ATTACHMENT B

TAILINGS CELL STABILITY ANALYSES

OBJECTIVES:

- Evaluate the global stability of the proposed Tailings Cells at Closure.

GIVEN:

- Topography for the original ground surface and Tailings Cells during operation is given in Golder (2008b).
- Closure configuration is given in Kleinfelder (2010).
- Laboratory strength test results for recompacted native soils and in-situ native soils are given in Golder (2008a). Material densities for native soils and structural fill was calculated as an average density from available strength tests (GA-TP-7, GA-TP-9, GA-BH-42 and GA-BH-47) as shown in the following table.

Table 1 – Site Soil Strength Tests (Golder, 2008a)

Material ID	Depth (ft)	Unit Weight (pcf)	Friction Angle (deg)	Cohesion (psi)
GA-TP-7	1.5 - 9	123.8	30	2
GA-TP-9	1 - 11	125.0	36	0
GA-BH-42	10 - 11	86.2	37	0
GA-BH - 47	2 - 3.5	91.4	34	0

- Liner interface friction properties from laboratory tests for various geosynthetics are given in Golder (2008a) and summarized in Table 2.

Table 2 – Liner Interface Strengths (Golder, 2008a)

Material ID	Peak		Residual	
	Friction Angle (deg)	Adhesion (psi)	Friction Angle (deg)	Adhesion (psi)
60 mil Tex HDPE vs. GeoComposite	21.2	7.7	14.8	0
60 mil Tex HDPE vs. Laminated GCL (Bentomat CLT), clay side against HDPE	20	1.7	13.1	0.8
Laminated GCL (Bentomat CLT) vs. Soil laminated side against soil	25.1	1.7	13.3	5.9
GCL (Bentomat DN) vs. Soil	35.5	0	30.5	2.6
60 mil HDPE vs. GCL (Bentomat ST) vowen side against HDPE	23.2	4.9	12.7	1.7

- Tailings densities at closure are given in Golder (2010).
- Cover material densities are given in Kleinfelder (2010).
- Peak seismic acceleration (A_{peak}) for design is 0.107g (Kleinfelder, 2008).

ASSUMPTIONS:

- The critical cross section identified for the stability evaluation is the north embankment of the Tailings Cell C (Section D in Golder, 2008b). This section was selected based on embankment height. One

should note that the embankment slopes and the closure cover slopes are designed the same for all tailings cells.

- Water table is assumed to coincide with the lowest point of the assumed tailings surface at closure (Golder, 2008b). Note that this assumption is conservative as it neglects the influence of desiccation and assumes that the drainage at the base of the tailings cell is ineffective.
- Use pseudo-static model to evaluate the seismic stability. Check seismic stability using a horizontal load coefficient of ½A_{peak}, or 0.05g (Hynes & Franklin, 1984).
- Minimum acceptable factor of safety (FS) for static conditions is 1.5 per the design criteria.
- Minimum acceptable FS for seismic conditions is 1.1 per the design criteria.
- The Bottom Liner is assumed to be a 1.0-foot thick soil layer with the friction angle equivalent to the peak friction angle for the weakest tested liner interface (see Table 2). Bottom liner cohesion was set to zero.
- Laminated GCL (placed on top of the Interim Cover Layer) was modeled as a 0.38 feet thick soil layer with the friction properties resembling the peak friction angle for the GCL-Soil interface (see Table 2) and cohesion set to zero.
- Strength properties were reduced 20% for seismic (pseudostatic) stability analysis as outlined in Table 3.
- For conservatism, the undrained tailings strength was utilized in both static and seismic analyses. The undrained tailings strength was assumed equal to 10% of the vertical effective stress (see e.g. Vick, 1983).

MATERIAL PROPERTIES:

- The material parameters used in the stability analyses are summarized in Table 3.

Table 3 – Material Properties

Material	Thickness (ft)	Unit Weight (pcf)	Static analysis		Seismic analysis	
			Friction Angle (deg)	Cohesion (psf)	Friction Angle (deg)	Cohesion (psf)
Native Ground	Varies	106.6	30.0	0	24.8	0
Structural Fill (average)	Varies	106.6	30.0	0	24.8	0
Bottom Liner	1.0	90	20.0	0	13.0	0
Tailings	Varies	97.7 / 125 (Note 1)	$0.1\sigma_v'$		$0.1\sigma_v'$	
Interim Cover Layer	2.0	100.3	30.0	0	24.8	0
Geosynthetic Liner	0.38	90	25.0	0	13.0	0
Radon Barrier	Varies	112.1	30.0	0	24.8	0
Bio - Intrusion Layer	0.5	100.3	33.0	0	27.5	0
Capillary Break	0.5	112.9	33.0	0	27.5	0
Vegetative Cover and Rock Mulch combined	4.0	100.3	30.0	0	24.8	0
Rock Blanket	1.0	105	35.0	0	29.3	0

Note: (1) Dry and saturated unit weights.

