Appendix E

Stability Evaluation of West Pit

REPORT

STABILITY EVALUATION OF THE WEST PIT, BOCA QUARRY HIRSCHDALE, CALIFORNIA

Submitted To: Teichert Aggregates
3500 American River Drive
Sacramento, California 95851

Submitted By: Golder Associates Inc.
1000 Enterprise Way, Suite 190
Roseville, California 95678

Distribution: 7 Copies – Jeff Thatcher, Teichert Aggregates
1 CD – Jeff Thatcher, Teichert Aggregates
1 Copy – Golder Associates, Roseville
1 Copy – Golder Associates, Reno

August 2010 **103-91727**

A world of capabilities delivered locally

Golder Associates

Table of Contents

List of Figures

List of Photographs

List of Appendices

1.0 INTRODUCTION

1.1 General

Teichert Aggregates' Boca Quarry is located approximately nine miles east of Truckee, California, just northeast of the community of Hirschdale. Teichert Aggregates (Teichert) has applied for an expansion to the quarry that involves excavation of a second pit (the West Pit) west of the existing pit (Figure 1). The California Department of Conservation, Office of Mine Reclamation (OMR) recommended that a detailed, site-specific stability evaluation analyzing both static and pseudo-static conditions for the final West pit slopes be performed. Teichert retained Golder Associates (Golder) to perform the stability evaluation.

1.2 Scope of Services

The scope of this work was originally defined in a letter regarding "Scope of Work, West Pit Stability Evaluation, Boca Quarry" dated June 4, 2010, to Chuck Unsworth, Geologist with Teichert Aggregates, and consisted of:

Perform geotechnical evaluations of the proposed slopes in the West pit, including:

- Site visit to review area of proposed pit and newly exposed roadcuts
- Review core logs and core from coreholes drilled in the proposed West pit
- Stability analysis of the final slopes in the proposed west pit
- Preparation of a report summarizing the stability analysis and results, and including recommendations for design of these final slopes

Available geologic information is provided by exploration drilling completed in the West Pit area by Teichert, shallow road cuts in the West Pit vicinity, and exposures of geologic units in the nearby East Pit. However, rock slopes have not been exposed and geotechnical drilling has not been completed near the West Pit final slopes, and therefore a detailed geologic model for the West Pit is not available. In addition, laboratory testing of the weaker geologic units that may be exposed in the pit wall have not yet been completed. The approach taken has therefore been to develop preliminary slope design recommendations based on available information and our experience with stability of slopes in similar materials under similar conditions, making certain assumptions regarding the geologic model and the geotechnical characteristics of the units. As the West Pit is developed, geologic mapping and geotechnical testing should be completed to confirm our assumptions. Should the assumptions prove not to be valid, additional stability analyses based on the actual geological and geotechnical conditions will be required.

1.3 Method of Work

Work was initiated with a visit to the core shed at Teichert's Perkins plant in Sacramento on May 6, 2010, by Rhonda Knupp, Senior Project Geologist from Golder's Reno office. The purpose of the visit was to review core from exploration coreholes drilled in the West Pit area. On June 17, 2010, R. Knupp visited the Boca Quarry west pit site to examine road cuts and existing exposures in the West Pit area. The stability evaluation is based on existing information collected during review of the core and road cuts, and conservative assumptions of the geological model and geotechnical characteristics of the geological units.

2.0 SITE CONDITIONS

The Boca Quarry was permitted in 1983 and operated until the late 1980s, when it became idle. The property was sold in the mid 1990s, and the new owner leased the quarry to a new operator who reopened it. Teichert obtained the lease in 2005, and has received a permit for expanding the existing East Pit. Teichert has completed reconnaissance mapping and drilled seven boreholes investigating the subsurface geology in the West Pit area. The general geology, as described by Iggy Rivas and Chuck Unsworth, Geologists with Teichert, is summarized below.

2.1 Geology

The north part of the proposed West Pit is composed of a series of generally horizontal basalt flows separated by layers of ash and tuff or intervals of basalt boulders, cobbles, and rubble. In the south part of the pit, soil, basalt, and rhyolitic lithic tuff are exposed at the surface, and are underlain by a layer consisting of basalt boulders in a clay matrix and locally interbedded with cinders. The basalt boulder layer is underlain by another layer of lithic tuff. The lithic tuff in the south area is generally poorly consolidated and moderately to strongly clay altered.

2.1.1 Description of Drill Core

Seven exploration coreholes have been drilled in the West Pit area. Three coreholes, DOB05DH-06, -07, and -08, were drilled in the south part of the West Pit in 2005. In 2008, four coreholes, DOB08DH-01 through -04, were drilled in the north area of the pit. All of the coreholes were vertical. Corehole locations are shown in Figure 1.

2.1.1.1 West Pit, South Area

Coreholes DOB05DH-06 through DOB05DH-08 were drilled in the south part of the proposed West Pit (Figure 1). Core from these drillholes indicates that the lithology in the area consists of, from the surface downward, a soil layer, a tuff layer, a basalt layer, and another tuff layer.

Soil

The soil overburden is exposed in several exploration trenches and is present in the drill core. It consists of boulders, cobbles, and smaller fragments of basalt in silty clay organic soil. The soil is dark brown and contains high plasticity clay. Soil thickness ranges from 0 to approximately 13.5 feet.

Upper Tuff

The thickness, composition, and texture of the upper tuff layer varies considerably with location. In DOB05DH-06 it is thin to nonexistent; if it is present it is mixed in with the soil overburden. In DOB05DH-07 it consists of a layer of angular, gravel-sized rock fragments in a silt matrix containing crystal fragments and minor clay. This layer is friable and poorly lithified, and grades into a mostly welded tuff that is locally unconsolidated. In DOB05DH-08 it consists of a layer of soft, poorly consolidated tuffaceous silt grading to ash. The ash is underlain by a more consolidated, fractured tuff that has the texture of shale, appears to be partially devitrified, and is easily picked apart (Photograph 1).

Basalt Boulders in Matrix

The basalt layer generally consists of boulders in a clay or clayey silt matrix, with local cinders and intervals of silty clay. The amount of matrix is highly variable, but appears to range from less than 5% to as much as 40%. Teichert anticipates that the unit will be similar to basalt that crops out along the property line north of the current crest of the north wall of the East Pit (Photograph 2). DOB05DH-08 contains 10 feet or so of core with no clay matrix that may represent a thin flow or intrusion.

Lower Tuff

The lower tuff in DOB05DH-06 consists of a number of layers with varying textures. The upper part is a tan, very soft, clay that grades to black clay containing rock fragments the size of pea gravel (Photograph 3). This unit is underlain by a layer of basalt boulders in a clay matrix, which is in turn underlain by a layer of sand-like material. Below this unit is a clay that is very poorly consolidated and soft. The clay grades into a poorly indurated tuff with angular rock fragments. In DOB05DH-07 the lower tuff consists of dark brown to tan, silty clay that grades to a tan, poorly consolidated silt (Photograph 4).

Unit Thicknesses and Geometries

Based on depth of the drillhole intersections of the contacts between the basalt unit and the upper and lower lithic tuff units, the basalt unit is thickest in the southwest (94 feet thick in DOB05DH-08) and thins to the north and east (65 feet thick in DOB05DH-07, and 42 feet thick in DOB05DH-06). Assuming a uniform dip for the contacts, the upper lithic tuff-basalt contact is oriented 06º/253º (Dip/Dip Direction), and the basalt-lower lithic tuff contact is oriented 05º/316º. The upper lithic tuff is at least 23 feet thick, and the lower lithic tuff is at least 33 feet thick.

2.1.1.2 West Pit, North Area

Of the four coreholes drilled in the north area, two encountered basalt flows and basalt boulder units with little to no ash, while the other two encountered basalt boulder units overlying a thick ash interval.

Coreholes DOB08DH-02 and DOB08DH-03

Coreholes DOB08DH-02 and DOB08DH-03 intersected basalt flows interlayered with intervals of basalt boulders, cobbles, and rubble. The basalt flows are fine grained and competent, and flow sequences range in thickness from about a foot to more than 103 feet. The basalt flows in DOB08DH-02 are generally moderately fractured (Photograph 5), but locally highly or lightly fractured. In DOB08DH-03 the flows are generally lightly fractured, with local moderately fractured zones.

The dip angles of the discontinuities within the basalt appear to be bimodal, with one group dipping 0°-10°, and the other dipping 20°-55°. Discontinuities are generally clean with occasional spots of hematite and rare local limonite stain. Infill is rare, and consists of 3mm or less of sand, silt, or clay.

