Orvana Resources
US Corp.

10199 Lake Road
Ironwood, Michigan 49938 USA
906.364.7577 office

January 21, 2013

Mr. Joe Maki
Michigan Department of Environmental Quality
420 5th Street
Gwinn, MI 49841

RE: Request for Amendment – Orvana Resources US Corp Nonferrous Metallic Mineral Mining Permit
Permit Number MP 01 2012

Dear Mr. Maki:

On behalf of Orvana Resources US Corp, we would to like request the above-referenced permit be amended to include the following language. Included in this request is clarification as found in the Orvana Resources US Corp Feasibility Study of March 2012 (BFS) which adjusts the underground mine plan to address concerns about planned subsidence. The changes in underground mining as described in the BFS are designed to result in no measurable surficial expression of subsidence.

Special Conditions K 14a and 14b should be added as follows:

K. Monitoring

14a. The permittee shall provide the MDEQ a plan to add stream monitoring locations on Unnamed Creek 2, Gijik Creek, Unnamed Creek, Namebinag Creek, Lehigh Creek, near their outlets to Lake Superior and Middle Branch of Gipsy Creek, upstream of the confluence of the East Branch of Gipsy Creek to monitor for potential mine seepage through historic bore holes. As soon as practical notify the MDEQ of a water quality violation and provide a corrective action plan for approval by MDEQ. The permittee shall implement the approved plan.

14b. The Permittee shall visually monitor Lehigh Creek downstream of the TDF to Lake Superior annually in June to determine whether significant erosion has occurred. In the annual report describe the extent and location of any bank sloughing or other major erosion observed and provide correction action plan for approval by MDEQ. The permittee shall implement the approved plan.

Special Condition K 15 should be added as follows:

K. Monitoring

15. In addition to Special Permit Condition K14, 14a, and 14b, the permittee shall submit a plan to the OOGM Upper Peninsula District Geologist to monitor surface water and aquatic biota. The permittee must receive written approval of the plan from the MDEQ before conducting any mining operations. The plan shall incorporate the following information:

    a. Surface Water Quality Control Sites: Since regional influences may cause either chronic or acute impacts to water quality, a long-term control data set is needed to help explain consequences of ore milling operations versus natural occurrences. Therefore, the permittee shall add surface water quality stations outside the influence of the Copperwood Mine site to serve as controls to the stations already being monitored as part of an approved long-term monitoring plan.

    b. Analytical methods used for ambient water samples shall include the US Environmental Protection Agency (USEPA) trace metals/elements methods.

    c. Aquatic Biota Sampling: To detect environmental impacts and evaluate compliance with Part 632 of the NREPA, the permittee shall continue to monitor and assess the fisheries, aquatic macroinvertebrate communities, and aquatic habitat at currently selected baseline monitoring locations and at acceptable control sites. A long-term aquatic sampling plan including a description of proposed control sites, sampling methods, and a standardized monitoring schedule shall be submitted to the OOGM Upper Peninsula District Geologist for approval.

    d. The current ambient monitoring stations selected by the company should be revisited on a periodic basis over the life of the discharge. To reduce the effects of seasonal variability, ambient monitoring should be conducted in the same season throughout the life of the facility operations.

Special Condition L 19 should be added as follows:

L. Contingencies

19. If surface subsidence is determined to cause impacts, reclamation plans to restore the affected areas shall be submitted to MDEQ for approval, and approved plans shall be included in the reclamation plan. As soon as practical notify the MDEQ of surface subsidence and provide a corrective action plan for approval by MDEQ. The permittee shall implement the approved plan.

Special Condition O 8 should be added as follows:

O. Reclamation Plan

8. A multi-layer cover system shall be constructed over the disposed tailings in the TDF with a grade that will divert 0.22 square miles of drainage to the West Branch of Gypsy Creek and 0.19 square miles of drainage to the Middle Branch of Gypsy Creek as described in Orvana's November 9, 2012 Part 301/303 application modification. The TDF cover system shall be designed to be consistent with the requirements of Rule 425.409 of Part 632 of the NREPA.

The Permit should also be amended to include the amended mining plan as described in the Feasibility Study of March 2012 and Appendix 1 (Call & Nicholas Geomechanical Report, March 2012) of said report. The Call & Nicholas Geomechanical Report, March 2012, is attached herein.

Sincerely,

ORVANA RESOURCES US CORP

David C. Anderson / kmr

David C. Anderson
Director Health, Safety, Environment and Public Relations

DCA/kmr

Enc.

GEOMECHANICAL EVALUATION OF ROOM AND PILLAR MINING AT ORVANA'S COPPERWOOD DEPOSIT

Prepared for

ORVANA

By

Larry R. Standridge
David E. Nicholas, P.E.

March 2012

CALL & NICHOLAS, INC.

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1.0 SUMMARY AND RECOMMENDATIONS

This section presents the results of a geomechanical evaluation of the Copperwood deposit performed by Call & Nicholas, Inc. (CNI) at the request of Steve Milne of Milne & Associates. The purpose of the study was to analyze geomechanical conditions at Copperwood and determine mine design parameters using a room and pillar mining method.

CNI has not visited the property, touched the core or been involved in any of the data collection. We have accepted the data as is. CNI's analysis and recommendations are based on available data provided by Orvana. The sources of data are:

- Keane, J. M., Partington, L., Kerr, T. (2011). *Prefeasibility Study of the Copperwood Project, Upper Peninsula, Michigan, USA* (Document No. Q431-02-028). Tucson, Arizona.
- Pakalinis & Associates (2010). *Report on Preliminary Stability Assessment - Copperwood Project to Orvana* (No. ORVM-1/10).
- Uniaxial compression test results provided by Orvana of test conducted at Michigan Tech
- Parker, Jack. (1966). Mining in a Lateral Stress Field at White Pine. *"Rock Mechanics Session," Annual General Meeting, Quebec City, April, 1966.* Transactions, Volume LXIX, 1966, 375-383.
- Vermeulen, Luke, "Evaluating the Relationship Between Moisture Induced Expansion and Horizontal Stress Orientation in Samples from the Nonesuch Formation" (M.S. Civil Engineering Thesis Defense, Michigan Technological University).
- Agapito, J. F. and Litsenberger, J. (1993). Depth and Horizontal Stress Challenges at White Pine. *Presentation at the SME Annual Meeting, Reno, NV, February 15-18, 1993,* Preprint no. 93-110.

The general input parameters controlling the design analyses are:

- Depth: 100 ft to 975 ft (Figure 1-1)
- Ore thickness: 7.5ft to 13 ft with 80% less than 11 ft (Figure 1-2)
- Bedding Orientation:
  - Strike: N20W to N30E
  - Dip: 7 to 12 degrees to the north
- Average Compressive strength (Table 1-1):
  - Ore weakest formation (Domino) = 5400 psi
  - Back (Red Laminated) = 7470 psi
  - Floor (Copper Harbor) = 9330 psi

- Pre Mine Stress Conditions:
  - Principal Stress Orientation:
    - Azimuth = North/South
    - Plunge = 0 deg
  - Principal Stress Magnitude = 2 to 3 times Overburden Stress
- Phreatic Surface: Unknown – assumed near surface
- Pore Pressure Conditions: Depressurized 15 ft into back and floor

1.1 Recommendations

The following summarizes the recommendations used in the economic analysis of the Copperwood deposit:

1) Mining Direction : Generally along strike and down dip
2) Room Width: 20 ft with 8 ft long 5/8 inch diameter grouted cable bolts on 4ft by 4 ft centers staggered
3) Pillar Criteria and Dimensions:
   a. On the Advance:
      i. Factor of safety (FOS) is greater than or equal to 1.5
      ii. 16.5 ft x 45 ft to 22 ft x 56 ft depending on depth (Table 1-2)
      iii. Long axis of pillar is in the longitudinal (bedding strike) direction of mining (Figure 16.9)
   b. On the Retreat:
      i. FOS is greater than or equal to 1.2
      ii. Mining is in the transverse (down dip) direction
      iii. 16.5 ft x 16.5 ft to 22 ft x 22 ft depending on depth (Table 1-3)
4) Access (Figure 1-3):
   a. Access Drift Width: 20 ft with 8 ft long 5/8 inch diameter grouted cable bolts on 4 x 4 ft centers staggered, 4 x 4 inch W4D4 wire mesh (Grade 75), and a minimum of 2 inches of 4000 psi shotcrete.
   b. Internal Pillars: 15 ft wide and at least 100 ft long with a minimum 2 inches of 4000 psi shotcrete
   c. Barrier Pillars:
      i. 45 ft wide and at least 200 ft long for depths of 0 to 500 ft with a minimum of two (2) inches of 4000 psi shotcrete
      ii. 65 ft wide and at least 200 ft long for depths from 500 ft to 1100 ft with a minimum of two (2) inches of 4000 psi shotcrete

5) Subsidence: The room and pillar plan is based on a no to low probability of pillar failure criteria.
   a. To minimize the risk of subsidence cracks intersecting Lake Superior, no mining should be performed within 200 ft of Lake Superior and there should be no pillar recovery within 500 ft of Lake Superior.
   b. If no pillars fail, the subsidence will range between zero feet and 0.3 ft.
   c. If the pillars do fail, the estimated subsidence would be between zero feet and 5 ft, depending on the pillar height, depth below the surface, and failed area.

1.2 Additional Geomechanical Work Required

Additional work has been divided into two groups: work required before mining starts and work that should be performed during mining.

1.2.1 Work Required Before Mining Starts

Additional work required before the project can go forward is as follows:

1) Drill four (4) to six (6) core holes to collect geomechanical data, to collect samples for rock strength testing and, if necessary, to install piezometers to measure the phreatic surface.
2) In addition to the above core holes, drill at least two oriented core holes to determine the orientation of the joints in the deposit.
3) The rock strength data base must be improved. Testing per rock type should include the following:
   a. Triaxial Compression – 8 tests per rock type
   b. Uniaxial Compression – 4 tests per rock type
   c. Fracture Shear Strength – 4 test per rock type

   We estimate there are at least seven rock types: three in the ore zone, two in the back and two in the floor.
4) Map joint sets in any underground workings or on exposed outcrops in the area to provide guidance on joint lengths, spacing and orientation.

1.2.2 Work Required During Mining

Once development starts, stress measurements should be made to determine the stress conditions at Copperwood. The results from the stress measurements should be used in a numerical model to determine if the mine plan, as proposed, has any stress conditions that would require changes to ground support, room widths, or orientation of mine workings.

As the mine opens, cell and/or scan line mapping should be performed to determine joint orientations, lengths, and spacing as well identifying any faults in the mining area. The structure mapping should continue as new areas of the mine open. The mine design can then be re-evaluated and modified if necessary.

A monitoring program will be required for the life of the mine. The primary foundation should be convergence monitoring of pillars and the back. In addition borehole extensometers should be used early in the mining to evaluate pillar performance and back performance during advance and retreat mining. Given the large area of the mine, a micro seismic system would provide total coverage of the mine and provide early warning to stress build up.

