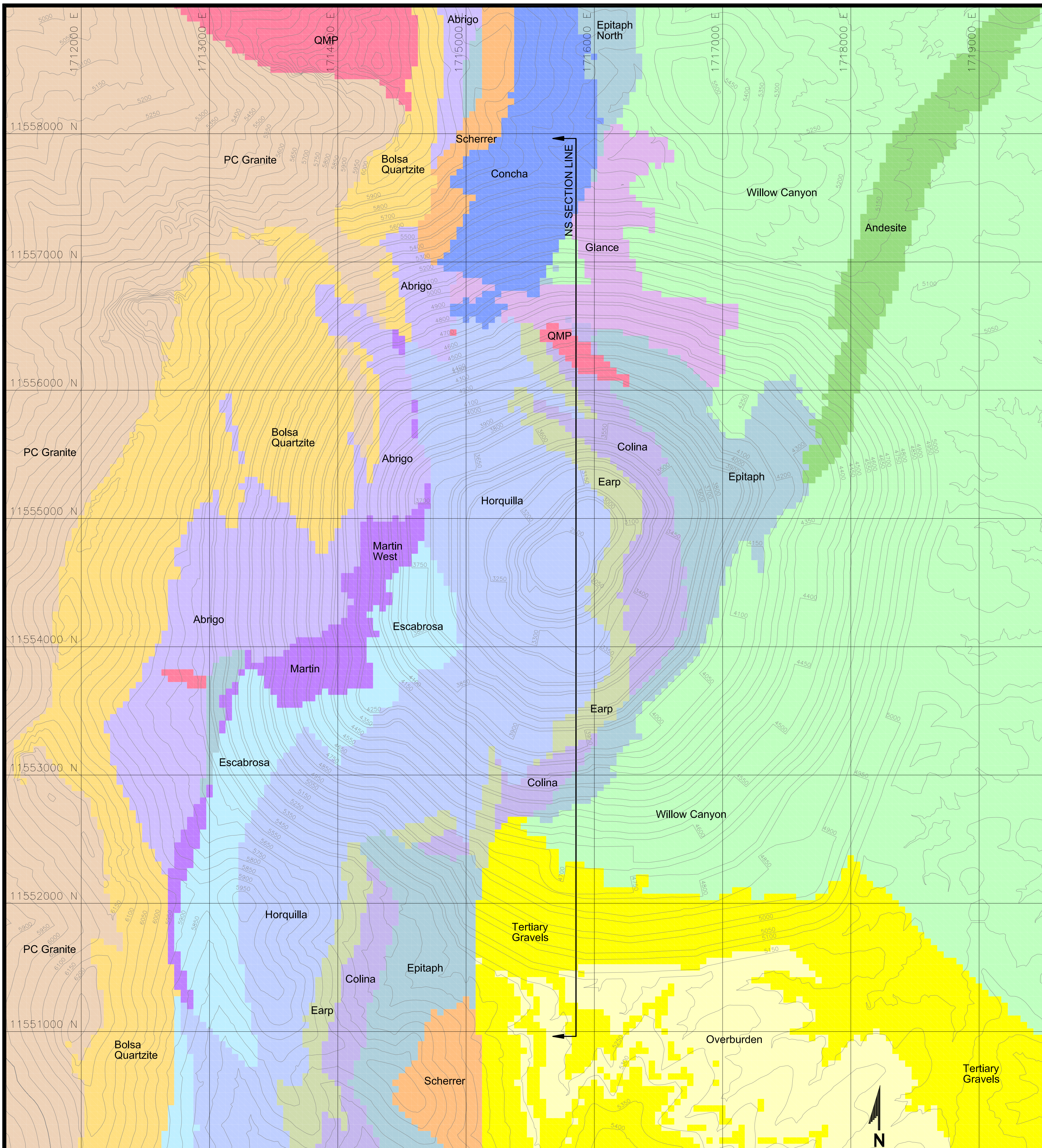
The slope angle was varied until a factor of safety of not less than 1.2 was obtained. This resulted in a slope angle of 35 degrees, which is recommended for design of the final pit south wall Tertiary gravel slope.