The boulders, cobbles, and rubble zones range from about four feet thick to 40 feet thick. In DOB08DH-03 the basalt comprising the boulders, cobbles, and rubble tends to be vesicular, while in DOB08DH-02 it is similar to the basalt in the flows. In DOB08DH-03 above about 55 feet depth, clayey soil or clay is present locally between clasts and filling fractures (Photograph 6). Below about 55 feet, and in DOB08DH-02, little to no soil or clay is present in the core (Photograph 7). Based on low recoveries in some of the core runs, fines could have comprised the majority of the intervals but washed away during drilling.

DOB08DH-03 intersected an ash layer from 23.5-25.5 feet. The ash has been altered to high plasticity clay. No ash layers were observed in the core from DOB08DH-02.

Coreholes DOB08DH-01 and DOB08DH-04

Coreholes DOB08DH-01 and DOB08DH-04 intersected basalt boulders, cobbles, and rubble overlying a thick ash layer. The first 43.5 feet of DOB08DH-01 consist of basalt cobbles and boulders in a matrix of friable silty sand or sand with silty clay, possibly an unconsolidated tuff. No fines are present in this horizon in DOB08DH-04, but any fines that were present could have washed away during drilling.

The ash layer below the rubble horizon is capped by a bedded lithic tuff, possibly a surge deposit, that is one to seven feet thick. In DOB08DH-01 bedding in the lithic tuff is generally 90° to the core axis (i.e., is flat-lying), but locally dips 30°. In DOB08DH-04 bedding in the lithic tuff is steep, dipping about 80°. This difference in dip most likely represents variations in the paleotopography. The ash underlying the lithic tuff is generally coherent but very friable and weak, and weathers to a high plasticity clay (Photograph 8). In DOB08DH-01 only the upper five feet or so are altered to clay, but in DOB08DH-04 the ash is strongly clay altered from the contact with the lithic tuff (~16 feet) to a depth of about 30 feet, then becomes progressively less altered to about 48 feet, where it is generally fresh. Bedding in the ash layer is either horizontal or dips 35°-45° in DOB08DH-01 (Photograph 9), and dips 15° in DOB08DH-04. Rare slickensides are present with the clay-altered ash intervals (Photograph 10).

DOB08DH-04 was terminated in the ash layer at 55 feet depth, but at 91.5 feet DOB08DH-01 encountered interlayered basalt flows and rubble below the ash layer, then intersected a lower ash layer at 125 feet. Vesicles in one of the basalt flows are aligned at 60°-70° to the core axis (i.e., aligned vesicles dip 20°-30°). The lower ash layer is fresh, but friable and weak.

Unit Thicknesses and Geometries

The basalt boulders, cobbles, and rubble unit in the upper portions of the north area drillholes is up to about 44 feet thick. The results of a three-point problem using DOB08DH-01, -03, and -04 and the lower contact of the unit suggest that the unit may have a dip direction of about 225° and a dip of about 10°; however, the lower contact in DOB08DH-02 is not consistent with this orientation as it is too shallow. This suggests that the unit has an irregular contact, or that the drillholes do not intersect the same unit, or both.

The basalt flows in DOB08DH-02 and -03 are up to 103 feet thick, while the ash layer in DOB08DH-01 and -04 is at least 44 feet thick (not including the lithic tuff that caps it). Because only two coreholes intersected each of these units, the orientations of the units remain unknown.

Unit Continuity

Due to the relatively large distance between the coreholes drilled in the southern area and those drilled in the northern area, whether any of the units encountered in the north area correspond with any encountered in the south area is unknown.

2.2 Hydrogeology

Golder understands that the groundwater elevation is below the bottom of the final West Pit based on discussions with Teichert staff.

2.3 Proposed West Pit

The proposed West Pit (Figure 1) encompasses the entire width of the property at the north end, and extends southwest to within approximately 250 feet of the southwest property boundary. The pit is approximately 3,400 feet long and 1,000 to 1,500 feet wide. Mining will extend to maximum depths of up to approximately 150 to 200 feet below ground surface (bgs). At reclamation, the final grades will form two upper terraces and a lower pit that is 80 to 150 feet bgs. The total elevation difference between the crest of the quarry on the upper terrace to the lower pit bottom is approximately 520 feet.

The proposed pit mines the north area to elevation 6000 feet, then steps down to the central area, which is mined to 5800 feet elevation. The pit steps down again to the south area, which is mined to elevation 5680 feet. Maximum wall heights are 200 feet in the north wall and in the step between the north and central areas. Overall slope angles are 45° or less. Design bench widths are 30 feet or less, and design bench heights are 40 feet or less.

3.0 STABILITY EVALUATION

3.1 General

Available information has been used to develop a general characterization of the geological conditions and material characteristics present at the site. However, a detailed geological model has not been developed, and laboratory testing has not been performed to measure the mechanical properties of the geotechnical units. Assumptions have been made regarding the distribution and geotechnical characteristics of the geological units, as discussed below. Should the geological and geotechnical conditions differ from those assumed for this evaluation, additional work may be required. Section 5 provides recommendations for confirming the geologic and geotechnical conditions.

3.2 Geotechnical Units

All of the geological units that are expected to be exposed in the walls of the West Pit comprise the following geotechnical units, or units with similar geotechnical properties:

- ***Soil*** – ranges in thickness from 0 to about 13.5 feet, and consists of boulders, cobbles, and smaller fragments of basalt in silty clay.
- ***Basalt Flows*** – have a high rock strength and are generally lightly to moderately fractured. Discontinuities generally contain no infill. Flow sequences can be up to at least 103 feet thick.
- ***Basalt Boulders, Cobbles, and Rubble*** – in silty clay, silt, or clay matrix; generally unconsolidated, and up to at least 94 feet thick. Percentage of matrix observed in the drill core from the West Pit area generally low; however, some or all of the fines may have been lost during drilling.
- ***Tuff and Ash*** – weak, with clay content varying from 0 to 100% depending on the degree of weathering. Due to the differences in geotechnical characteristics between fresh and highly weathered Tuff and Ash, this unit has been subdivided based on weathering:
  - ***Fresh Tuff and Ash*** – poorly consolidated sandy silt or silty sand, up to 44 feet thick
  - ***Highly Weathered Tuff and Ash*** – high plasticity clay; up to 14 feet thick

3.3 Hydrogeology

We understand that all pit slopes will be above the groundwater elevation; therefore, only dry slopes were considered for the stability evaluation.

3.4 Rock Mass Stability

A rock mass stability analysis was performed to evaluate the potential for rock mass failure in the West Pit slopes. When there is no structural control of stability of a rock slope, slope failures can develop by a combination of movement along structures and failure through intact rock. Such failures are termed rock mass failures, and generally occur only for weak rock masses or very large slopes. Analysis of rock mass failures requires estimates of rock mass strength followed by stability analyses by limit equilibrium methods or other means.

3.4.1 Rock Mass Rating and Material Properties for Basalt Flows

When drill core is available, the strength and quality of a rock mass can be estimated using geotechnical parameters recorded during core logging in conjunction with the Rock Mass Rating (RMR) system, a rock mass classification system developed by Bieniawski (1976; 1989). Teichert geologists logged rock strength rating, Rock Quality Designation (RQD) rating, discontinuity spacing rating, and Joint Condition Rating (JCR) according to RMR_{89} (Bieniawski, 1989) during geological logging of the Basalt Flows core. For the purposes of rock mass stability analysis, the RMR_{89} ratings were converted to RMR_{76} ratings (Bieniawski, 1976). Weighted averages of the RMR_{76} ratings are summarized in Table 1. The RMR calculations are included in Appendix A.

TABLE 1

WEIGHTED AVERAGE RMR_{76} RATINGS FOR BASALT FLOWS CORE

Strength Rating	RQD Rating	Discontinuity Spacing Rating	Joint Condition Rating	Groundwater Rating	Total RMR Rating	Feet of Core Logged
9	12	9	17	10	57	84

The average RMR_{76} rating of 57 corresponds to a fair to good quality rock mass. This classification is reasonable based on our observations of the Basalt Flows core.