The saturated tailings density of 125 pcf was used for stability analyses. For the tailings specific gravity of Gs=2.8 (Golder, 2010), one can determine the average tailings void ratio as:

$$e = \frac{Gs\,\rho_w}{\rho_{dry}} - 1 = \frac{2.8 \times 62.4\,pcf}{97.7\ pcf} - 1 = 0.788\,.$$

From the known tailings void ratio, the bulk tailings density was determined as

$$\rho = \frac{\rho_w (Gs + e)}{1 + e} = \frac{62.4\,pcf\ (2.8 + 0.788)}{1 + 0.788} \approx 125\ pcf\ .$$

METHOD:

- Stability analyses were performed with RocScience's limit equilibrium program SLIDE. Minimum factors of safety were determined using the program's search algorithm and calculations based on the Spencer method.

CALCULATIONS:

- The SLIDE stability results are presented in Figures 1 and 2.

RESULTS:

- The static and seismic analyses yield factors of safety which exceed the minimum requirements as shown in the table below.

Table 4 – Stability Analysis Summary

Failure Zone	Surface Type	Static Factor of Safety	Pseudo-Static Factor of Safety
Global	Circular	4.7 (Note 1)	1.4

Note: (1) Berm veneer failure

CONCLUSIONS

- Based on stability modeling, Tailings Cells meet the stability design.
- The lowest factor of safety is determined for a design seismic event.
- The above analyses are considered conservative based on the strength parameters used and the assumptions made.

REFERENCES:

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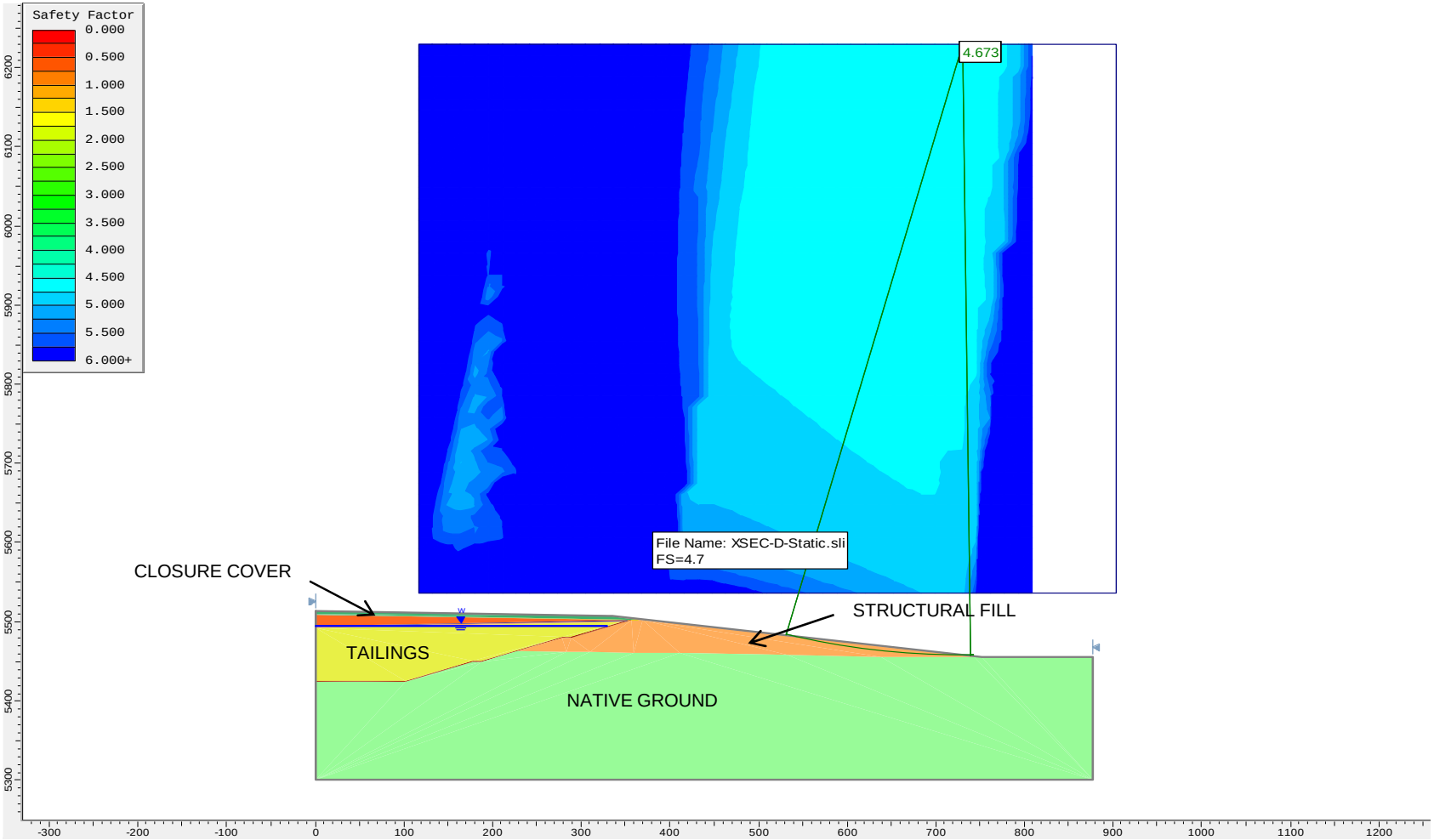
Vick, S.G. (1983**).** Planning, Design, and Analysis of Tailings Dams, by, John Wiley & Sons , New York, 1983, 369 p., ISBN 0-471-89829-5, reprint was published in 1990 by BiTech Publishers Ltd. , Richmond B.C., Canada (ISBN 0-921095-12-0)