Table 1. Hydraulic Conductivity Values Provided by Engineering Analytics
Rosemont Copper

Hydrogeologic Unit	Hydraulic Conductivity (cm/sec)		
	Likely Minimum	**Likely Average**	**Likely Maximum**
Willow Canyon (Ksd)	3.5E-08	3.5E-07	3.5E-06
Tertiary Gravels (Qtg1)	3.5E-06	3.5E-05	3.5E-04
Tertiary Gravels – lowest permeability (Qtg2)	3.5E-08	3.5E-07	3.5E-06

Table 2. Tertiary Gravels Geotechnical Laboratory Testing Performed for CNI
Geotechnical Feasibility Study

Test Type	Number of Tests	Depth of Tested Samples (ft.)
Fracture Direct Shear	3	86, 258, 336
Uniaxial Compression	3	96, 257, 336
Triaxial Compression (Unconsolidated, Undrained)	3	69, 251, 310
Tensile Strength (Brazilian Disc Tension)	5	69, 251, 257, 310, 336



NOTE: COORDINATE SYSTEM IS UTM–FT

PIT SHOWN IS MOOSE MOUNTAIN CONSULTANTS P627 2012 FINAL PIT, WITH 2012 GEOLOGIC BLOCK MODEL.

SCALE 0 400 800 FEET (1"=800')

LEGEND

- OVERBURDEN
- EPITAPH DOLOMITE
- COLINA LIMESTONE
- EARP FORMATION
- HORQUILLA LIMESTONE
- ESCABROSA LIMESTONE
- MARTIN FORMATION
- QTZ MONZONITE PORPHYRY
- ANDESITE
- ARKOSE WILLOW CANYON FORMATION
- CONCHA LIMESTONE
- ABRIGO FORMATION
- BOLSA QUARTZITE
- PRECAMBRIAN GRANITE
- GLANCE CONGLOMERATE
- SCHERRER FORMATION
- TERTIARY GRAVELS

CALL & NICHOLAS, INC.