3.4.2 Rock Mass Strength

The rock mass strength for the Basalt Flows was estimated using the RMR_{76} value of 57 with Hoek and Brown's rock mass strength criterion (Hoek and Brown, 1988). A value of 25 was chosen for the constant m_i for basalt (Hoek and Karzulovic, 2000), resulting in values of 2.3543 for m_b, 0.001966 for s, and 0.504 for a, for a 70% disturbed rock mass. For the stability analysis, the uniaxial compressive strength of the basalt was estimated at 11,000 psi, and the unit weight was estimated at 180 pcf (Hoek and Bray, 1981). The strength parameters used for the analysis are summarized in Table 2.

TABLE 2

BASALT FLOWS STRENGTH PARAMETERS USED FOR STABILITY ANALYSIS

RMR	UCS (psi)	Unit Wt. (pcf)	m_i	Disturbance	m_b	s	a
57	11,000	180	25	70%	2.3543	0.001966	0.504

3.4.3 Material Properties for Soil; Basalt Boulders, Cobbles, and Rubble; and Tuff and Ash Units

In the absence of laboratory testing data, material properties can be estimated using published data ranges. Unit weights were estimated from Hoek and Bray (1981). The Soil is a silty clay, with a conservative field estimate of 40 for the plasticity index (PI). Using Gibson's relationship between PI and friction angle (Gibson, 1953; Figure 2), a friction angle of 23° was chosen for the Soil. The Soil was assigned a nominal cohesion of 100 psf.

The Highly Weathered Tuff and Ash unit was conservatively assumed to be composed of high plasticity clay, with an estimated PI of 80 based on the strongly clay-altered tuff and ash in the core. This PI corresponds to a friction angle of 19° according to Gibson (1953). Fresh Tuff and Ash contains little or no clay, and has an estimated PI of 5. Gibson's chart indicates a friction angle of 29° for this PI. A cohesion of 200 psf was assigned to both Tuff and Ash units based on an exposure of ash in the northwest wall of the East Pit that stands at 44° over 25 vertical feet and 39° over 45 vertical feet (Photograph 11).

The amount of matrix in the Basalt Boulders, Cobbles, and Rubble is highly variable, and is difficult to quantify because much of the matrix may have been washed away during drilling. The percentage of matrix in this unit is estimated to range from 0-40% based on the material that was recovered, but low core recoveries in the 2008 coreholes suggest that the percentage of matrix could be higher. Due to this uncertainty in the composition and character, a conservative friction angle of 32° was used for the Basalt Boulders, Cobbles, and Rubble unit.

The material properties used for stability analysis are summarized in Table 3.

TABLE 3

MATERIAL PROPERTIES USED FOR STABILITY ANALYSES

Geotechnical Unit	Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Soil	120	23	100
Basalt Boulders, Cobbles, and Rubble	150	32	0
Fresh Tuff and Ash	100	29	200
Highly Weathered Tuff and Ash	110	19	200

3.4.4 Rock Mass Stability Analyses

Rock mass stability analyses were run using the Rocscience limit equilibrium analysis program Slide 5.0 (Rocscience, 2010). Slide generates Factors of Safety (FOS) according to a Spencer solution for potential circular slip surfaces.

Because no geological model is available, analyses were run for "generic" slopes developed entirely in a single geotechnical unit. Analysis of only one case was required for the Basalt Flows due to the relatively high rock strength and rock mass quality; and only one case was required for the Basalt Boulders, Cobbles, and Rubble unit because it is modeled with no cohesion. In the Tuff and Ash units, the slope angle was varied for different slope heights until a static FOS of 1.3 was computed, which Golder considers suitable for the proposed end use as undeveloped open space. Slopes up to 60 feet high were modeled; all ash units intersected in the drillholes are less than 45 feet thick.

3.4.4.1 Basalt Flows

For the Basalt Flows, a 200-foot high slope with a 45° slope angle was analyzed, as designed for the West Pit. Slide calculated a static FOS of 5.2 for this case (Figure 3), indicating a low risk of rock mass failure in slopes developed entirely in the Basalt Flows as modeled.

3.4.4.2 Weathered Tuff and Ash

Slopes of heights ranging from 20 feet to 60 feet were analyzed in the Weathered Tuff and Ash. The slope angles required for FOS = 1.3 range from 22° to 38°, as indicated in Table 4 and Figure 4.

TABLE 4

SLOPE ANGLES REQUIRED FOR FOS = 1.3 IN HIGHLY WEATHERED TUFF AND ASH

Slope Height (ft)	Slope Angle
20	38°
30	29°
40	26°
50	24°
60	22°

3.4.4.3 Fresh Tuff and Ash

For the Fresh Tuff and Ash unit, slope heights from 30 to 60 ft were analyzed. Required slope angles for FOS = 1.3 ranged from 34° to 45° in this unit. The results are summarized in Table 5 and Figure 5.

TABLE 5

SLOPE ANGLES REQUIRED FOR FOS = 1.3 IN FRESH TUFF AND ASH

Slope Height (ft)	Slope Angle
30	45°
40	40°
50	36°
60	34°

3.4.4.4 Basalt Boulders, Cobbles, and Rubble

The Basalt Boulders, Cobbles, and Rubble unit is modeled with no cohesion, and therefore the slope angle required to calculate a FOS of 1.3 is not related to the slope height. The analysis indicates that a slope angle of 25° is required for a FOS of 1.3 (Figure 6).

3.4.5 Pseudo-Static Analysis

A pseudo-static analysis was performed to evaluate the stability of the slopes during a seismic event. This is the most commonly used method of evaluating the effects of seismic loading corresponding to the design earthquake events. In a pseudo-static limit equilibrium analysis, a lateral force is added to a potential failure mass, with magnitude equal to some fraction of the weight of the slide mass. The fraction is defined in the form of a seismic coefficient, k, which is typically assumed to be less than the peak ground acceleration (PGA) and is expressed as a percentage of gravity.

The USGS's on-line seismic hazards database indicates that the PGA associated with an earthquake event that has 10% probability of exceedance in a 50-year period is 0.26g. This design earthquake event has an expected recurrence interval of 475 years. In addition, the online database indicates that the largest significant earthquake sources have moment magnitudes of approximately 7.0 at distances of 15 kilometers from Boca Quarry.

There are a number of methods for selecting seismic coefficients. For this project, Golder considers Pyke's (1991) method appropriate. Pyke (1991) recommends the use of a relationship between PGA, seismic coefficient, and moment magnitude of earthquake for earthquake magnitudes between 6.5 and 8.25. This relationship is shown in Figure 7.

Figure 7, in conjunction with the USGS seismic hazards data for the site, indicate that the ratio of the seismic coefficient and the design PGA should be about 0.25, which results in a design seismic coefficient of 0.07 (0.26g x 0.25 = 0.07). For Boca Quarry, Golder used a more conservative seismic coefficient of 0.1.

The pseudo-static analyses results in FOS > 1.0 for all slope heights up to 60 feet in the Highly Weathered Tuff and Ash, and in FOS > 1.10 for all slope heights up to 60 feet in the Fresh Tuff and Ash. The FOS for the pseudo-static analysis of the Basalt Boulders, Cobbles, and Rubble unit is 1.1. A pseudo-static FOS > 1.0 is considered acceptable using this approach for the Boca Quarry.

3.5 Structural Stability

No major structures have been identified in the vicinity of the proposed pit; however, several faults have been identified in the East Pit. One steeply-dipping fault is exposed in the north wall of the East Pit, and several other faults are located in the northwest wall. Based on the steeply-dipping fault in the north wall of the East Pit, rock quality will be reduced in the vicinity of any faults encountered in the West Pit.

Joint sets in the Basalt Flows generally dip 0°-10°or 20°-55°. Clean joints dipping more than about 40° into the pit could cause local planar failures if the joints are continuous and strike within about 20° or less of the strike of the pit wall. Joint infill is rare, but up to 3mm of clay, silt, or sand infill is present in joints in the drill core. Joints dipping into the pit and containing 1 mm of more of infill may be problematic at flatter dips, on the order of about 20°.

4.0 CONCLUSIONS

The pit is above the groundwater table; groundwater is not expected to influence slope stability, and no slope dewatering will be required.

The Basalt Flows comprise a fair to good quality rock mass, and slopes developed to heights of 200 feet in the Basalt Flows are indicated to be stable at the design overall slope angle of 45° provided the conditions encountered are as assumed. The design bench heights of 40 feet and catch bench widths of 30 feet require a bench face angle of 75°. This would require careful excavation and/or controlled blasting techniques.

For a static FOS = 1.3, design overall slope angles for Highly Weathered Tuff and Ash range from 38° to 22° for slope heights ranging from 20 feet to 60 feet, as presented in Figure 4. Slopes lower than 20 feet can be developed at 45°.