Table 1-1: Average UCS for Geologic Units at Copperwood

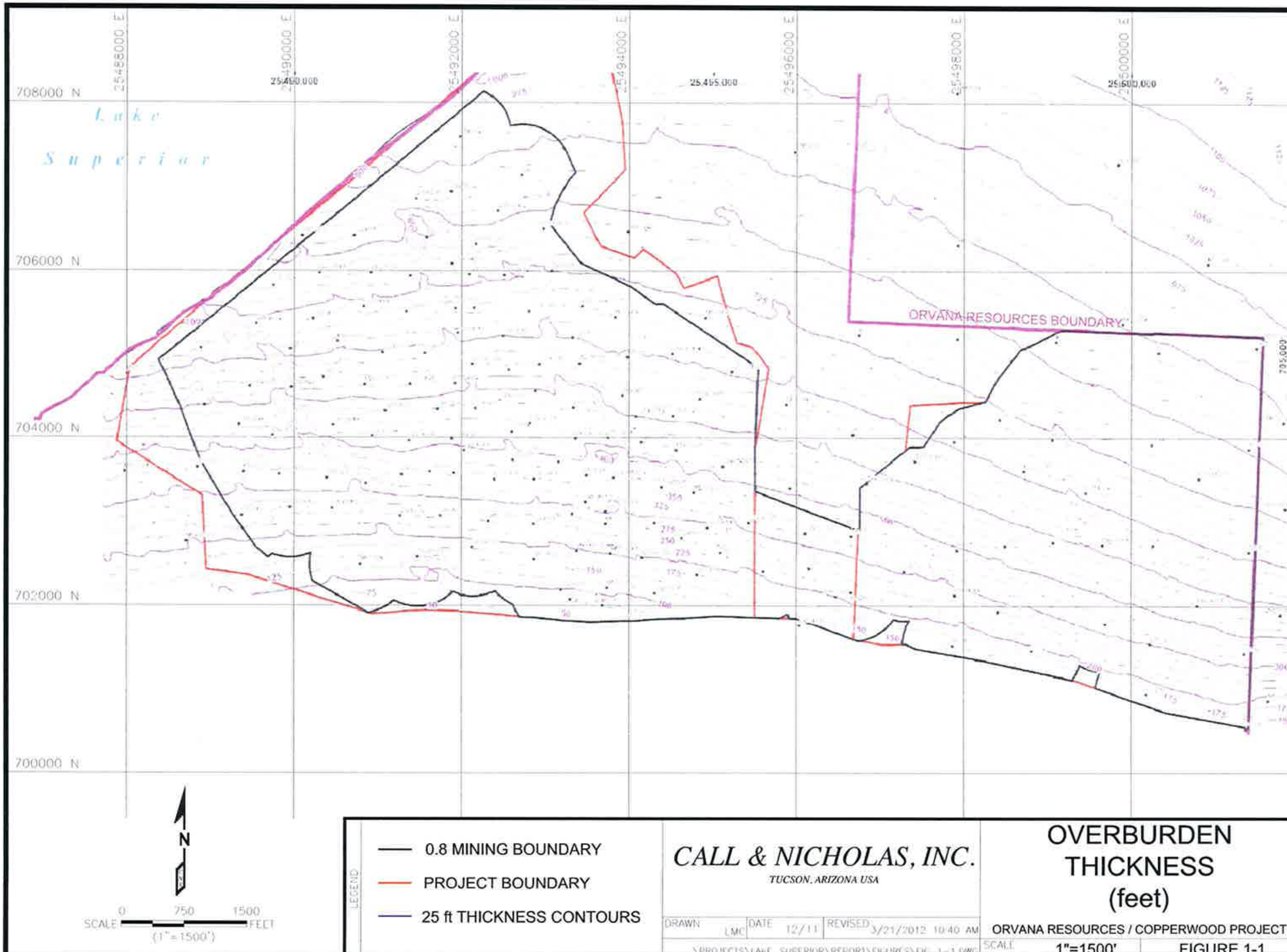
Main Ore Body			
Mining Position	Rock Unit	Number of Samples	Average UCS (psi)
	Upper Sandstone	5	9,210
Back	Red Siltsone	5	5,160
Back	Gray Siltstone	3	11,060
Back/Pillar	Red Laminated	15	7,470
Back/Pillar	Gray Laminated	9	11,130
Pillar	Red Massive	7	11,100
	Domino	17	5,400
Floor	Copper Harbor	18	9,330

Table 1-2: Advance Mining Pass Pillar Dimensions for Copperwood

Overburden Thickness (ft)	Length (ft)	Width (ft)	Area (ft^2)	Height (ft)	FOS	Recovery
300	46	17	782	11	1.8	68.0%
600	53	20.5	1086.5	11	1.7	63.3%
800	56	22	1232	11	1.6	61.4%
950	58	23	1334	11	1.6	60.2%
300	45	16.5	742.5	10	1.7	68.7%
600	52	20	1040	10	1.6	63.9%
800	55	21.5	1182.5	10	1.6	62.0%
950	56	22	1232	10	1.6	61.4%
300	44	16	704	7.5	1.7	69.4%
600	50	19	950	7.5	1.6	65.2%
800	52	20	1040	7.5	1.6	63.9%
950	54	21	1134	7.5	1.6	62.6%

Table 1-3: Retreat Mining Pass Pillar Dimensions for Copperwood

Overburden Thickness (ft)	Length (ft)	Width (ft)	Area (ft^2)	Height (ft)	FOS	Recovery
300	17	17	782	11	1.2	76.3%
600	20.5	20.5	1086.5	11	1.2	71.6%
800	22	22	1232	11	1.2	69.7%
950	23	23	1334	11	1.2	68.5%
300	16.5	16.5	742.5	10	1.2	77.0%
600	20	20	1040	10	1.2	72.2%
800	21.5	21.5	1182.5	10	1.2	70.3%
950	22	22	1232	10	1.2	69.7%
300	16	16	704	7.5	1.2	77.8%
600	19	19	950	7.5	1.2	73.6%
800	20	20	1040	7.5	1.2	72.2%
950	21	21	1134	7.5	1.2	70.9%



LEGEND

— 0.8 MINING BOUNDARY

— PROJECT BOUNDARY

— 25 ft THICKNESS CONTOURS

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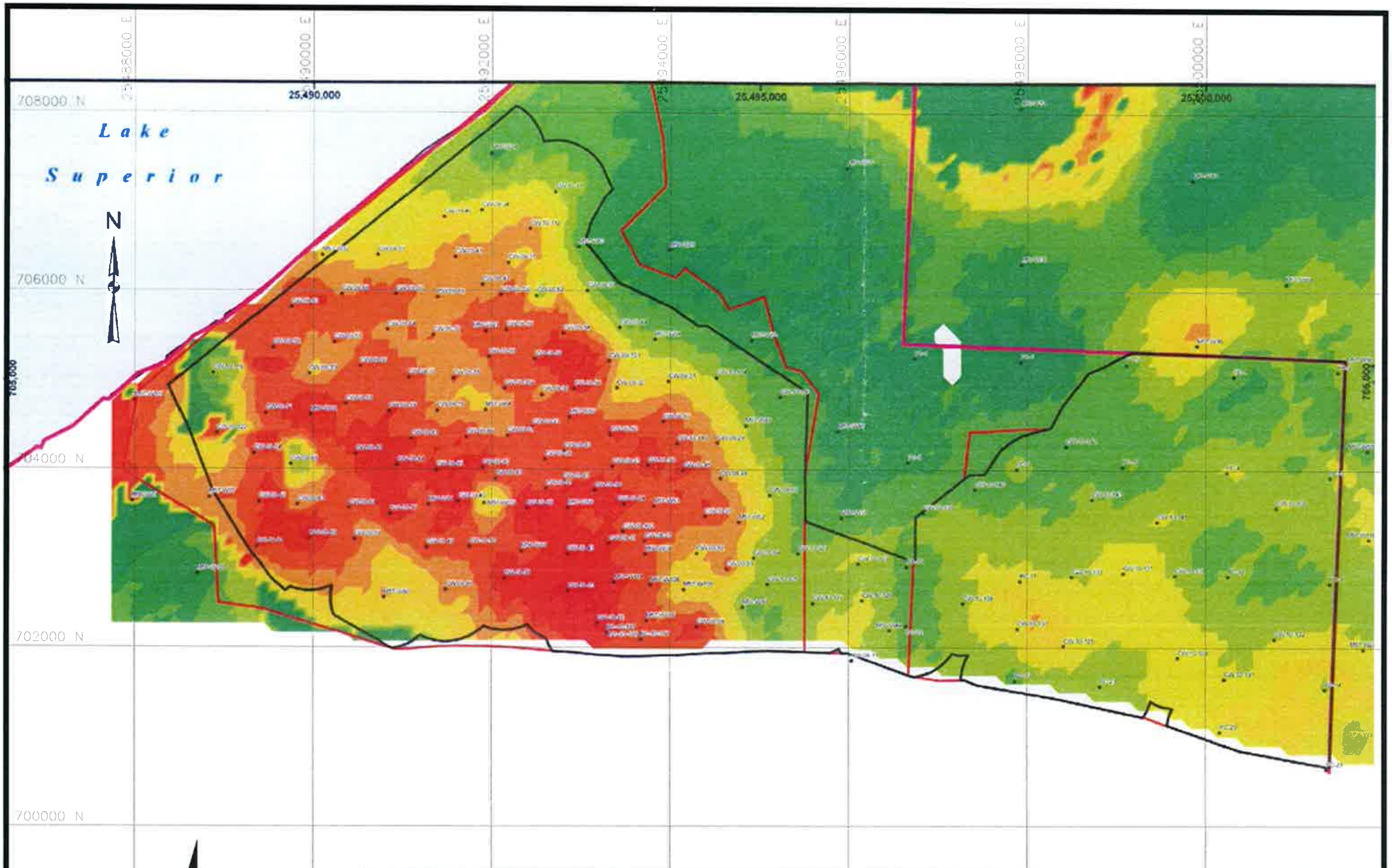
\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_1-1.DWG

OVERBURDEN THICKNESS (feet)

ORVANA RESOURCES / COPPERWOOD PROJECT

SCALE 1"=1500' FIGURE 1-1



LEGEND

Ore Thickness (Feet): < 4, 6, 6, 7, 8, 9, 10, 11, 12, > 12

0.8 MINING BOUNDARY

PROJECT BOUNDARY

SCALE 0 750 1500 FEET (1"=1500')

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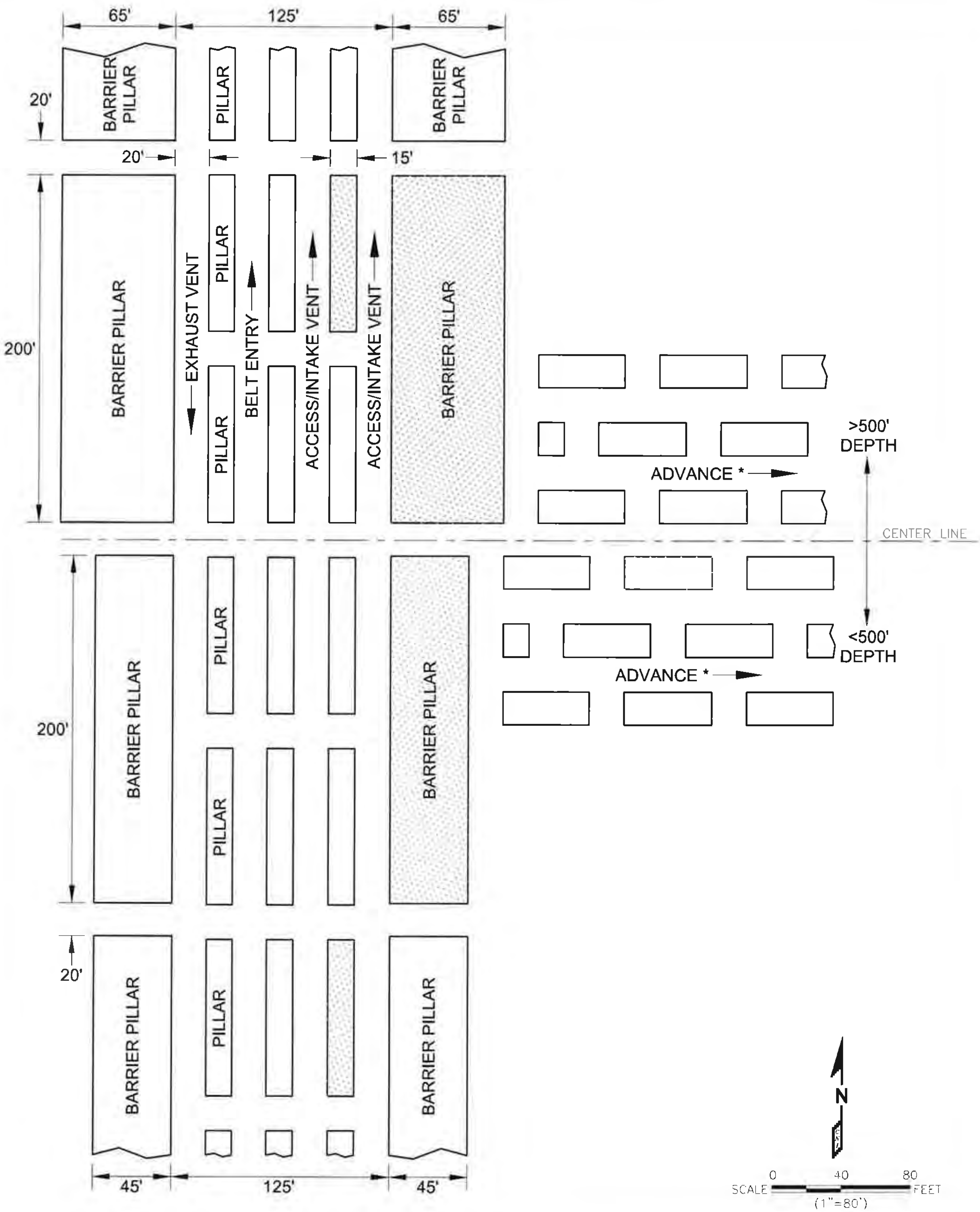
MINERALIZED ZONE THICKNESS (feet)

ORVANA RESOURCES / COPPERWOOD PROJECT

SCALE 1"=1500'

FIGURE 1-2



LEGEND

* ADVANCE PILLAR SIZES BASED ON 10' PILLAR HEIGHT AT 500' DEPTH

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Access Area Design

ORVANA RESOURCES / COPPERWOOD PROJECT

SCALE: 1"=80' | FIGURE 1-3

2.0 GEOLOGY

The Copperwood deposit is located adjacent to Lake Superior in the Upper Peninsula, Michigan in Gogebic County. The mineralized zone is contained in the Parting Shale at the base of the Nonesuch Formation shale and immediately above the Copper Harbor Formation (Figure 2-1).