TUCSON, ARIZONA USA

ROCK TYPE ON P627 FINAL PIT

AUGUSTA RESOURCES / ROSEMONT

DRAWN	DATE	REVISED	SCALE	
LMC	09/07	7/20/2012 1:19 PM	1"=800'	FIGURE 1

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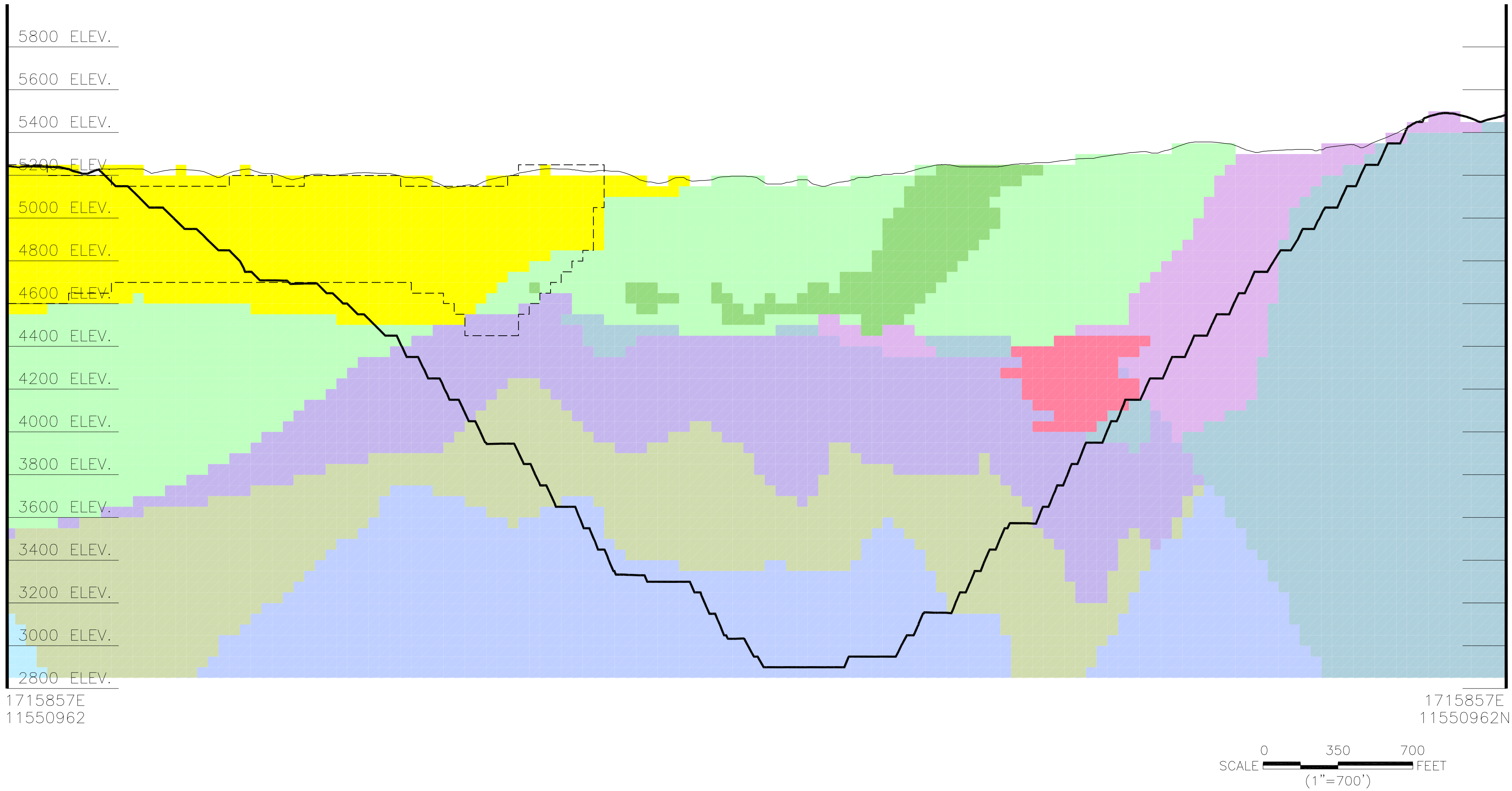

PIT SHOWN IS MOOSE MOUNTAIN CONSULTANTS P627 2012 FINAL PIT, WITH 2007 GEOLOGIC BLOCK MODEL.

LEGEND

- COLINA LIMESTONE
- EARP FORMATION
- HORQUILLA LIMESTONE
- ESCABROSA LIMESTONE
- QTZ MONZONITE PORPHYRY
- ANDESITE
- ARKOSE WILLOW CANYON FORMATION
- GLANCE CONGLOMERATE
- TERTIARY GRAVELS
- ORIGINAL TOPOGRAPHY
- MM P627 FINAL PIT
- 2012 TERIARY GRAVELS INTERPRETATION

CALL & NICHOLAS, INC.