For a static FOS = 1.3, design overall slope angles for Fresh Tuff and Ash range from 45° to 34° for slope heights from 30 feet to 60 feet, as presented in Figure 5. Slopes less than 30 feet high can be developed at 45°.

The Basalt Boulders, Cobbles, and Rubble unit is modeled with no cohesion, and the calculated FOS does not depend on slope height. A slope angle of 25° is required for a static FOS = 1.3 in the Basalt Boulders, Cobbles, and Rubble unit.

Pseudo-static analyses indicate acceptable FOS values for the Basalt Flows, the Tuff and Ash units, and the Basalt Boulders, Cobbles, and Rubble unit at the slope angles required for a static FOS = 1.3.

5.0 RECOMMENDATIONS

Since no geological model is available and the distribution of the geological units in the vicinity of the pit walls is not known, slopes within the Basalt Boulders, Cobbles, and Rubble; the Fresh Tuff and Ash; and the Highly Weathered Tuff and Ash units should be designed conservatively until a reliable geological model can be constructed and slope designs can be developed based on engineering analyses supported by laboratory testing.

- Slopes developed within the Basalt Flows should be designed at 45°
- Slopes developed within the Highly Weathered Tuff and Ash should be designed according to Figure 4 for slopes 20 to 60 feet high, and at 45° for slopes less than 20 feet high
- Slopes developed within the Fresh Tuff and Ash should be designed according to Figure 5 for slopes 30 to 60 feet high, and at 45° for slopes less than 30 feet high
- Slopes developed within the Basalt Boulders, Cobbles, and Rubble should be designed at 25°
- Soil slopes should be excavated at 2(H):1(V)

If, during excavation, a Basalt Boulders, Cobbles, and Rubble unit is discovered to be more than 60 feet thick, a qualified engineer should be consulted before the slope is developed to a height of over 60 feet. The engineer should sample the material for laboratory testing to verify the assumptions made in this report regarding material properties, and the recommended slope designs should be re-evaluated based on the laboratory testing results.

Any Highly Weathered Tuff and Ash layer or Fresh Tuff and Ash layer that is more than 15 feet thick should be sampled and tested to confirm the material properties, and the design slopes re-evaluated as appropriate.

Slopes developed within the Tuff and Ash units may be highly erodible and surface water should be diverted around the pit crest where these materials are present.

A 20-ft wide catch bench should be incorporated at the top and base of any Fresh or Highly Weathered Tuff and Ash units encountered in the pit wall that are more than 20 feet thick.

If any major structures are identified in the vicinity of the proposed new pit walls, the impact they may have on slope stability should be evaluated by a qualified geotechnical engineer.

The pit slopes should be inspected periodically, and slope performance and geological conditions should be documented. This information should be used to review, and revise as appropriate, the geological and geotechnical models and slope design recommendations provided in this report. Such inspections and slope design reviews should be performed:

- Annually; or
- At any time that operations encounter conditions that vary significantly from the geological and geotechnical models documented in this report; or
- At any time that slopes developed according to the recommendations of this report show indications of significant instability.

This observational and review approach, supported by strength testing of representative materials, would enable more reliable calculation of safety factors for slopes prior to pit closure than calculations based on corehole investigations alone.

For the stability analyses, assumptions were made regarding the material properties, distribution, thickness, and orientation of the units. The assumptions are based on discussions with Teichert geologists, observations of the units in drill core and in exposures at the project site, and on our experience with similar materials elsewhere. Should conditions be encountered that differ from those assumed for this stability evaluation, the slope design recommendations presented in this report should be re-evaluated by a qualified engineer.

6.0 CLOSING

We appreciate the opportunity to prepare this slope stability evaluation. We will finalize the report after we receive your review comments and your required distribution list.

GOLDER ASSOCIATES INC.

Kenneth G. Haskell, P.E.
Principal Engineer

Rhonda Knupp
Senior Project Geologist

REGISTERED PROFESSIONAL ENGINEER
KENNETH G. HASKELL
No. C053290
Exp. 6/30/11
CIVIL
STATE OF CALIFORNIA

Document ID: 10149

7.0 REFERENCES

Bieniawski, Z.T., 1976. Rock Mass Classifications in Rock Engineering: Proceedings of the Symposium on Exploration for Rock Engineering, Rotterdam, Vol. 1, p. 97-106.

Bieniawski, Z.T., 1989. Engineering Rock Mass Classifications: Wiley, New York. 251pp.

California Division of Mines and Geology, 1997. Guidelines for Evaluating and Mitigating Seismic Hazards in California, Special Publication 117.

Gibson, R.E., 1953. Experimental Determination of the True Cohesion and True Angle of Internal Friction in Clays: Proceedings of the 3rd International Conference on Soil Mechanics and Foundation Engineering, Zurich, Switzerland, v. 1, pp.126-130.

Hynes-Griffin, M. E., and Franklin, A. G. (1984). Rationalizing the Seismic Coefficient Method, Miscellaneous Paper GL-84-13: U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Hoek, E., and Bray, J.W., 1981. Rock Slope Engineering. Institution of Mining and Metallurgy. Revised Third Edition, p. 23.

Hoek, E., and Brown, E.T., 1988. The Hoek-Brown Failure criterion – a 1988 Update. Proceedings of the 15th Canada Rock Mechanics Symposium, University of Toronto, pp. 31-38.

Hoek, E., and Karzulovic, A., 2000. Rock-Mass Properties for Surface Mines, in Slope Stability in Surface Mining. Society for Mining, Metallurgy, and Exploration, Inc., pp. 59-69.

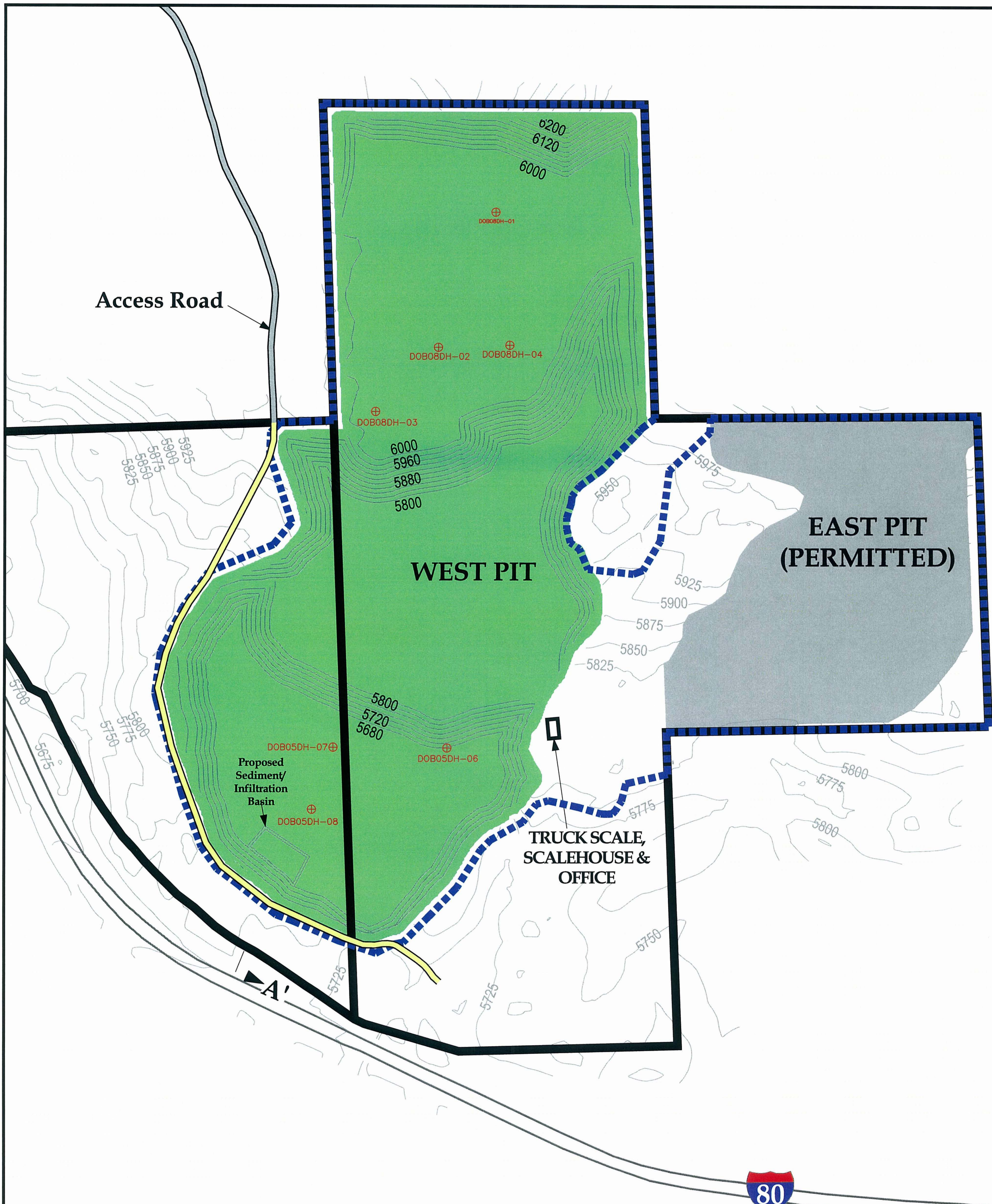
ICBO, 1997. Uniform Building Code: International Conference of Building Officials, Whittier, California.