FIGURES



Golder Associates

Denver, Colorado

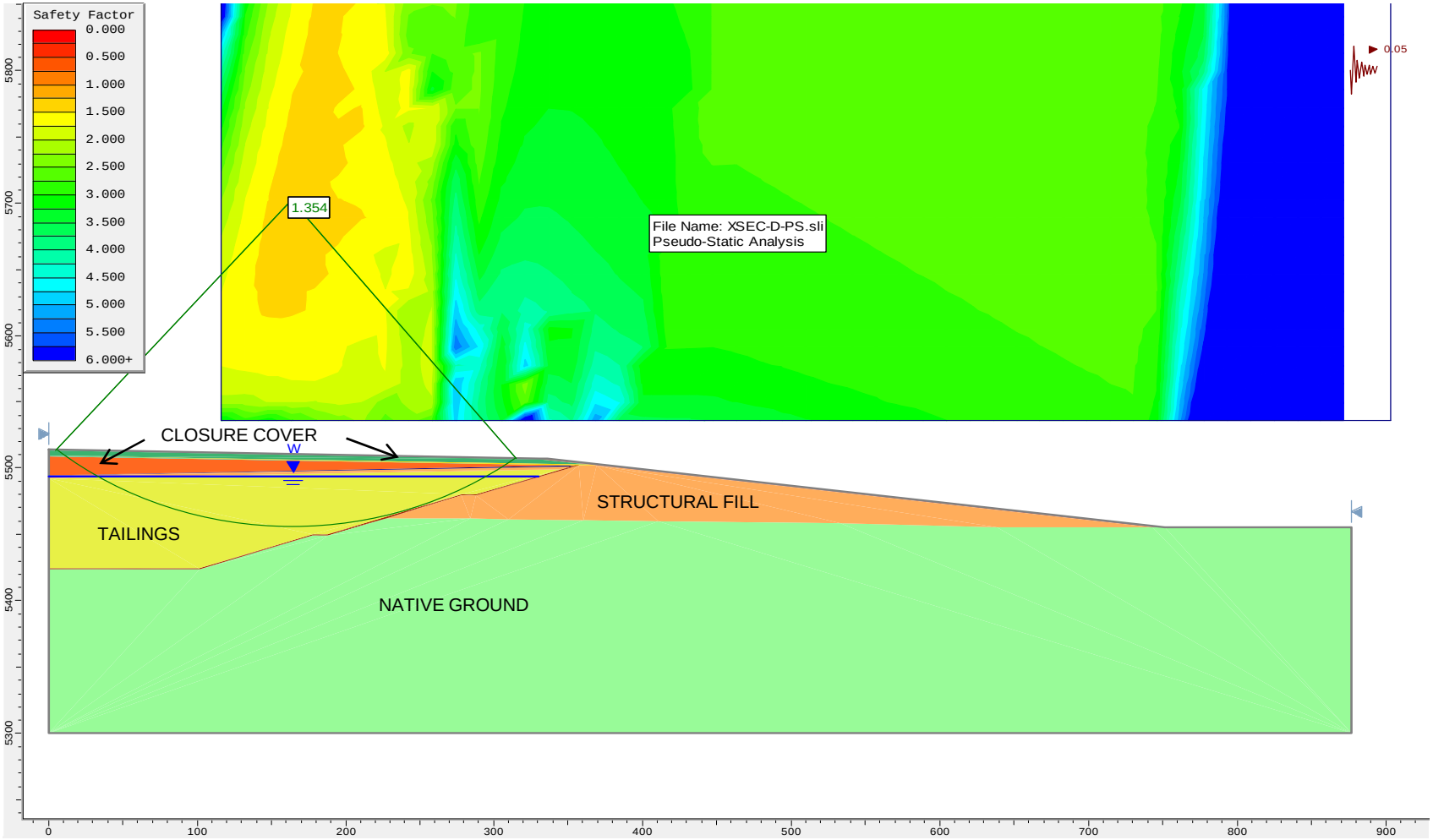
TITLE

TAILINGS CELLS AT CLOSURE
STATIC STABILITY ANALYSIS

CLIENT/PROJECT

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT - MONTROSE COUNTY, COLORADO

DRAWN	GG	DATE	Nov-10	JOB NO.	073-81694
CHECKED	DLG	SCALE	AS SHOWN	DWG. NO.	
REVIEWED	KFM	FILE NO.		FIGURE NO.	FIGURE 1



Golder Associates

Denver, Colorado

TITLE

TAILINGS CELLS AT CLOSURE
PSEUDO-STATIC STABILITY ANALYSIS

CLIENT/PROJECT

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT - MONTROSE COUNTY, COLORADO

DRAWN	GG	DATE	Nov-10	JOB NO.	073-81694
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