The copper bearing sequence, which will also comprise the pillars, consists of the following units;

- Domino – the principal copper host, comprised of black shale and siltstone with an average thickness of 5.2 feet.
- Red Massive – a siltstone with an average thickness of 0.9 feet.
- Gray Laminated – a thinly bedded gray siltstone with an average thickness of 3.3 feet.

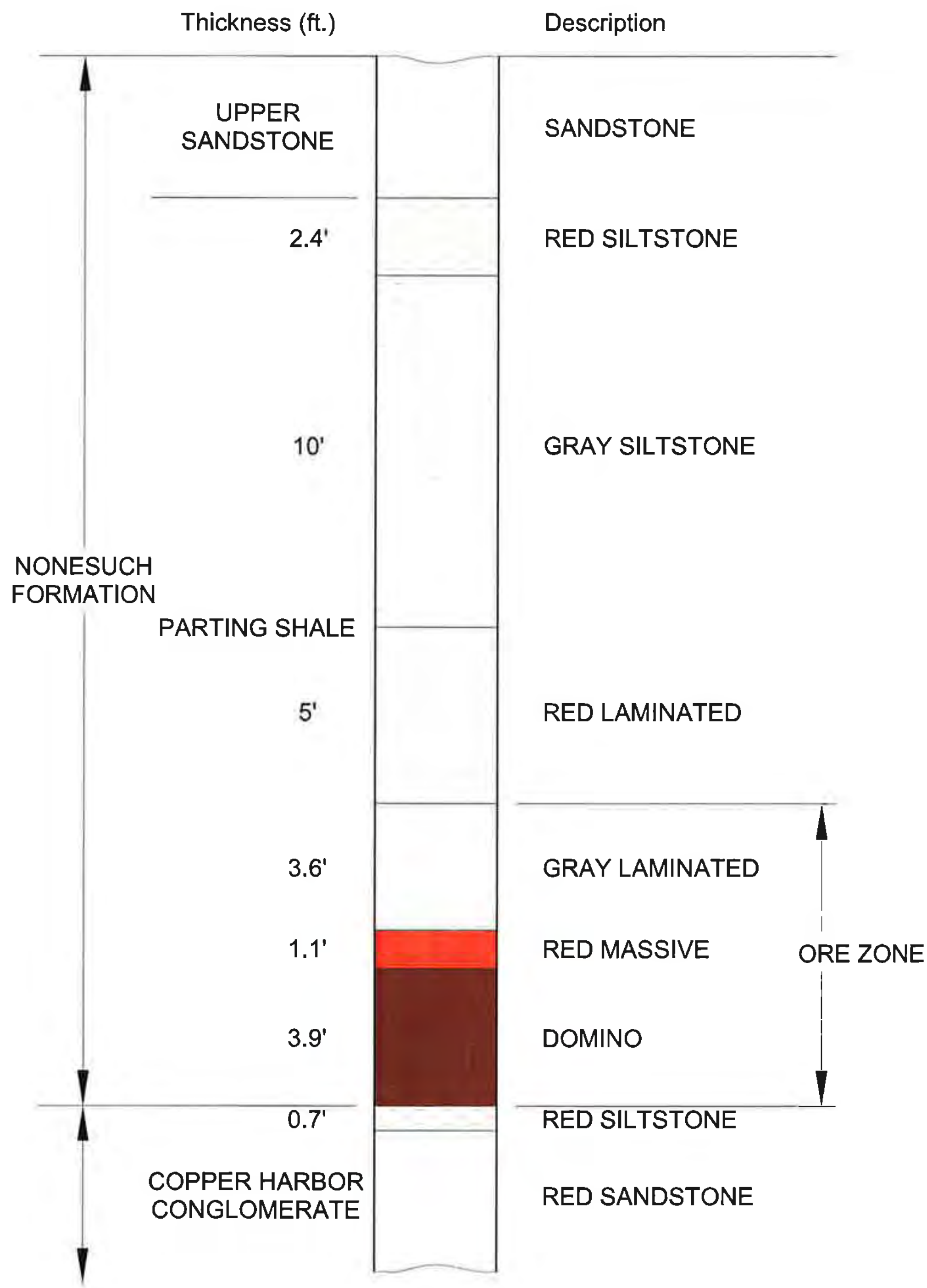
The back at Copperwood will mainly be in the Red Laminated unit. The average thickness of this siltstone unit is 4.6 feet with ranges from 0 to 10 feet. In some areas, due to grade cut offs, the upper portion of the Gray Laminated will not be mined and will remain in the back.

The floor will be in the units at the top of the Copper Harbor Formation. In some areas this will be the Red Siltstone unit, which is dominated by interlaminated siltstone and shale, while in others it will be a massive bedded sandstone with calcite cement.

2.1 Geologic Structure

The mineralized sequence within the Nonesuch Formation has a strike between N20W and N30E and dips gently to the north at 7 to 12 degrees. The overburden thickness increases from 66 feet at the southern project boundary to approximately 975 feet at the northern limits of the deposit. A north dipping shallow thrust fault striking N65E, with 10 to 23 feet of vertical displacement, has been interpreted from modeled surfaces and drill core. The lateral extent of this fault is unknown. Figure 2-2 shows the surface of the mineralized sequence along with the interpreted fault. CNI expects there to be more structures than just this one fault and that these structures are likely to impact pillar stability.

COPPERWOOD STRATIGRAPHY



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STRATIGRAPHIC COLUMN

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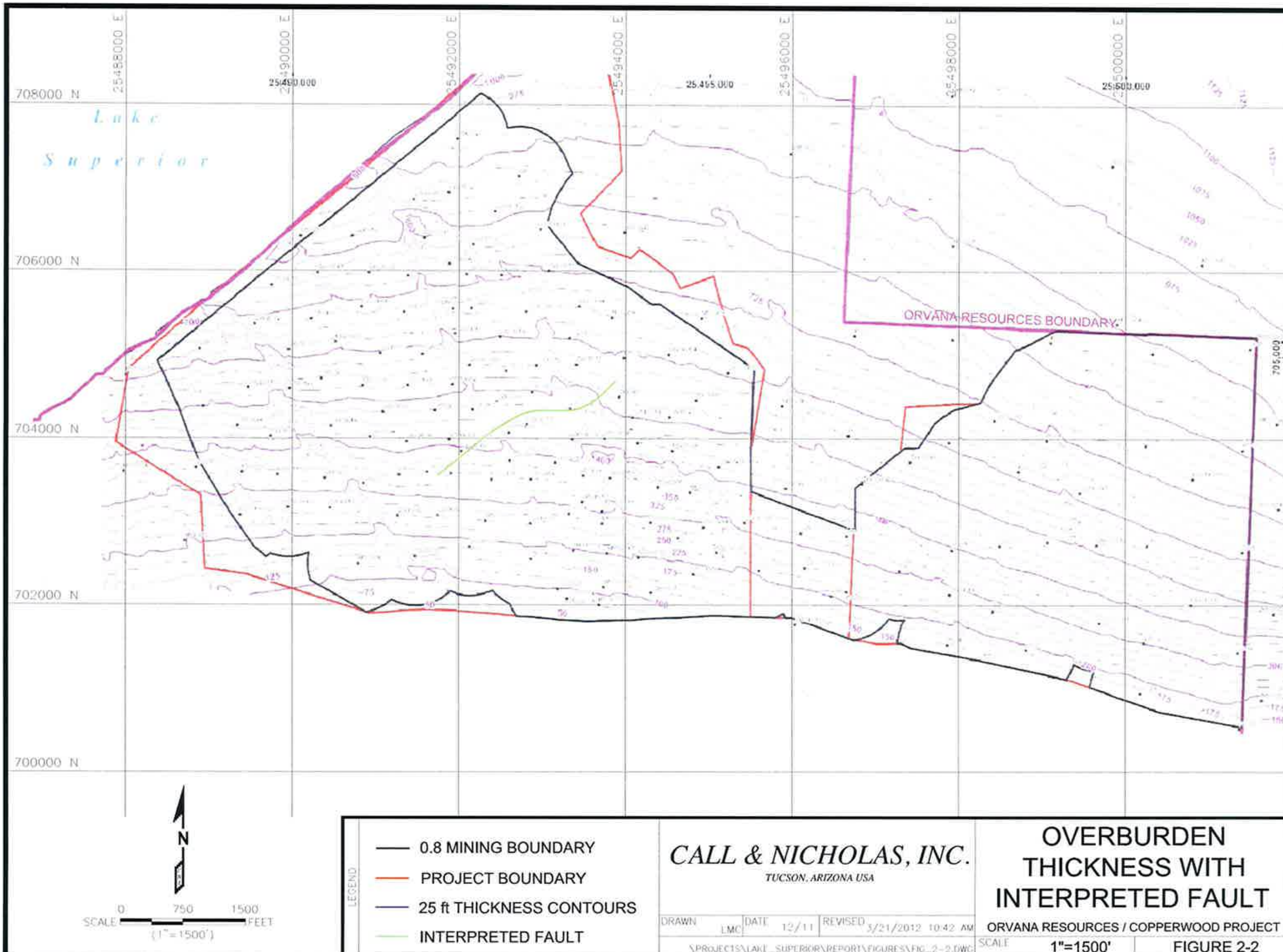
\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_2-1.DWG			SCALE 1"=5'	FIGURE 2-1



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SCALE 0 750 1500 FEET
(1"=1500')
LEGEND
0.8 MINING BOUNDARY
PROJECT BOUNDARY
25 ft THICKNESS CONTOURS
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CALL & NICHOLAS, INC.
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\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_2-2.DWG
OVERBURDEN THICKNESS WITH INTERPRETED FAULT
ORVANA RESOURCES / COPPERWOOD PROJECT
SCALE 1"=1500'
FIGURE 2-2

3.0 PRE-MINE STRESS CONDITIONS AND HYDROLOGY

No stress measurements are available for the Copperwood deposit; however, stress measurements were taken at the White Pine Mine. The White Pine Mine, located about 18 miles northeast of Copperwood, produced about 4.5 billion lbs of copper between 1954 and 1996 from the same overall Stratigraphic position as the Copperwood mineralized zone. High horizontal stresses at White Pine, which in some instances were more than three times the vertical stress, caused both back and pillar failures. The back failures were often violent and occurred days or even months after the back was exposed. The mining methods at White Pine, including pillar dimensions, ground support, and mine orientation, were modified to deal with the impacts of the horizontal stresses.

For the purpose of this study, stress ratios of 2H:1V up to 3H:1V have been assumed at Copperwood. These ratios are similar to those experienced at White Pine. The orientation is assumed to be a North-South direction perpendicular to the Keweenaw Fault. Table 3-1 presents the magnitude and orientation assumptions for the principal stresses at Copperwood. The magnitude and orientation of the horizontal stress field should be measured at Copperwood to verify this assumption. If necessary, the ground support, pillar designs and/or development orientations may need to be modified to reduce the impact of the high horizontal stresses.