TUCSON, ARIZONA USA

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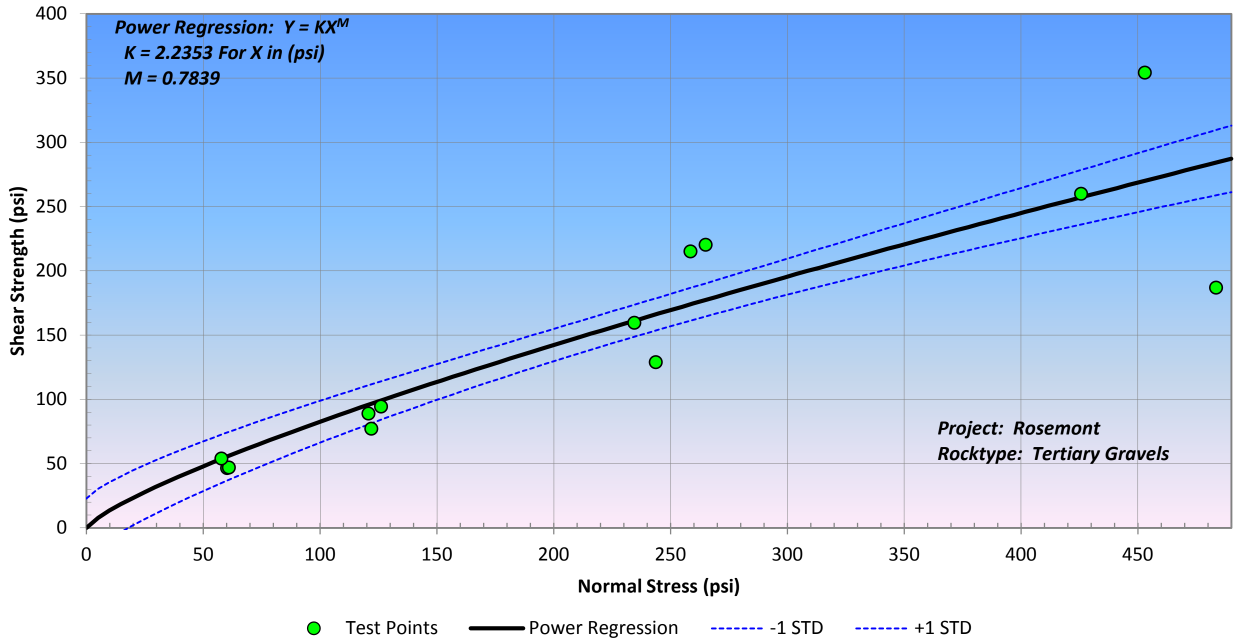
CROSS SECTION NS (Looking West)

AUGUSTA RESOURCES / ROSEMONT

SCALE		
	1"=700'	FIGURE 2

Laboratory Test Values							
Project ID	Rock Type	Test Number	Normal Load (lbs)	Shear Load (lbs)	Shear Area (in^2)	Normal Stress (psi)	Shear Stress (psi)
939-2050-86	Tertiary Gravels	1	229.80	177.80	3.82	60.16	46.54
939-2050-86	Tertiary Gravels	2	455.70	336.00	3.78	120.67	88.97
939-2050-86	Tertiary Gravels	3	906.90	754.00	3.42	264.99	220.31
939-2050-86	Tertiary Gravels	4	907.40	755.20	3.51	258.50	215.14
939-2050-86	Tertiary Gravels	5	1582.90	1238.00	3.49	452.98	354.28
939-2050-258	Tertiary Gravels	1	225.60	174.00	3.70	60.92	46.99
939-2050-258	Tertiary Gravels	2	455.00	288.10	3.73	121.89	77.18
939-2050-258	Tertiary Gravels	3	904.50	478.70	3.71	243.64	128.95
939-2050-258	Tertiary Gravels	5	1810.30	700.00	3.74	483.47	186.94
939-2050-336	Tertiary Gravels	1	245.20	229.20	4.25	57.73	53.96
939-2050-336	Tertiary Gravels	2	508.80	381.10	4.04	126.05	94.42
939-2050-336	Tertiary Gravels	5	994.70	677.10	4.24	234.47	159.61
939-2050-336	Tertiary Gravels	6	1743.10	1064.60	4.09	425.69	259.99