Petersen, M.D., W.A. Bryant, C.H. Cramer, T. Cao, and M. Reichle, 1996. Probabilistic Seismic Hazard Assessment for the State of California. Department of Conservation, Division of Mines and Geology Open-File Report 96-08.

Pyke, R., 1991. Selection of Seismic Coefficients for Use in Pseudo-static Slope Stability Analyses: http://www.tagasoft.com/TAGAsoft/TAGAsoft/Discussion/article2_html.

Rocscience, 2010. Slide v. 5.044.

FIGURES



Graphics provided by Teichert

LEGEND:

- Existing Access Road
- Proposed County Access Road (Approx. Location- To Be Built)
- Index Contour
- Parcel Boundary
- Ultimate Disturbed Area
- West Pit Mining Area
- East Pit (Permitted)
- DOB05DH-08 Exploration Corehole

NORTH

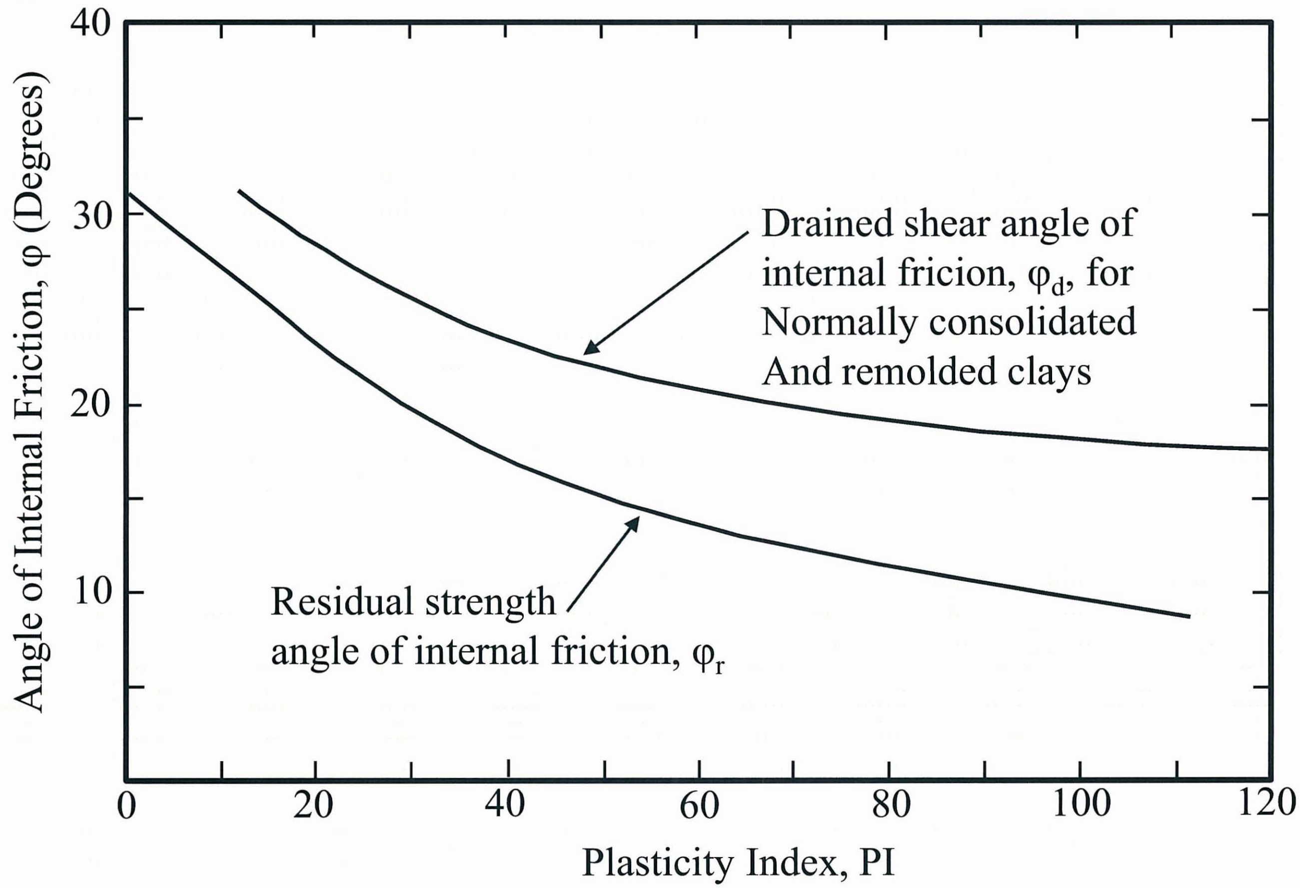
0 300 600 FEET

PROPOSED WEST AND EXISTING EAST PITS
BOCA QUARRY

FIGURE 1

Golder Associates
SACRAMENTO, CALIFORNIA

PROJECT No. 103-91727 DATE 08/05/2010



AFTER GIBSON (1953)