CNI has not seen any hydrology data for the Copperwood project site but has assumed that the phreatic level is near the surface. For analysis purposes, it is assumed that the mining area will be depressurized in a zone extending from 15 feet above the back to 15 feet below the floor and that this depressurized condition will continue for the life of mine.

Table 3-1: Stress Assumptions for Copperwood

Copperwood Stress Assumptions		
Principle Stress	Orientation	Magnitude
σ_1	North/South	(2 to 3) * ρ * h
σ_2	Vertical	ρ * h
σ_3	East/West	(0.5 to 0.8) * ρ * h

Where:

ρ = Density
h = Depth

4.0 ROCK STRENGTHS

A key element of any geotechnical study is the determination of the mechanical properties of the various rock types within and around the area to be mined. The strength properties of the rock must be defined for both the fractures and intact rock. With these properties the rock-mass strength can be estimated.

The term rock mass refers to the rock on a large scale and represents the composite system of intact rock, faults, joints, and other planes of weakness present within a given rock unit. Since rock-mass properties cannot be measured directly, estimates of the rock-mass properties are made using methods that relate the rock-mass properties to the more easily measured intact rock and fracture shear strength properties. Therefore, the mechanical properties of the rock mass will be dependent on the characteristics of the intact rock and the discontinuities present.

4.1 Intact Shear Strength

In a uniaxial compression test, a cylinder of drill core is loaded axially without lateral confining load until the sample fails. Unless the specimen fails along an obvious discontinuity, the compressive strength determined by uniaxial compression testing should be assigned to the intact rock. For this study, 79 uniaxial compression tests were reviewed. These tests were conducted at Michigan Tech on samples collected from the main ore body. Table 4-1 contains the number of samples and the average UCS for each of the geologic units tested while Figure 4-1 shows the distribution of the uniaxial test results for the Domino, which is the weakest unit in the pillars.

At White Pine, for comparison, the UCS for dry samples collected from the pillars ranged from 19,500 to 29,700 psi while the range of UCS for the Domino at Copperwood is between 1,230 and 16,600 psi. The rocks at White Pine typically experienced a 50% or more reduction in UCS when wet (10,200 – 10,500 psi). The samples tested at Copperwood were dry so additional test should be performed on saturated samples to determine wet UCS strengths.

Additional parameters needed to determine the intact shear strength have been estimated using empirical methods from the UCS results. Tensile strength of intact rock is typically between $\frac{1}{10}$ and $\frac{1}{16}$ of the UCS. For this study a tensile strength equal to $\frac{1}{12}$ of the UCS has been used. The estimate for the linear triaxial compressive strength, defined by the intact friction angle (ϕ_s) and the intact cohesion (c_s), is based on the following equations where $m = \frac{UCS}{Tension}$ (or 12);

$$\phi_s = 0.85 \cdot \left[\tan^{-1}\left(\frac{m-1}{2\sqrt{m}} \right) \right] \qquad c_s = 0.98 \cdot \left(\frac{\sigma_c}{2\sqrt{m}} \right)$$

Table 4-2 presents the average UCS along with the estimated tensile strength, intact friction angle, and intact cohesion for the units tested.

4.2 Estimate of Fracture Shear Strength

Fracture shear strength is the shear strength along existing fractures within the rock. This strength is typically determined by direct-shear test conducted on two pieces of rock core that are separated by a natural fracture; a load perpendicular to the fracture is applied, and then the shear load necessary to displace the blocks relative to each other is monitored. The shear strengths of the fractures for each rock type can then be calculated by using the data from multiple direct shear tests at varying normal loads.

In the absence of direct-shear test, CNI estimated the fracture shear strengths based on laboratory test for similar rock types from different locations. For this study a shear friction angle (ϕ_f) of 28° with a shear cohesion (c_f) of 2 psi were used.

4.3 Rock Quality Designation (RQD)

RQD is used to represent the degree of fracturing within the rock-mass. It is defined as the percentage of drill core with a length ≥ 2 times the core diameter. Figure 4-2 shows the distribution of the RQD data for the mineralized zone at Copperwood. An RQD of 80%, which approximately 90% of the logged core is greater than, was assumed for calculations during this evaluation.

4.4 Rock-Mass Strength

Rock-mass strength parameters are necessary to evaluate geotechnical conditions and support requirements of the proposed mine openings. Through the assessment of intact-rock properties, fracture properties and the intensity of fracturing, empirical estimates of the rock-mass strength can be derived. The rock-mass shear strength is bracketed on the high end by the intact rock strength and on the low end by the fracture shear strength.

Rock-mass strength values were estimated for the Red Laminated, Domino, and Red Sandstone rock types (Table 4-3) using an approach developed at CNI (Karzulovic, Antonio. 2009. "Rock Mass Model." In Guidelines for Open Pit Slope Design, edited by John Read and Peter Stacey, 128-130. Australia: CSIRO Publishing.). The Red Laminate is the dominant rock type in the back while the Red Sandstone occurs mainly in the floor, and the Domino is the weakest unit in the pillars. The method derives estimates of the rock-mass strength through a combination of fracture and intact shear strengths along with the degree of fracturing (RQD) present in the rock mass. An example showing the Domino rock-mass calculation is illustrated in Figure 4-3.

Table 4-1: Uniaxial Compressive Test Data

Main Ore Body		
Unit	# Samples	Average UCS (psi)
Upper Sandstone	5	9,210
(Red) Siltstone	5	5,160
Gray Siltstone	3	11,060
Red Laminated (B	15	7,470
Gray Laminated	9	11,130
Red Massive	7	11,100
Domino (Pillar)	17	5,400
Copper Harbor (Fl	18	9,330

Table 4-2: Intact Properties used in Rock-Mass Strength Calculations

Intact Properties				
Unit	Average UCS (psi)	Estimated Values		
		Tensile Strength (psi)	Friction Angle (deg)	Cohesion (psi)
Upper Sandstone	9,210	770	49.1	1300
(Red) Siltstone	5,160	430	49.1	730
Gray Siltstone	11,060	920	49.1	1560
Red Laminated	7,470	620	49.1	1060
Gray Laminated	11,130	930	49.1	1570
Red Massive	11,100	930	49.1	1570
Domino	5,400	450	49.1	760
Copper Harbor	9,330	780	49.1	1320

Table 4-3: Rock-Mass Strength Values

Rock-Mass Strengths				
Rock Type	Mining Position	Tensile Strength (psi)	Friction Angle (deg)	Cohesion (psi)
Red Laminated	Back	75	39.6	210
Domino	Pillar	55	39.6	160
Red Sandstone	Floor	95	39.6	270