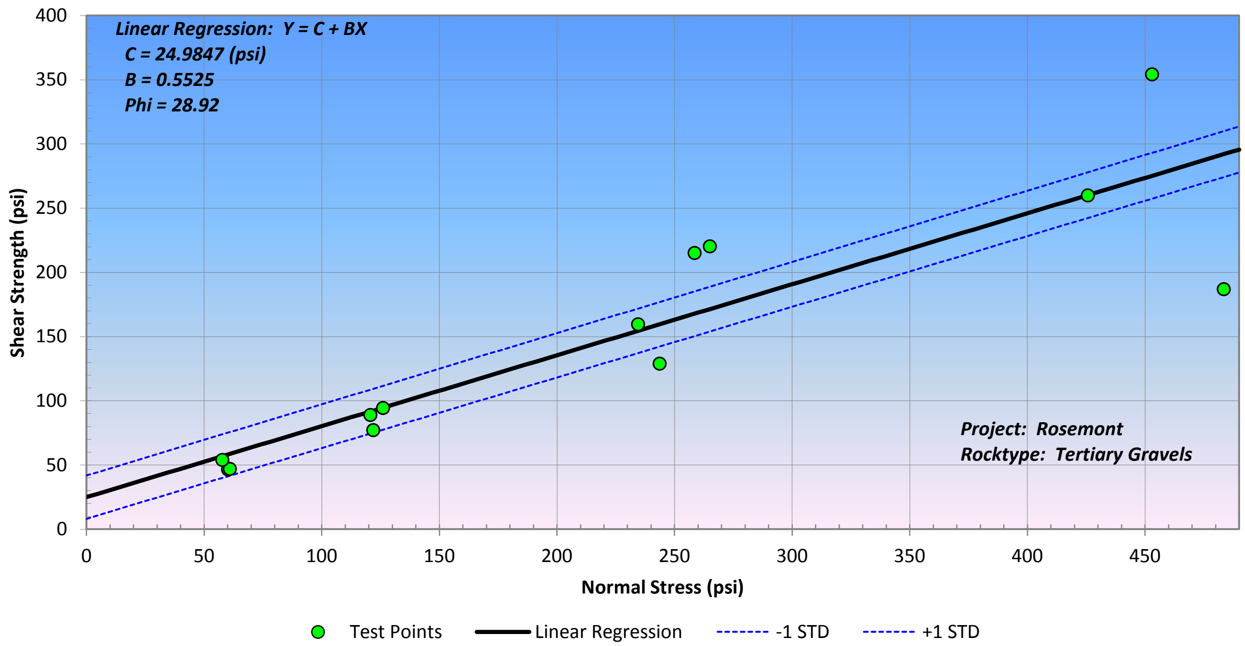
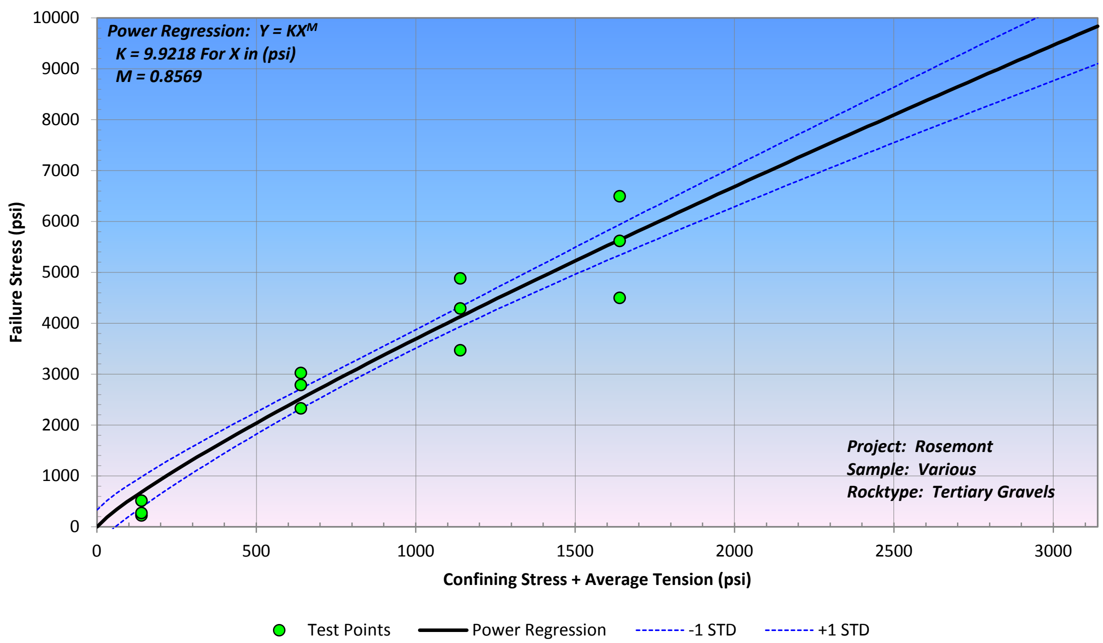