FIGURE **2**

RELATIONSHIP BETWEEN PLASTICITY INDEX AND FRICTION ANGLE

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

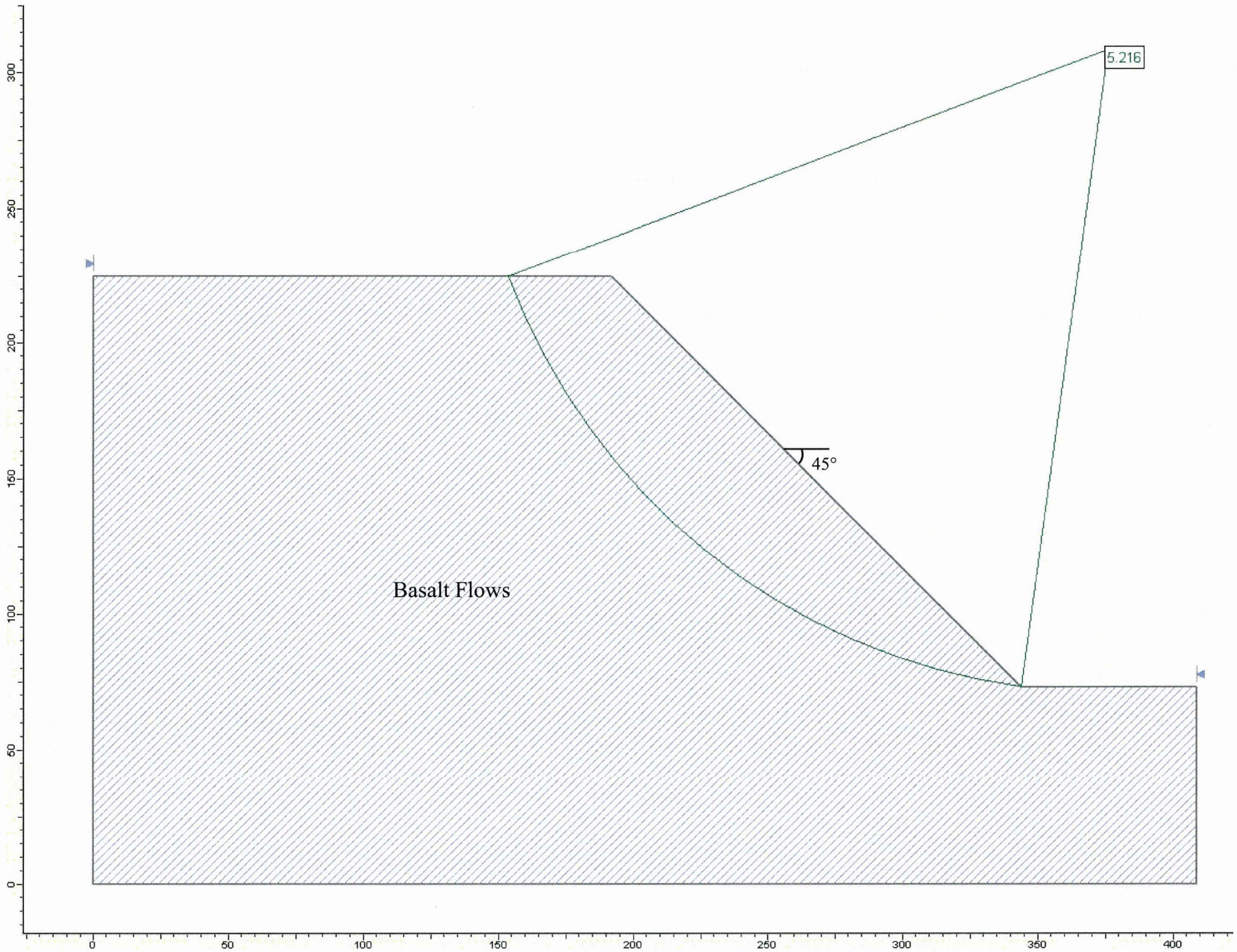


FIGURE 3
STABILITY ANALYSIS RESULTS, BASALT FLOWS
Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

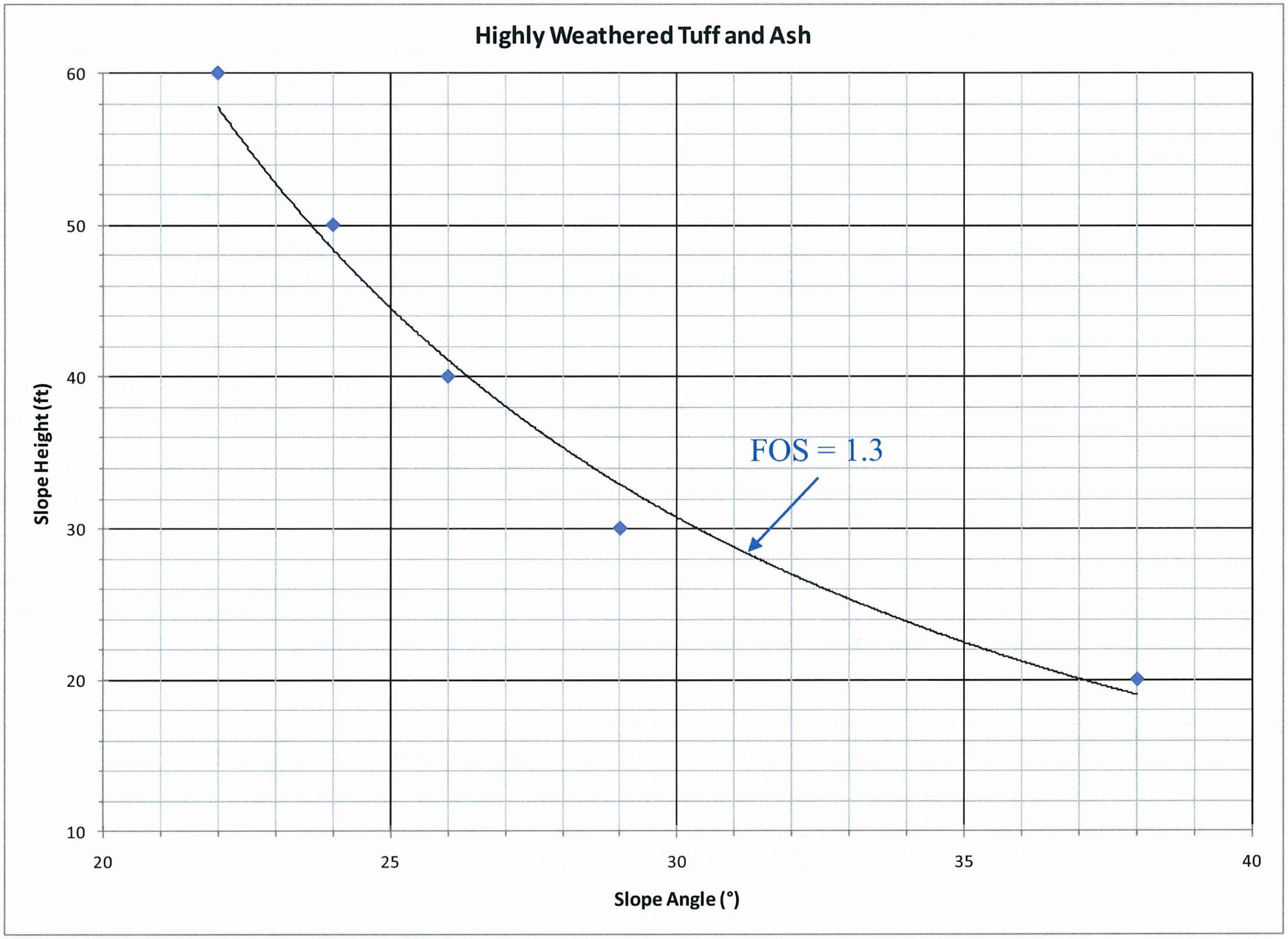


FIGURE 4

SLOPE DESIGN CHART, HIGHLY WEATHERED TUFF AND ASH

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

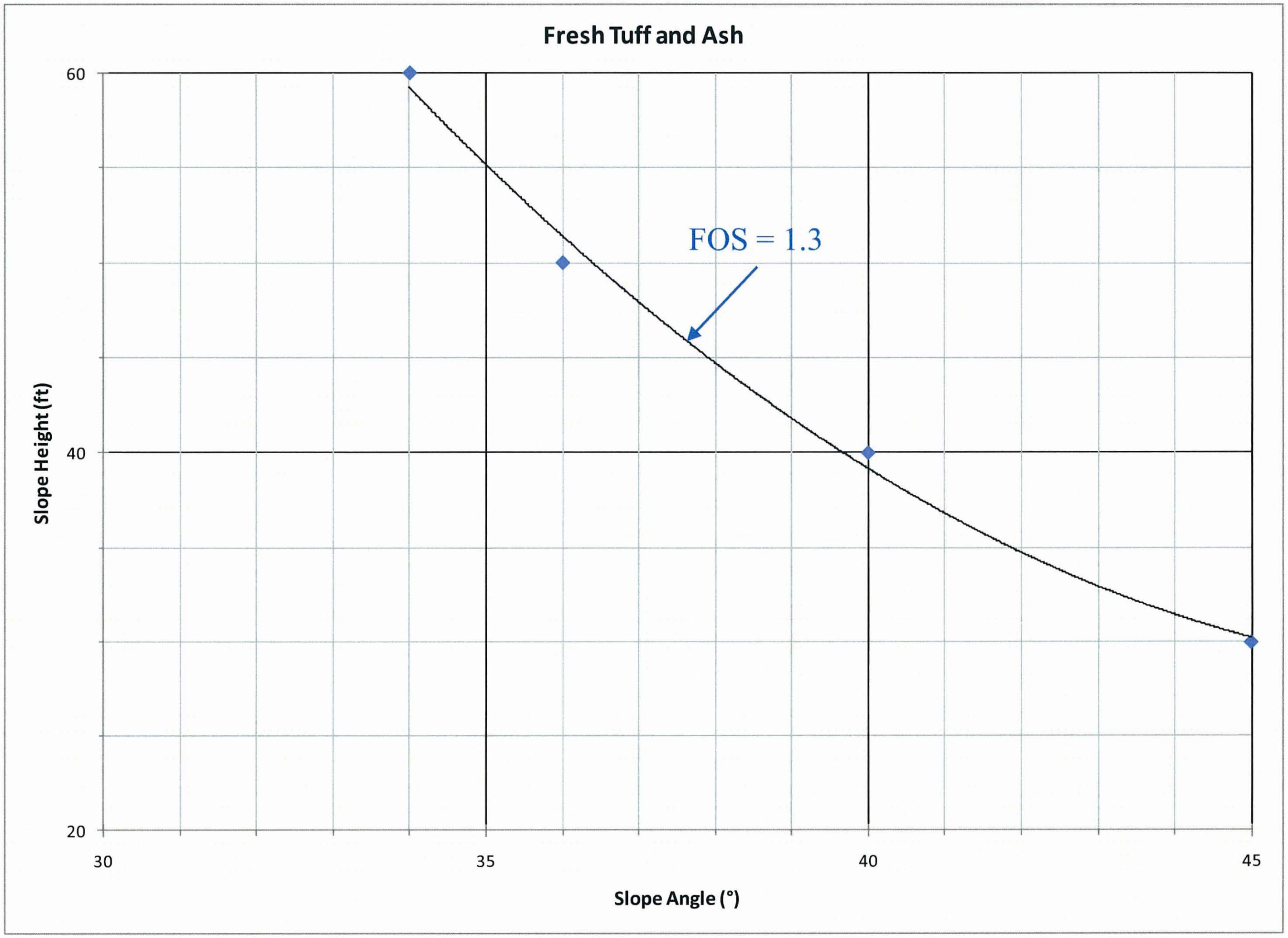


FIGURE 5

SLOPE DESIGN CHART, FRESH TUFF AND ASH

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

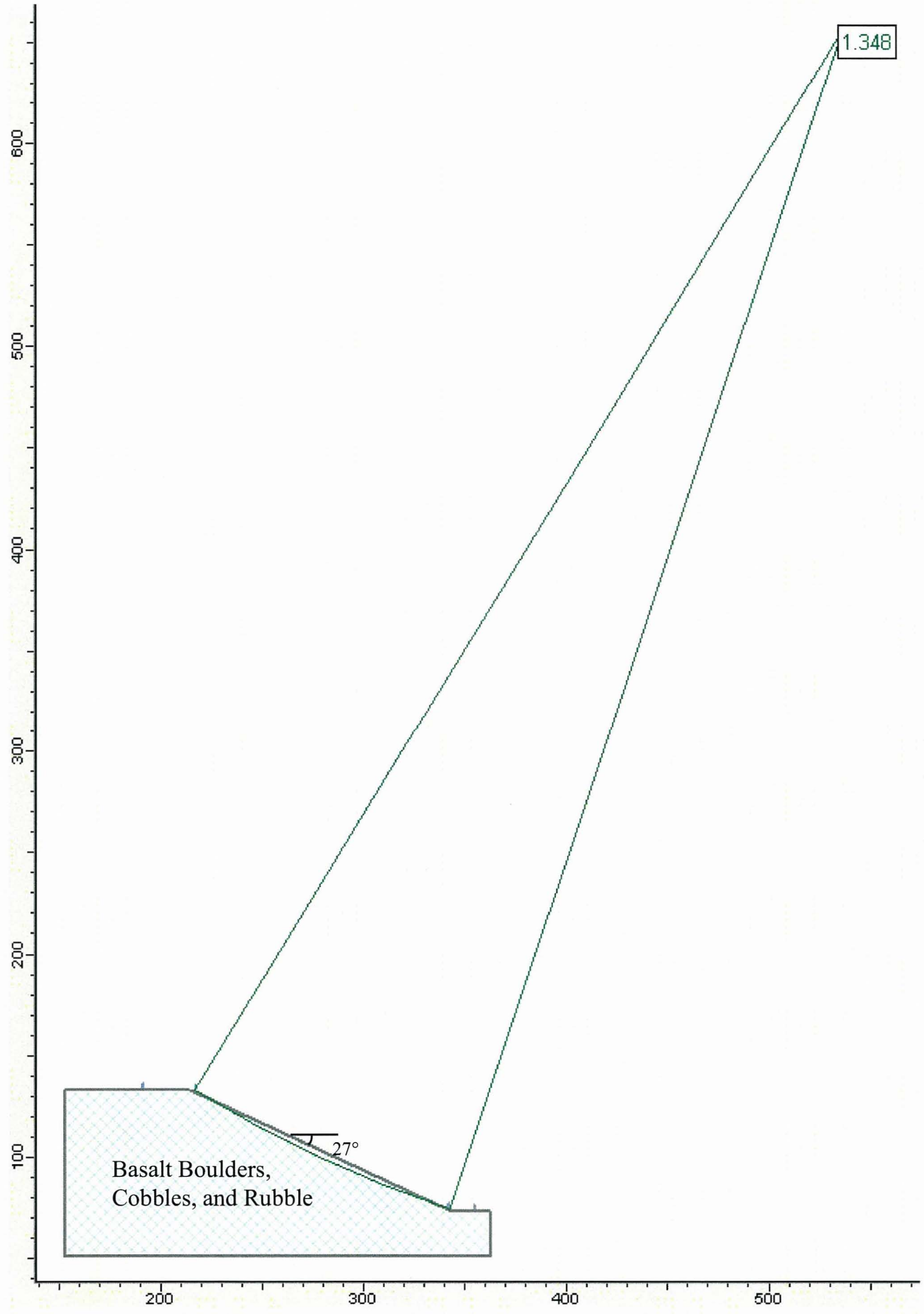