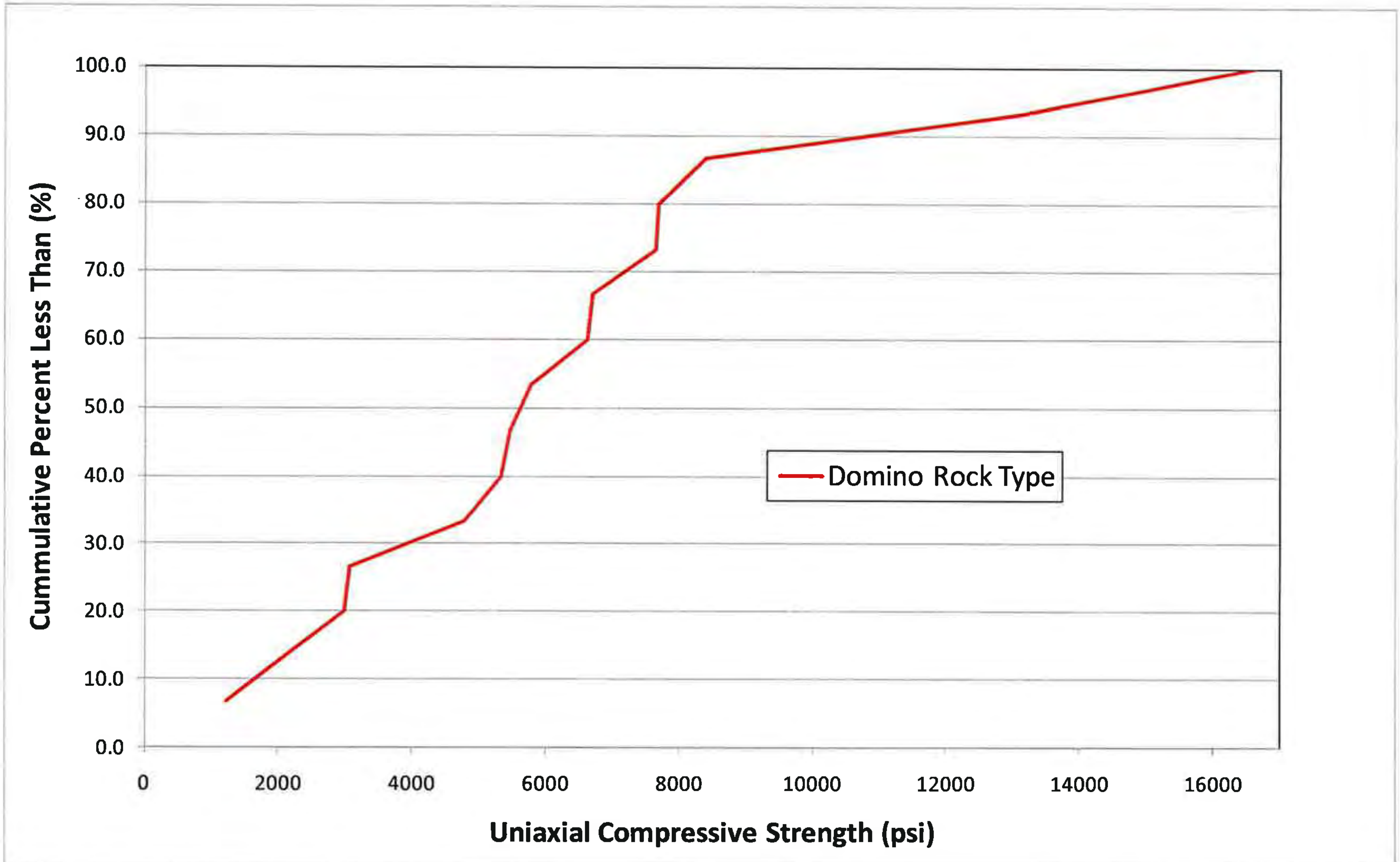


Figure 4-1: Distribution of Domino UCS Test

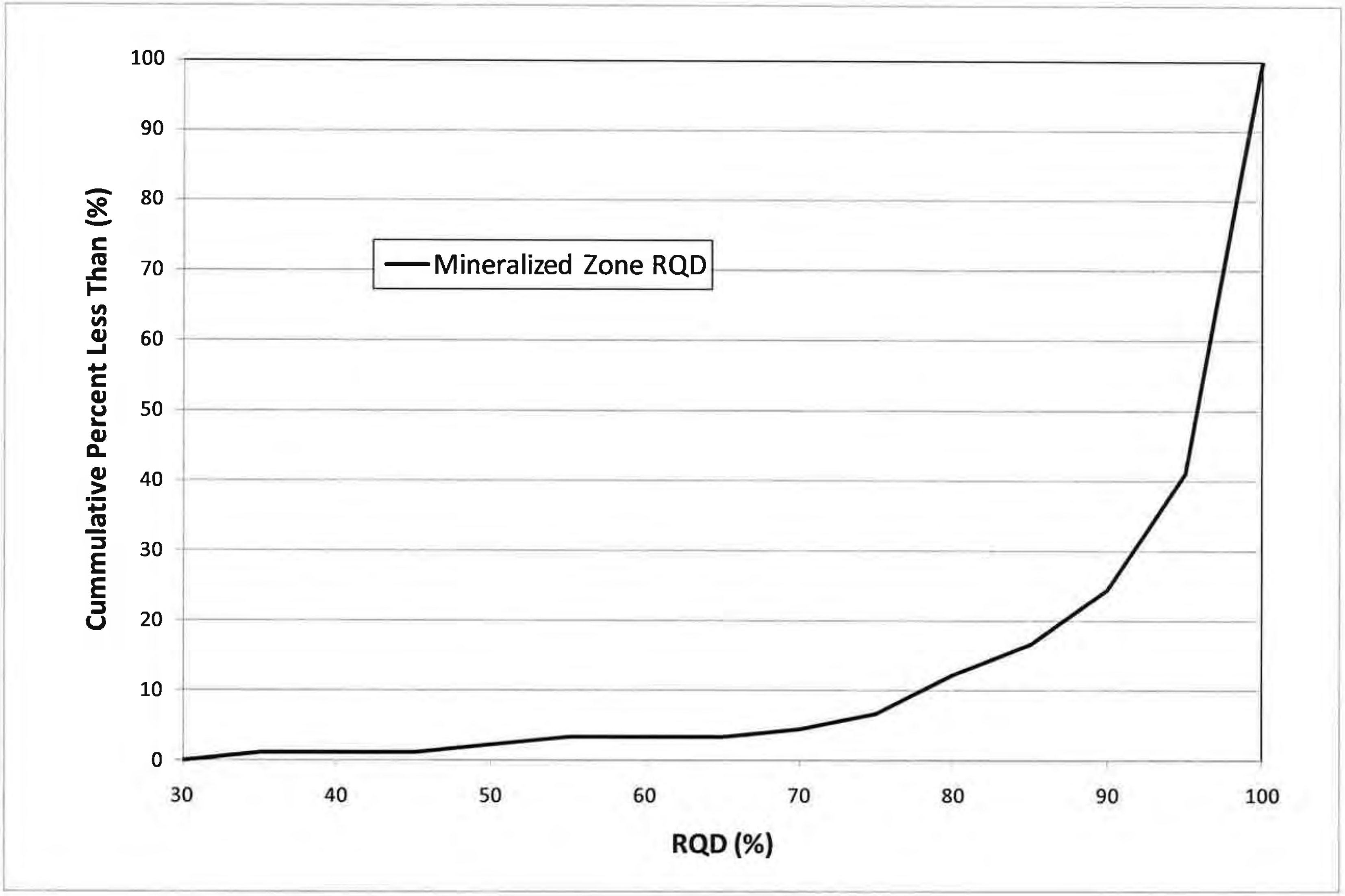


Figure 4-2: RQD Distribution for Mineralized Zone

(a) Substance

σ_{cs} = 5403.0 psi

σ_{ts} = 450.3 psi

for : $\frac{E}{\sigma_c}$ = 740.3

E_s = 4.000 (10^6) psi

ν_s = 0.25

$m = \frac{\sigma_c}{\sigma_t}$ = 12.00

	Empirical	Triaxial
$\phi_s = 0.85 \cdot \left[\tan^{-1}\left(\frac{m-1}{2\sqrt{m}}\right)\right]$ =	49.1 °	49.1 °
$c_s = 0.98 \cdot \left(\frac{\sigma_c}{2\sqrt{m}}\right)$ =	764.3 psi	764.3 psi

(b) Fracture

Filling: None

ϕ_f = 28.0 °

c_f = 2 psi

RQD = 80 %

k_s = 0 psi/in

$k_n = 20 \cdot k_s$ = 0 psi/in

c_{rf} = 0.5

Mi = 25

RMR = 45

S3 Max = 2500

(c) Mass

PRS = % Rock Substance PRF = % Rock Fracture

$PRS(\phi) = \left[0.3775 \cdot e^{0.0075 \cdot RQD}\right]^2$ = 0.4731

$PRS(c) = \left[0.225 \cdot e^{0.013 \cdot RQD}\right]^2$ = 0.4052

$PRF(\phi) = 1 - PRS(\phi)$ = 0.5269

$PRF(c) = 1 - PRS(c)$ = 0.5948

$\phi_m = \tan^{-1}\left[PRS(\phi) \cdot \tan(\phi_s) + PRF(\phi) \cdot \tan(\phi_f)\right]$ = 39.6 °

$c_m = \left[PRS(c) \cdot c_s + PRF \cdot c_f\right] \cdot c_{rf}$ = 155.5 psi

$E_m = E_s \sqrt{PRS(c)}$ = 2.546 (10^6) psi

$\nu_m = \frac{1 - \sin\phi_m}{2 - \sin\phi_m}$ = 0.27

$\sigma_{cm} = 2c_m \tan(45 + \frac{\phi_m}{2})$ = 660.2 psi

$\sigma_{tm} = \frac{\sigma_{cm} \cdot \sigma_{ts}}{\sigma_{cs}}$ = 55.0 psi

γ_s = 165 lbs/ft^3

Figure 4-3: Rock-mass Calculation for Domino

5.0 ROOM AND PILLAR DIMENSIONS

Based on the geomechanical characteristics, CNI has provided following parameters for room and pillar mining at the Copperwood property:

1. Mining Sequence
2. Room Parameters
   a. Orientation of primary rooms
   b. Room widths
   c. Ground support
3. Pillar dimensions given mining thickness, overburden thickness (OBT), and rock strengths
4. Access Parameters
   a. Room Widths
   b. Pillar Sizes
   c. Ground Support

5.1 Mining Sequence

From a geomechanical point of view, mining of the Copperwood deposit should utilize an advance mining pass with pillar dimensions that result in a high reliability, and retreat to the mine entrance with a partial pillar recovery. The access location has already been identified and is located on the south end of the deposit. Consequently advance mining should start at the north, end and progress to the south. Because of the time to develop the access to the north, advance mining can be performed in some of the areas until access to the north is reached. Panels should be defined to fit the mining sequence but from a geotechnical point of view, a panel width that includes three or four rooms would be appropriate.

The panels can be developed on the advance out to the east and west limits. The distance between primary mining and pillar recovery should be in the range of 300 ft. This distance should provide sufficient buffer so that the ground in the primary mining is not impacted by the stress change due to pillar recovery.

5.2 Room Orientation, Widths, and Support

From a mining operation perspective, the long axis of development should be parallel to the strike of bedding which is between N20W and N30E. This will provide the least amount of dilution and result in a flat floor. The design recommendations call for production drifts in an east/west orientation with crosscuts being aligned parallel to dip in a north/south direction. From White Pine's experience with high horizontal stress, they found that developing the dominant room parallel to the primary stress reduced failures in the back. Unfortunately the direction of the horizontal stress is near north/south which is perpendicular to the continuous room but parallel with the crosscuts. The high horizontal stress at White Pine was in the range of 4000 to 10,000 psi while at Copperwood the high horizontal stress will be in the range of 800 to 4000 psi. The rock mass compressive strength of the rock in the back is in the range of 4000 to 6000 psi which should be able to handle most of the high stress.

The work performed by Marston & Associates for the prefeasibility study indicated that a 20 ft room width was acceptable. CNI agrees with this assessment as long as a beam equal to ¼ of the span can be maintained.

The ground support required to minimize instability due to the high stress is as follows (Figure 5-1):

1. Fully grouted cable bolts 8 ft long and 5/8 inch diameter
2. Bolt spacing of 4 ft centers and staggered

Welded wire mesh or straps can be used in areas where the rock is highly fractured.

5.3 Production Pillars

Pillar dimensions were determined by calculating the load that the pillars can carry using A.H. Wilson's (1972) method and comparing that to the estimated load on the pillar.

Wilson's method of calculating the load carrying capacity of a pillar is based on field measurements where the outer yield zone carries little load but confines the core of the pillar and the confined core carries most of the load. The load on the production pillars was based on the tributary load area (TAL), which means that each pillar is designed to carry the entire overburden load halfway to each adjacent pillar. The tributary area load was used because the width of the deposit is so great that the stresses cannot arch across the entire deposit (Figure 5-2). The calculation for tributary area load (TAL) is as follows:

$$TAL = (W + R) * (L + R) * OBT * \gamma$$

Where:

W = Pillar width (ft) L = Pillar length (ft)
R = Room width (ft) OBT = Over Burden Thickness (ft)
γ = Density (lb/ft^3)

The over burden thickness at Copperwood ranges from approximately 100 ft in the south to nearly 975 ft at the northern boundary of the project area (Figure 5-3) while the mineralized zone ranges from 7.5 to 13 ft (Figure 5-4). The design criteria used to determine ore pillar dimensions are as follows:

1. Load = TAL to the surface
2. OBT ranges = 300, 600, 800, and 950 ft
3. Pillar heights = 7.5, 10, and 11 ft
4. Minimum FOS:
   a. Primary Mining – FOS ≥ 1.5
   b. Pillar Recovery – FOS ≥ 1.2

The rectangular pillar dimensions for the advance mining pass (Table 5-1) range from 16.5 ft x 45 ft to 22 ft x 56 ft depending on the overburden thickness and depth. They are offset from one side of the panel drift to the other at a distance equal to half the pillar length (Figure 5-5). The purpose of this offset is to limit the intersection area during primary mining and to ensure easy access for the pillar recovery. The offset creates a geometry where the crosscuts on one side of the panel drift line up with the center of the pillar on the opposite side. The pillar recovery is accomplished by bisecting the rectangular pillars with a 12 ft wide room of material from the center (length wise) of the pillars resulting in two square pillars (Table 5-2).

As additional rock strength testing, geologic mapping, hydrology, monitoring, and pillar performance becomes available, the pillar analysis should be updated to ensure acceptable safety factors or to maximize recovery.

As presented in Section 4, the units in the back (Red Laminated) and floor (Red Sandstone) have a significantly higher rock-mass strength than the pillar units (Domino). Therefore the pillars should not punch into the back or floor.

5.4 Access

For access and ventilation four drifts are required. The access drifts must be stable for the life of the mine and therefore require a high reliability. The four access drifts are 20 ft wide separated by long internal pillars that are 15 ft wide and at least 100 ft long. Cross cuts, which can be up to 20 ft wide, should be offset between drifts to minimize intersection area. They can, however, be aligned to improve access but additional ground support may be required.

To provide the high reliability and minimize maintenance, the ground support required is as follows:

1) 8 ft long, 5/8 inch diameter fully grouted cable bolts
2) Bolt spacing of 4 ft centers and staggered
3) 4 x 4 inch W4D4 wire mesh (Grade 75)
4) Shotcrete the pillars with a minimum of 2 inches of 4000 psi.

The shotcrete is needed to minimize the air slacking of pillar's sides. If air slacking were permitted then the effective pillar dimensions would be reduced, possibly resulting in instability.

The internal pillars are designed at a FOS ≥ 1.5 using the tributary area load with an overburden thickness of 800 ft. The access drifts are isolated from the mining panels by barrier pillars on each side. The barrier pillars are designed at a FOS ≥ 1.5 with an area load equivalent to the load transfer distance (LTD) over the mining panels plus half the width of the access area for 500 and 800 ft depths (Figure 5-6). This load design assumes that the production pillars adjacent to the barrier pillars have all failed. The load calculation for the barrier pillars is as follows:

$$Load = (1/2A_w + W + T_m)(L + R)D\gamma$$

Where:

A_w = Access width (125 ft)
W = Pillar width (ft)
T_m= Maximum load transfer distance $[0.2822(D) - 3.835 \times 10^{-5}(D)^2 - 8]$
L = Pillar length (ft)
R = Room width (ft)
D = Depth or Overburden Thickness (ft)
γ = Density (lb/ft^3)