Figure 3. Tertiary Gravels Fracture Shear Strength from Direct-Shear Testing

Laboratory Test Values					
Project ID	Sample ID	Rock Type	Test Number	Confining Stress (psi)	Failure Stress (psi)
939	939-2050-96	Tertiary Gravels	1	1500.00	5618.59
939	939-2050-96	Tertiary Gravels	2	500.00	2787.17
939	939-2050-96	Tertiary Gravels	3	1000.00	4291.36
939	939-2050-257	Tertiary Gravels	1	1000.00	3469.76
939	939-2050-257	Tertiary Gravels	2	1500.00	4499.50
939	939-2050-257	Tertiary Gravels	3	500.00	2328.10
939	939-2050-336	Tertiary Gravels	1	500.00	3023.50
939	939-2050-336	Tertiary Gravels	2	1000.00	4882.55
939	939-2050-336	Tertiary Gravels	3	1500.00	6496.45
939	939-2050-69	Tertiary Gravels	1	0.00	224.00
939	939-2050-251	Tertiary Gravels	1	0.00	514.00
939	939-2050-310	Tertiary Gravels	1	0.00	272.00
939	939-2050-69	Tertiary Gravels	1	-59.00	0.00
939	939-2050-251	Tertiary Gravels	1	-190.00	0.00
939	939-2050-257	Tertiary Gravels	1	-126.00	0.00
939	939-2050-336	Tertiary Gravels	1	-272.00	0.00
939	939-2050-310	Tertiary Gravels	1	-51.00	0.00