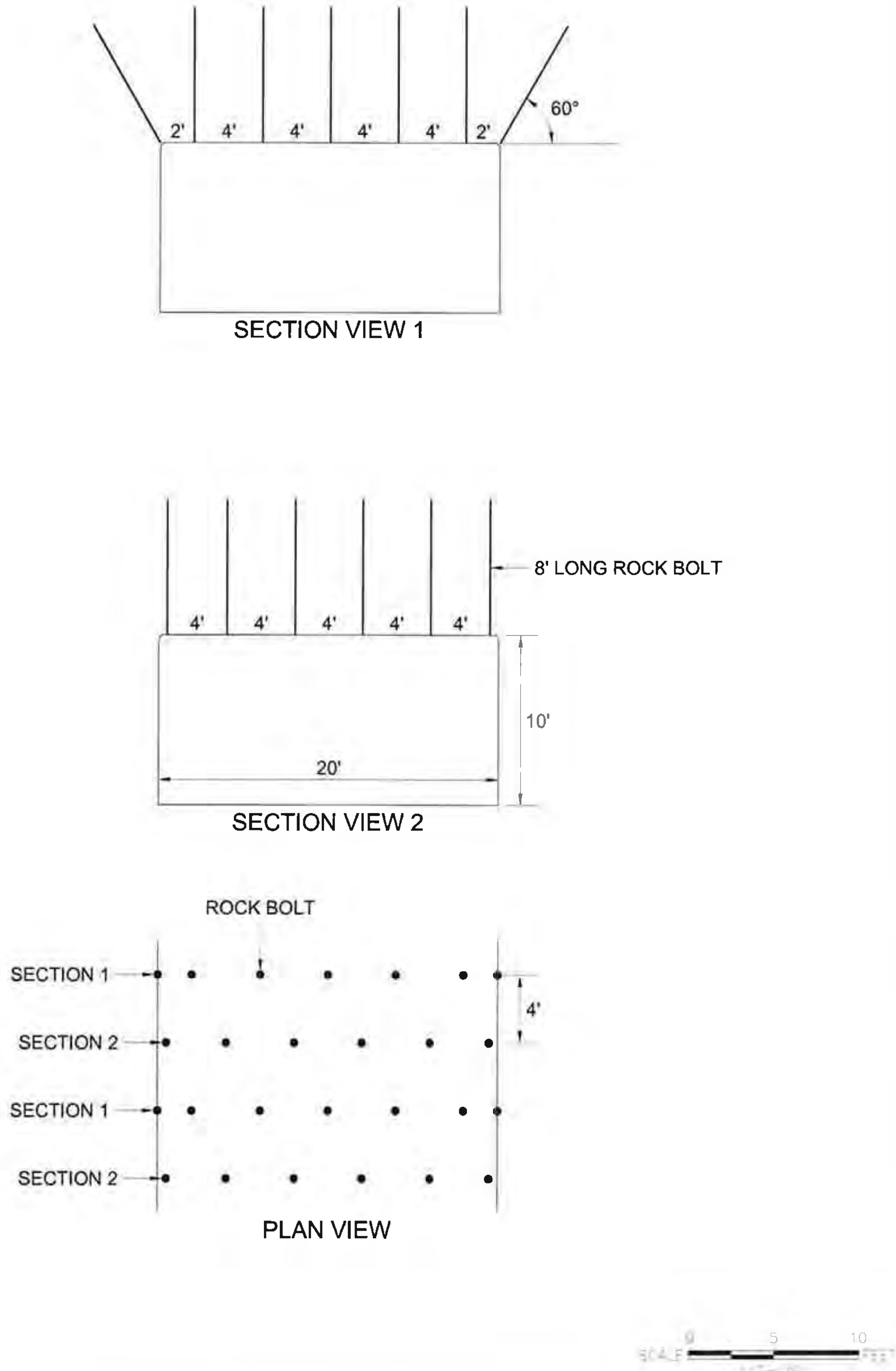
Figure 5-7 shows the layout for the access areas as they transition from the 500 ft OBT design to the 800 ft OBT design.

Table 5-1 – Advance Mining Pass Pillar Dimensions for Copperwood

Overburden Thickness (ft)	Length (ft)	Width (ft)	Area (ft^2)	Height (ft)	FOS	Recovery
300	46	17	782	11	1.8	68.0%
600	53	20.5	1086.5	11	1.7	63.3%
800	56	22	1232	11	1.6	61.4%
950	58	23	1334	11	1.6	60.2%
300	45	16.5	742.5	10	1.7	68.7%
600	52	20	1040	10	1.6	63.9%
800	55	21.5	1182.5	10	1.6	62.0%
950	56	22	1232	10	1.6	61.4%
300	44	16	704	7.5	1.7	69.4%
600	50	19	950	7.5	1.6	65.2%
800	52	20	1040	7.5	1.6	63.9%
950	54	21	1134	7.5	1.6	62.6%

Table 5-2 – Retreat Mining Pass Pillar Dimensions for Copperwood

Overburden Thickness (ft)	Length (ft)	Width (ft)	Area (ft^2)	Height (ft)	FOS	Recovery
300	17	17	782	11	1.2	76.3%
600	20.5	20.5	1086.5	11	1.2	71.6%
800	22	22	1232	11	1.2	69.7%
950	23	23	1334	11	1.2	68.5%
300	16.5	16.5	742.5	10	1.2	77.0%
600	20	20	1040	10	1.2	72.2%
800	21.5	21.5	1182.5	10	1.2	70.3%
950	22	22	1232	10	1.2	69.7%
300	16	16	704	7.5	1.2	77.8%
600	19	19	950	7.5	1.2	73.6%
800	20	20	1040	7.5	1.2	72.2%
950	21	21	1134	7.5	1.2	70.9%



LEGEND

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PROPOSED ROCK BOLT PATTERN PRODUCTION MINING

ORVANA RESOURCES / COPPERWOOD PROJECT

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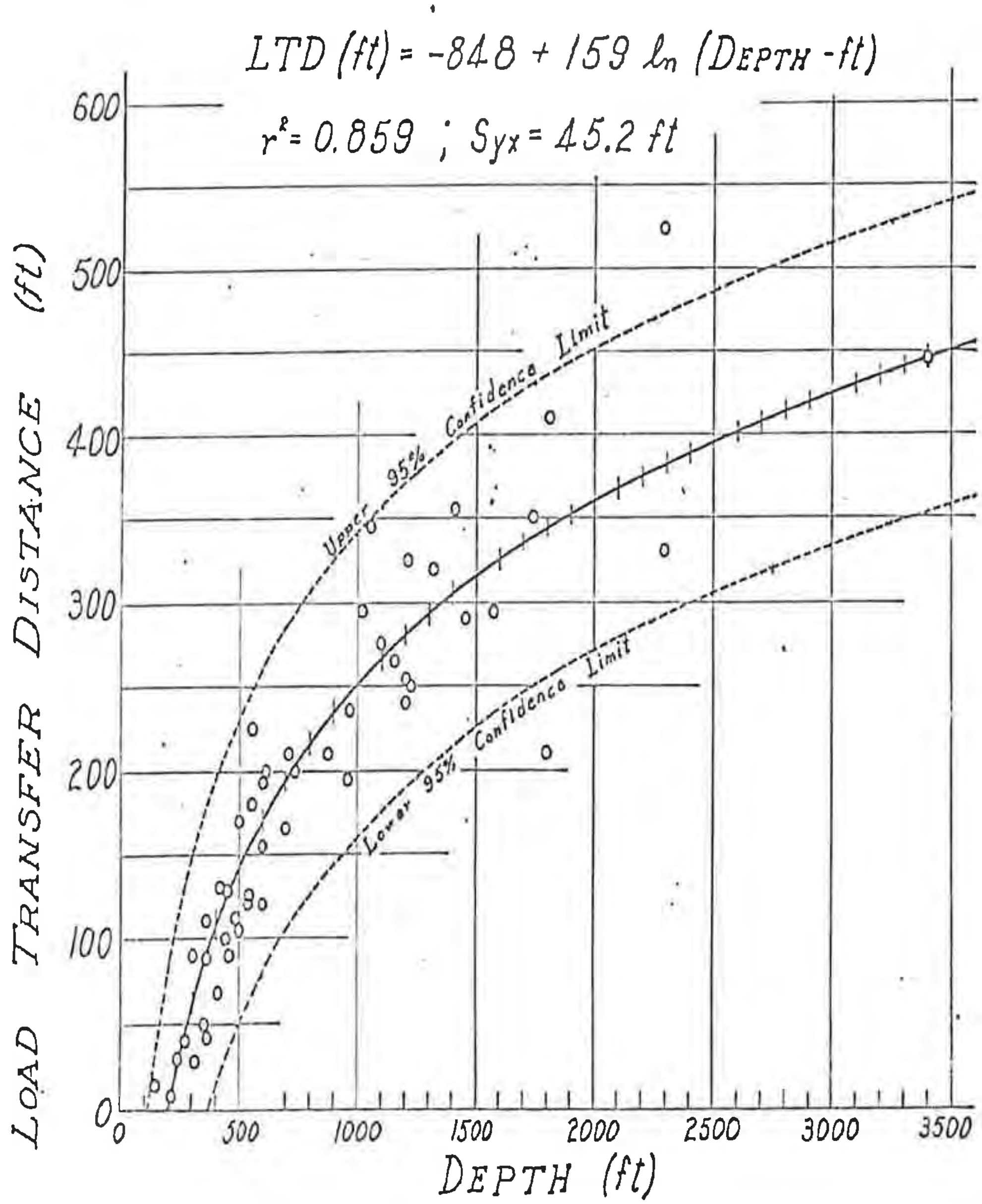
PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-1.DWG

SCALE 1"=10' | FIGURE 5-1



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MAXIMUM TRANSFER DISTANCE RELATED TO DEPTH FOR COAL

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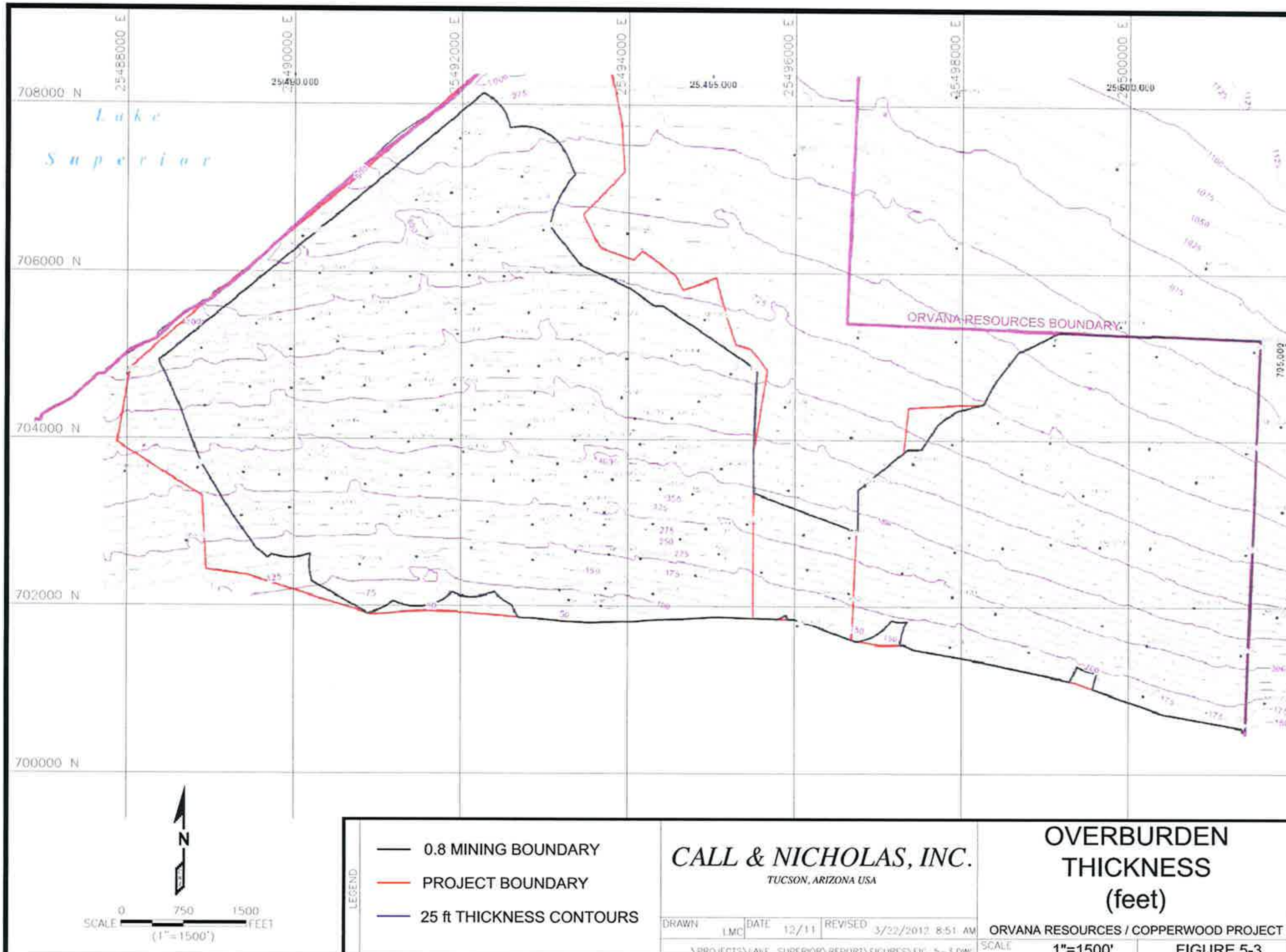
\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-2.DWG

SCALE N.T.S. | FIGURE 5-2



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\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-3.DWG

OVERBURDEN THICKNESS (feet)

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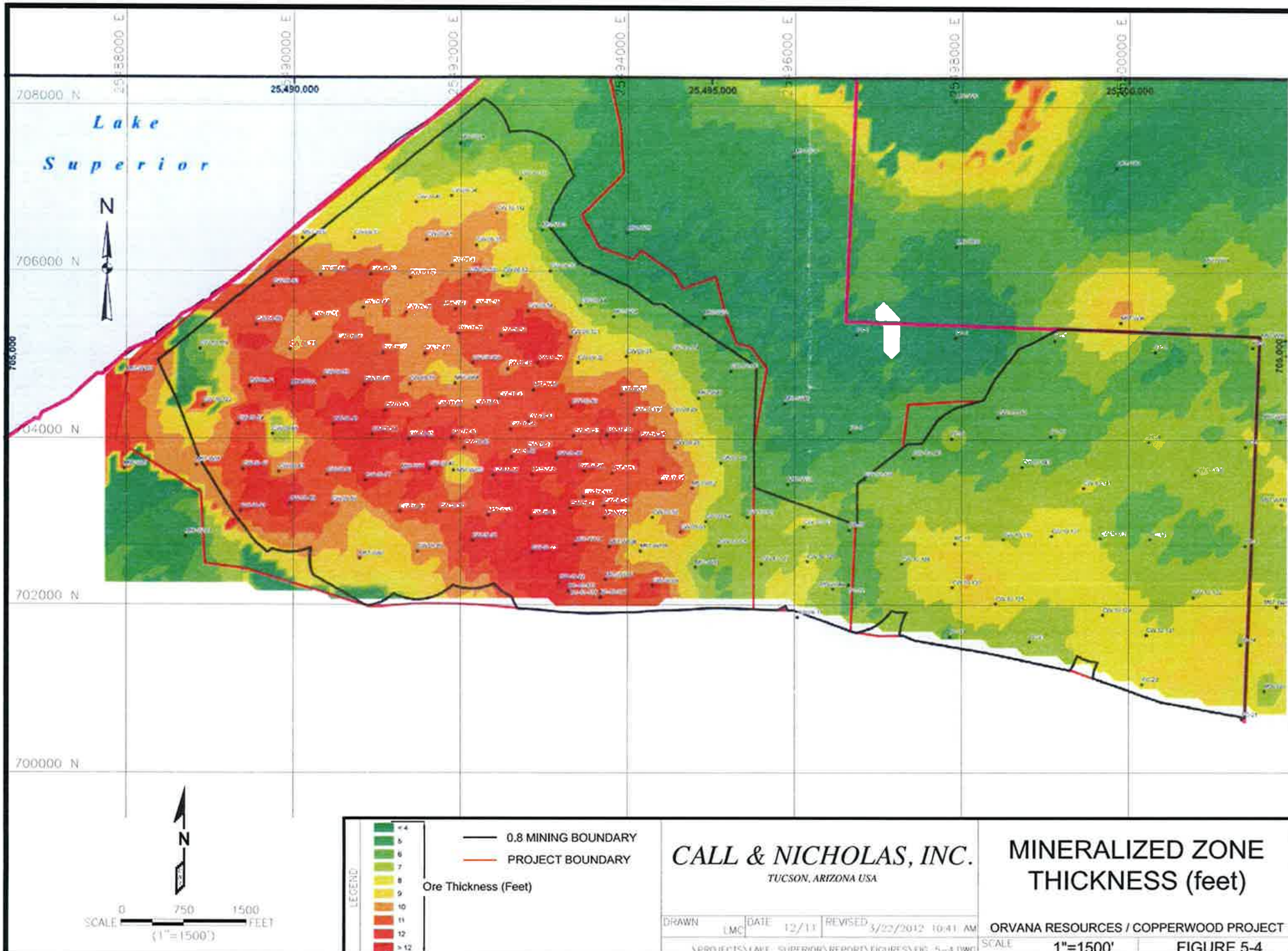
SCALE 1"=1500' | FIGURE 5-3



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\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-4.DWG

MINERALIZED ZONE THICKNESS (feet)

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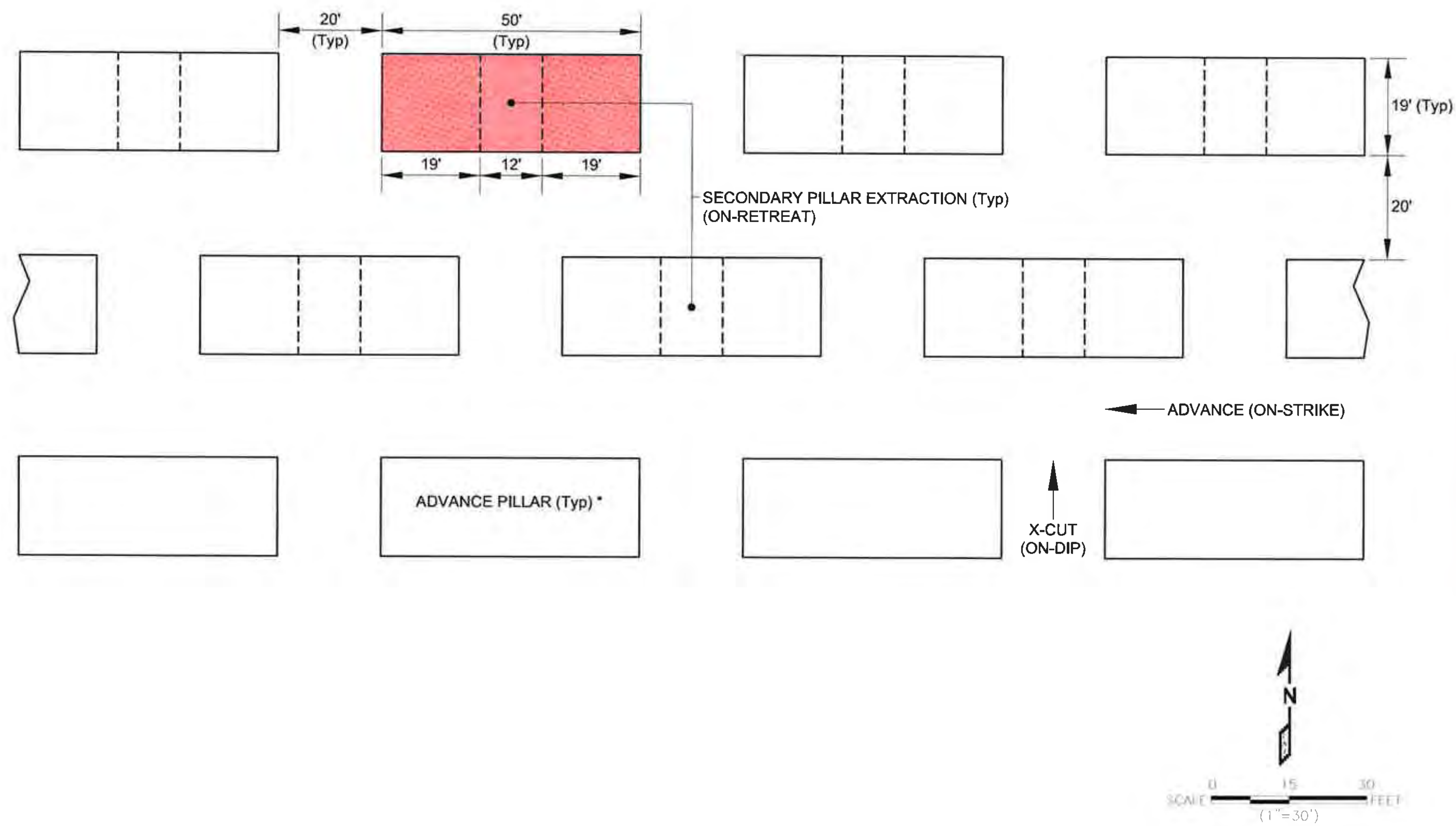
SCALE 1"=1500'

FIGURE 5-4



LEGEND

ADVANCE EXTRACTION ~ 65%
RETREAT EXTRACTION ~ 9%

* PILLAR BASED ON 10' AVERAGE PILLAR HEIGHT IN COPPERWOOD MAIN AREA.
* PILLAR SIZE VARIES WITH PILLAR HEIGHT AND OVERBURBEN THICKNESS.

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\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-5.DWG

PRODUCTION PILLAR LAYOUT AT 500' DEPTH

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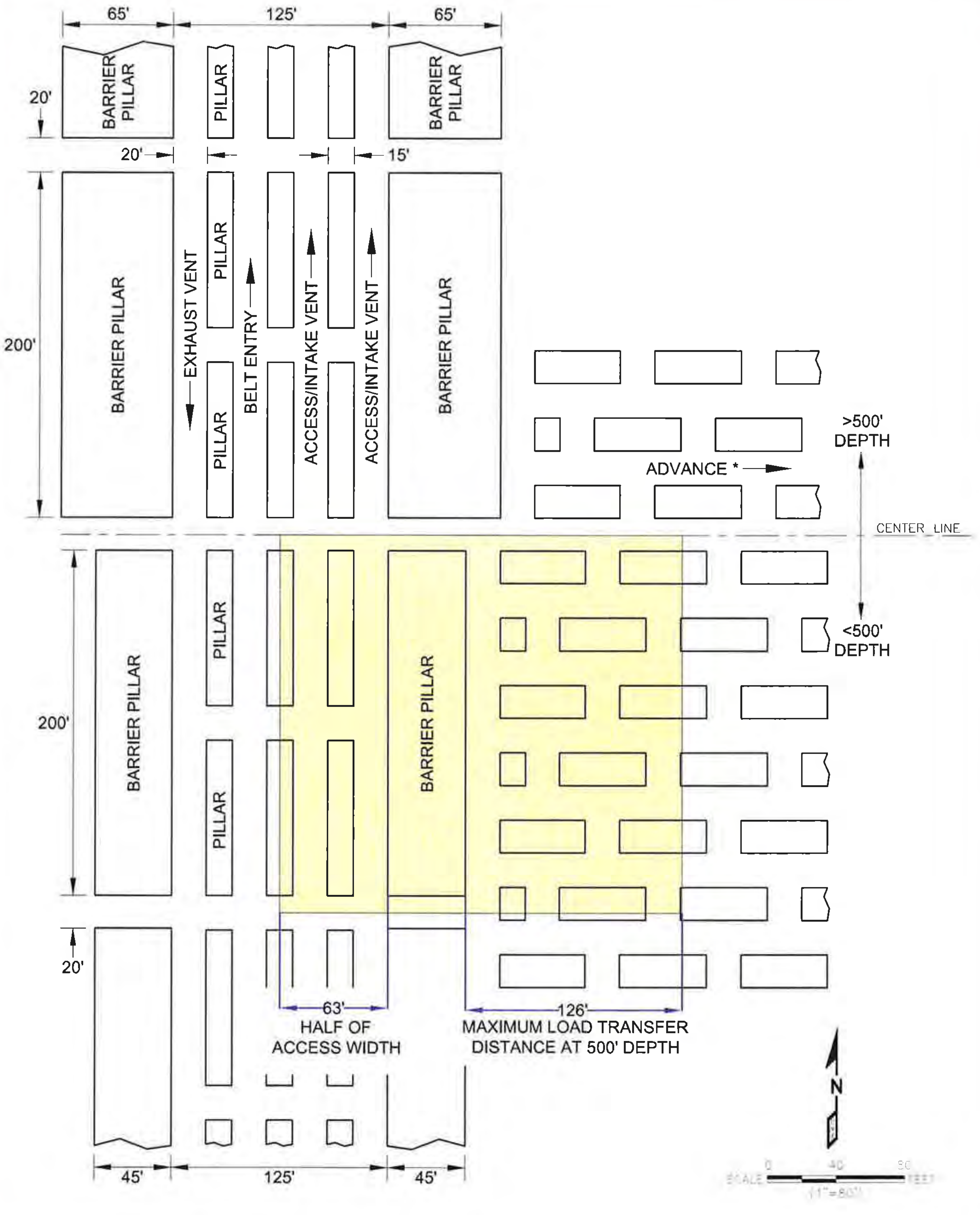
SCALE 1"=30' | FIGURE 5-5