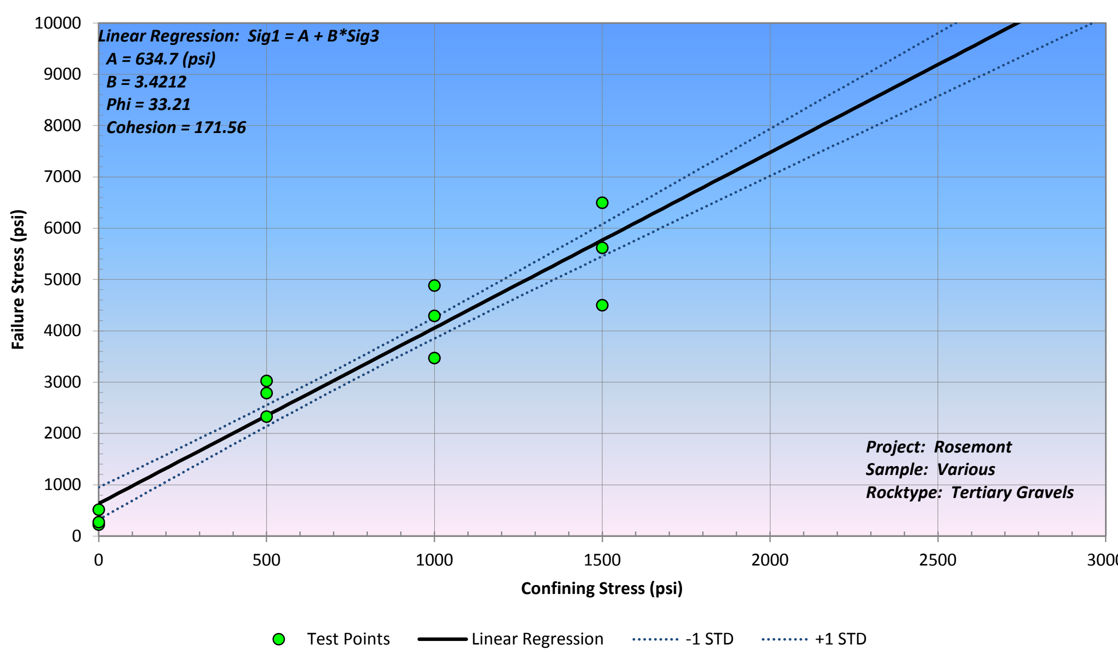


Figure 4. Intact Shear Strength for Tertiary Gravels

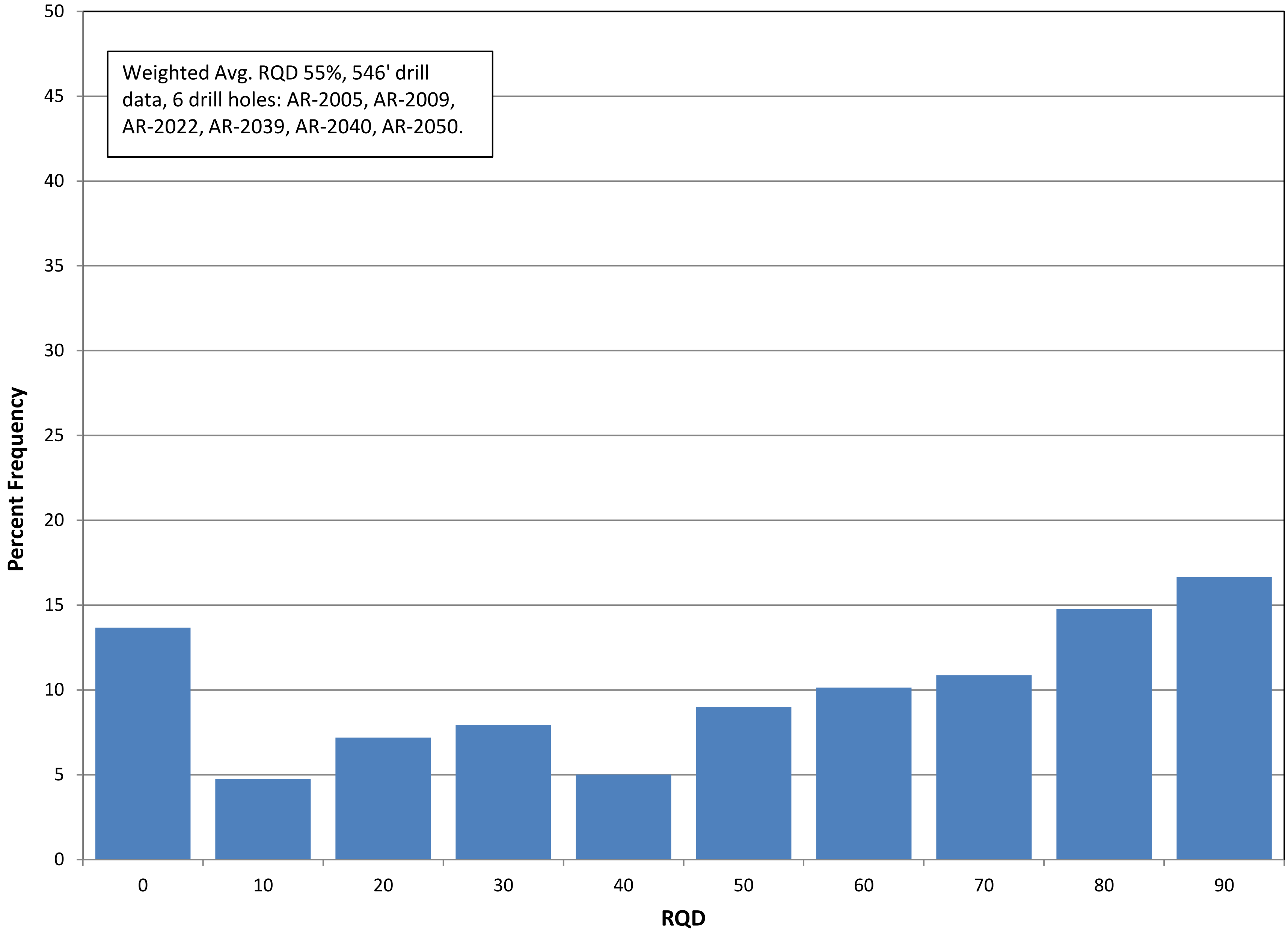


Figure 5. RQD Data Distribution for Rosemont Tertiary Gravels

Date:	6/19/2012	***Rocktype:***	Tertiary Gravels
Project:	Rosemont	***By:***	LRS

Intact Triaxial Values					
Linear Regression: S1 = A + βS3					
Cohesion:	171.6	*psi*	***S.D. C:***	84.8	*psi*
Phi:	33.2	*(deg)*	***S.D. Phi:***	2.5	*(deg)*
Power Regression: S1 = K(S3+T)^M					
note: this is a shifted K & M					
K:	9.9218		***U Slope:***		
M:	0.8569		***L Slope:***		
			U Intc:		
			L Intc:		
			Bound:		