LEGEND

TRIBUTARY AREA LOAD APPLIED TO BARRIER PILLARS AT 500' DEPTH

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TRIBUTARY AREA LOAD FOR BARRIER PILLARS

ORVANA RESOURCES / COPPERWOOD PROJECT

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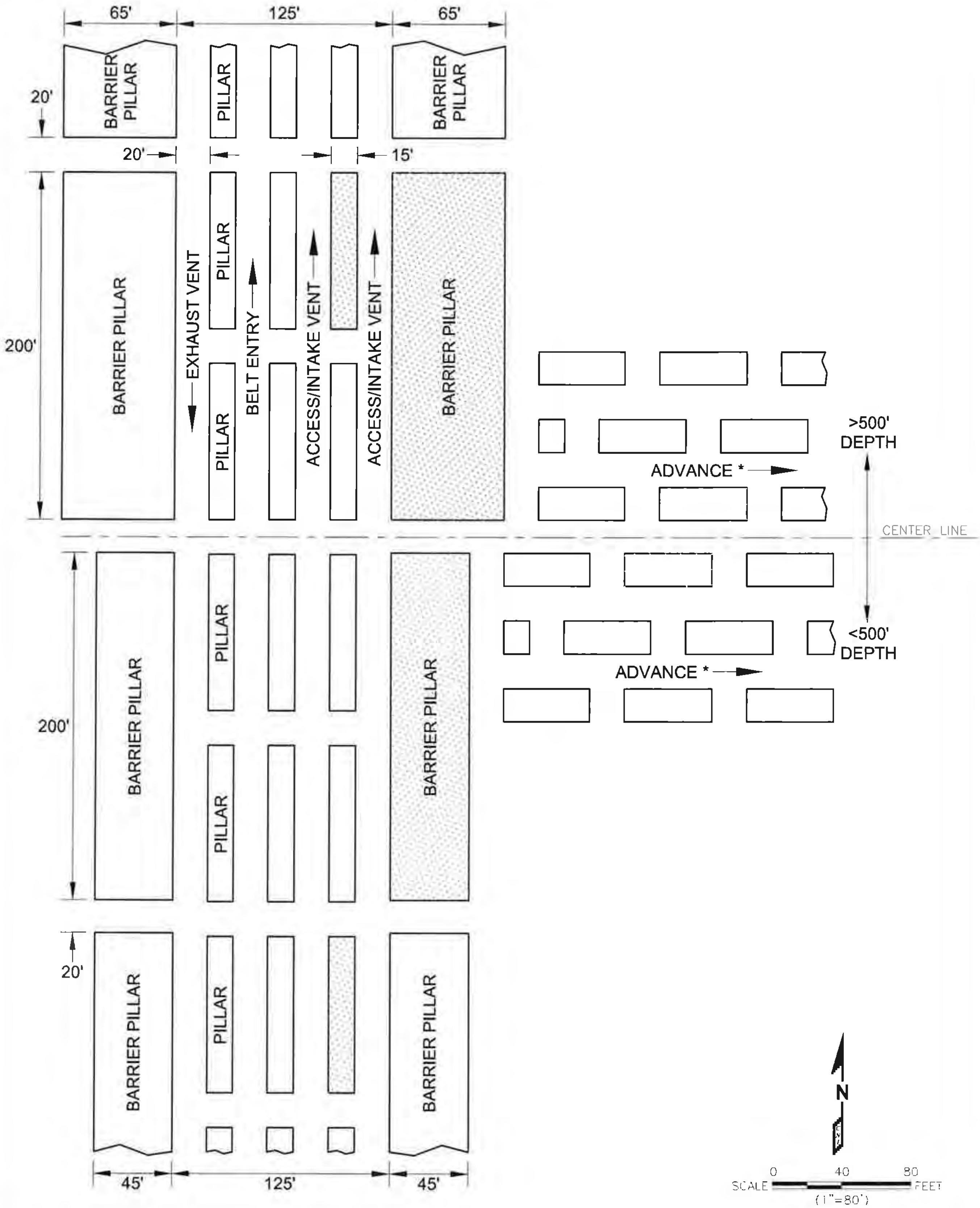
LMC	12/11	3/21/2012 3:02 PM	1"=80'	FIGURE 5-6

\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_5-6.DWG



LEGEND

* ADVANCE PILLAR SIZES BASED ON 10' PILLAR HEIGHT AT 500' DEPTH

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Access Area Design

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SCALE 1"=80'

FIGURE 5-7

6.0 SUBSIDENCE AND CAVING TO THE SURFACE

Two failure mechanisms can result in surface effects, caving or chimney subsidence and trough subsidence. Caving subsidence would result in a rubblized zone from the underground workings to the surface Trough subsidence is the result of flexure of the beds due to limited or no ground support from pillars.

6.1 Caving Subsidence

The caving subsidence is a function of ore thickness, swell factor during caving and depth to ore. Given a mining height of15 ft and swell factor of 25% in the cave there should be no surface effects for depths greater than 200 ft. The pillars have been designed for a minimum depth of 300ft which results in the pillars at depths of 200 ft or less exceeding the minimum design FOS of 1.6 on the advance and 1.2 on the retreat. Therefore CNI does expect surface disturbances due to caving, however, it is still possible for local poor ground conditions to cause localized collapses that could impact the surface.

6.2 Trough Subsidence

The pillar design and spacing provides for a low probability of pillar failure. Even if the pillars do not fail, however, they do yield (strain). It is estimated that this yielding could be as much as 2%, so a 15 ft pillar would converge around 0.3 ft. Given this, if no pillars fail, the subsidence will range between zero feet and 0.3 ft. This small amount of subsidence can be measured given the quality of equipment available today, however, it is unlikely it could be detected on visual inspection.

If the pillars do fail, the amount of subsidence will depend on the extraction ratio, pillar height, depth below the surface, and area failed. The range of expected subsidence from pillar failure is between zero and 5.5 ft (if all of the pillars fail). This range is based on the following equation (Abel, 1983);

$$Subsidence(\%\, of mining\ height) = 0.9 * \left(1.39 + 5.57 * \left[\left(\frac{K * D}{1 - R}\right) * \left(\frac{H}{W}\right)\right]\right)$$

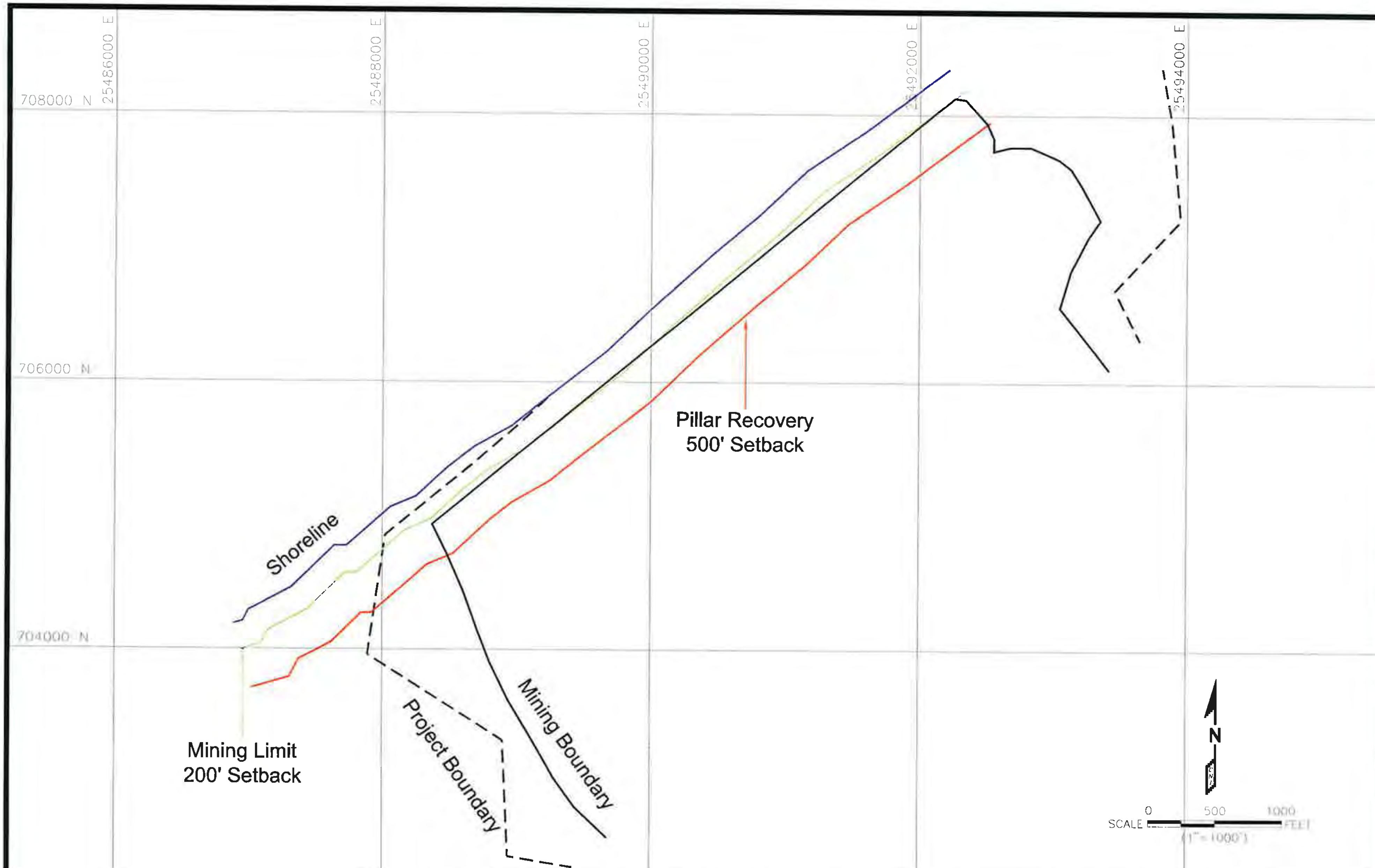
Where:

K = 0.0226 MPa/m
D = Depth (m)
R = Extraction Ratio
H = Mining Height (m)
W = Pillar Width (m)

6.3 Crack Limits and Lake Superior

To minimize any potential impact to Lake Superior due to subsidence cracking, there should be no mining with in 200 ft of Lake Superior and no pillar recovery within 500 ft of the shore line (Figure 6-1). The 200 ft setback was recommended in the prefeasibility study as a request by Orvana. CNI has not changed this recommendation because 200 ft should provide enough freeboard in case of pillar failure that result in a caving to the surface.

Cracks due to trough subsidence can extend outside of the mining limits. Crack limits in sedimentary rocks range from 45 to 70 deg (Figure 6-1). The crack angle could be flatter if there were any major geologic structures that had a dip less than 55 deg. CNI has recommended no pillar recovery within 500 ft of the shoreline. Limiting pillar recovery relative to the shoreline results in a low probability that these pillars will fail during mining. Significant trough subsidence can only be expected if we have a large area, in the range of OBT^2, in failure. Assuming no failures occur closer than 500 ft, for depths up to 500 ft the crack angle would have to be equal to or less than 45 degrees while at a depth of 900 ft the crack angle would have to be flatter than 60 degrees to intersect the lake. Given the same mining thickness, as depth of overburden increases the crack angle should increase. Therefore the 500 ft setback distance of no pillar recovery should be adequate to ensure Lake Superior is not impacted subsidence cracking.



LEGEND

- 0.8 MINING BOUNDARY
- PROJECT BOUNDARY
- SHORE LINE
- MINING LIMIT (200 Feet)
- SET BACK (500 Feet)

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\PROJECTS\LAKE_SUPERIOR\REPORT\FIGURES\FIG_6-1.DWG

SETBACK REQUIREMENTS FROM LAKE SUPERIOR SHORELINE

ORVANA RESOURCES / COPPERWOOD PROJECT

SCALE 1"=1000' | FIGURE 6-1