Compression Values		
Lab Derived Data		
UCS:	336.7	*psi*
Tension:	139.6	*psi*
E Mod:	1.00	*psi x10^6*
ν:	0.25	
Density:	145.0	*lbs/ft^3*
ks	0.0	psi/in
kn=20*ks	0.0	psi/in

Fracture Direct Shear Values					
Linear Regression: τ = c + tan(ϕ) σn					
Cohesion:	24.98	*psi*	***S.D. C:***	23.5	*psi*
Phi:	28.9	*(deg)*	***S.D. Phi:***	5.0	*(deg)*
Power Regression: τ = K(σn)^M					
K:	2.2353		***U Slope:***		
M:	0.7839		***L Slope:***		
			U Intc:		
			L Intc:		
			Bound:		

Other Inputs		
Rock Characterization		
RQD:	55.0	*%*
RQD SD:	5.0	*%*
rcf:	0.5	
Max σn:	3000	*psi*
PRS(ϕ)	0.3252	
PRF(ϕ)	0.6748	
PRS(C)	0.2115	
PRF(C)	0.7885	

Rock Mass Calculated Values								
MEAN			**-1 Std Dev**			**Elastic Properties**		
Coh:	28.0	*psi*	***Coh:***	15.7	*psi*	***Em:***	0.46	*psi x10^6*
Phi:	30.4	*(deg)*	***Phi:***	27.0	*(deg)*			
K:	1.7393		***K:***					
M:	0.826		***M:***			**FLAC Props**		
C:	18.9	*psi*	***C:***		*psi*	***K:***	6.530E+07	*psf*
νm:	0.33		***νm:***	0.35		***G:***	2.488E+07	*psf*
σcm:	97.7	*psi*	***σcm:***	51.4	*psi*	***-1SD K:***	7.519E+07	*psf*
σtm:	40.5	*psi*	***σtm:***	21.3	*psi*	***-1SD G:***	2.447E+07	*psf*

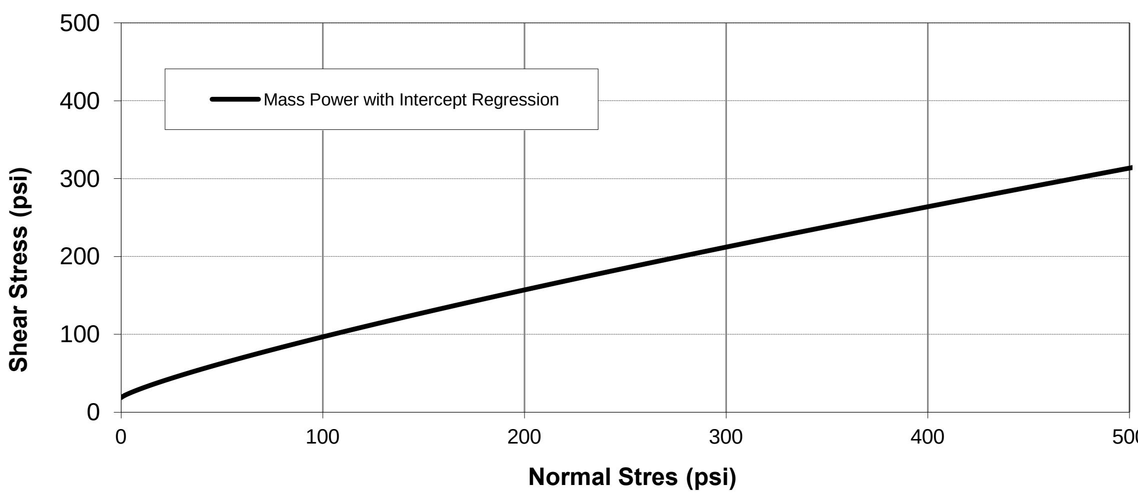


Figure 6. Rock Mass Calculation Sheet for Tertiary Gravels