FIGURE 6

STABILITY ANALYSIS RESULTS, BASALT BOULDERS, COBBLES, AND RUBBLE

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

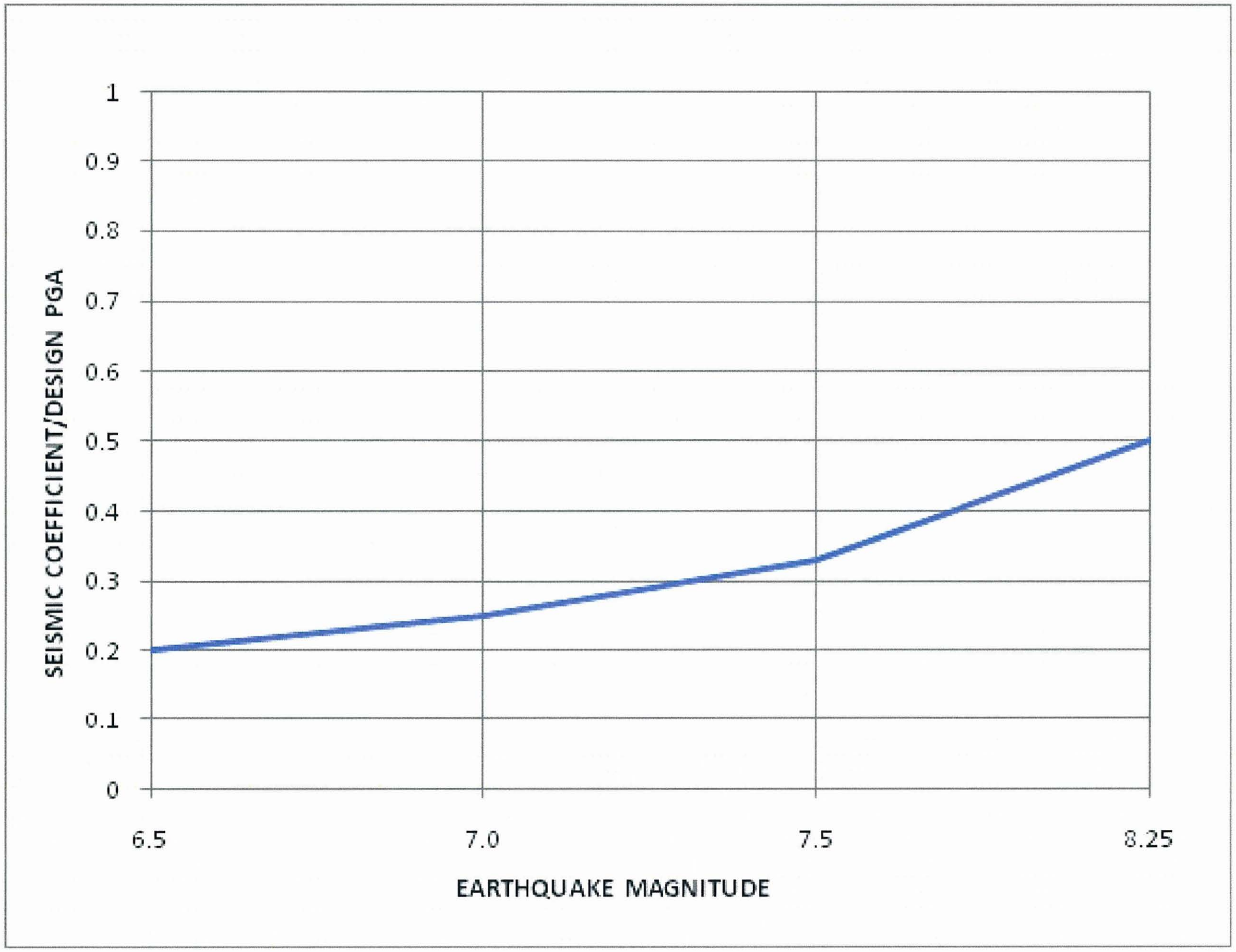


FIGURE 7

PYKE'S (1991) SEISMIC COEFFICIENT RELATIONSHIP

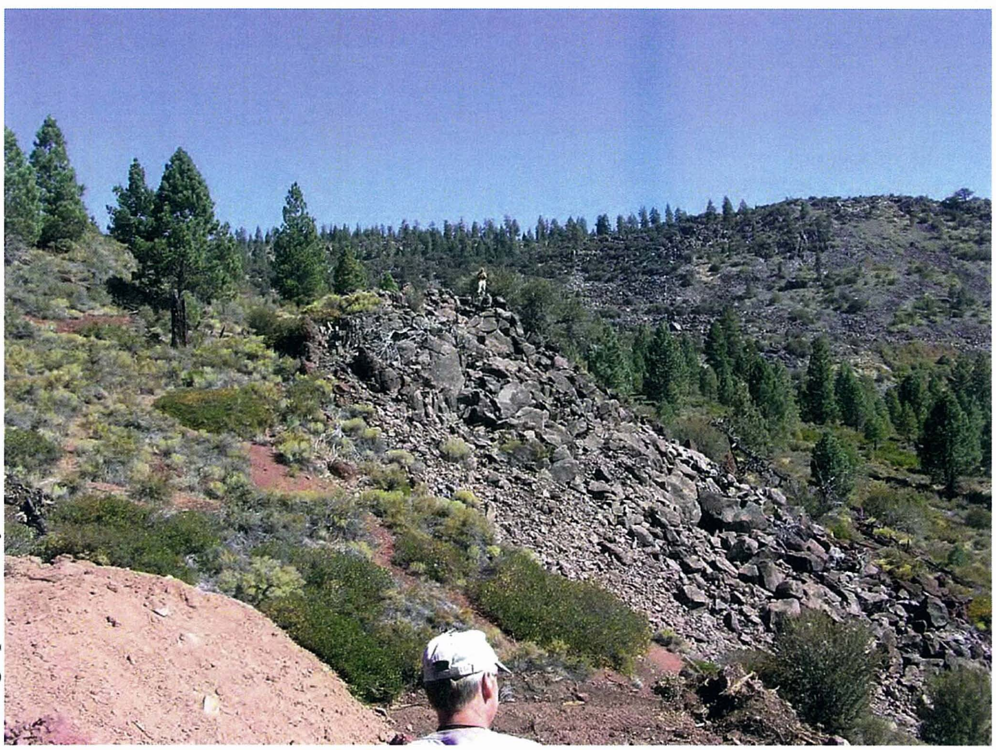
Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates

PHOTOGRAPHS

PHOTOGRAPH 1. Weak, highly fractured Upper Tuff in DOB05DH-08

Photograph Courtesy of Chuck Unsworth, Teichert

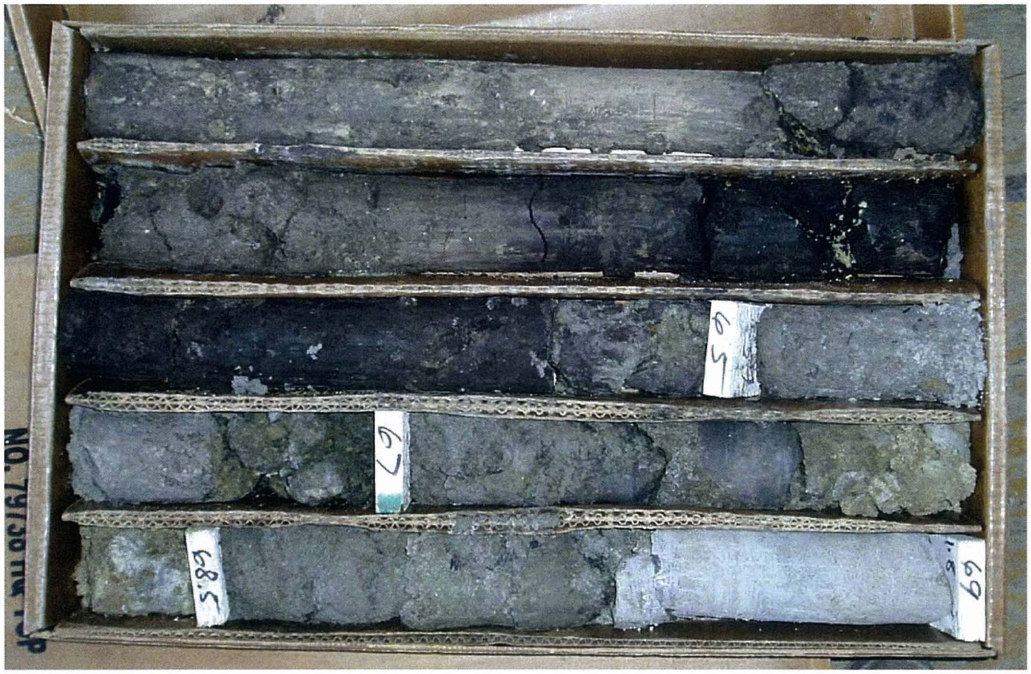


PHOTOGRAPH 2. Basalt (agglomerate?) along property line north of East Pit

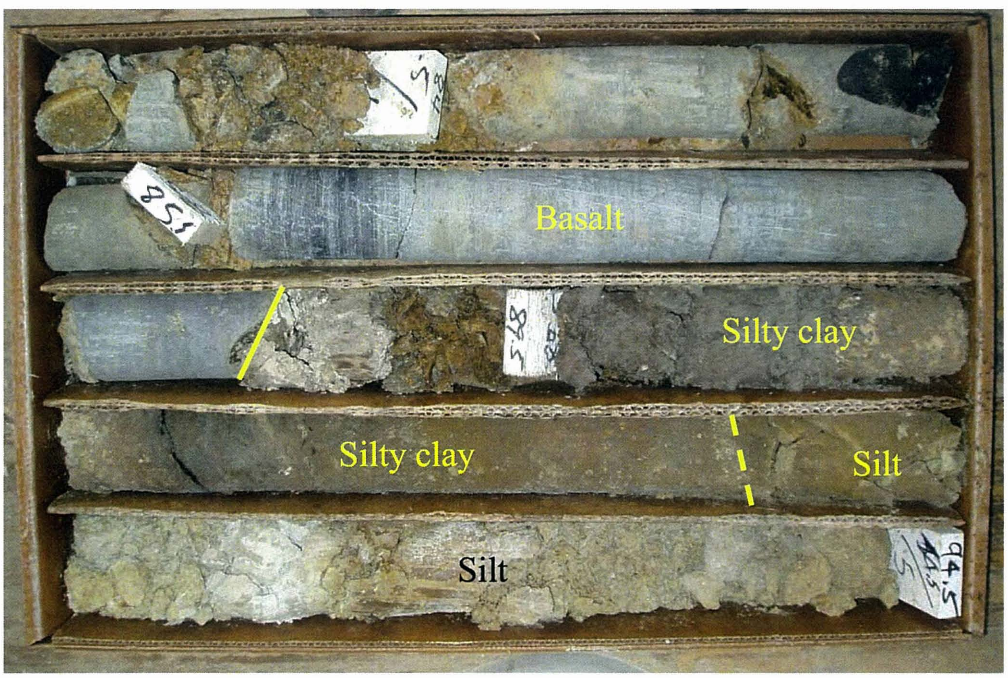
PHOTOGRAPHS 1 & 2

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

Golder Associates



PHOTOGRAPH 3. Clay in Lower Tuff unit in DOB05DH-06



PHOTOGRAPH 4. Clay and silt in lower tuff in DOB05DH-07

PHOTOGRAPHS 3 & 4

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

PHOTOGRAPH 5. Typical basalt in DOB08DH-02

PHOTOGRAPH 6. Sandy clay between clasts in DOB08DH-03

PHOTOGRAPHS 5 & 6

Teichert/Boca Quarry West Pit /CA Job No. 103-91727

PHOTOGRAPH 7. Basalt boulders and cobbles with no fines in DOB08DH-03

PHOTOGRAPH 8. Highly weathered ash in DOB08DH-04

PHOTOGRAPHS 7 & 8

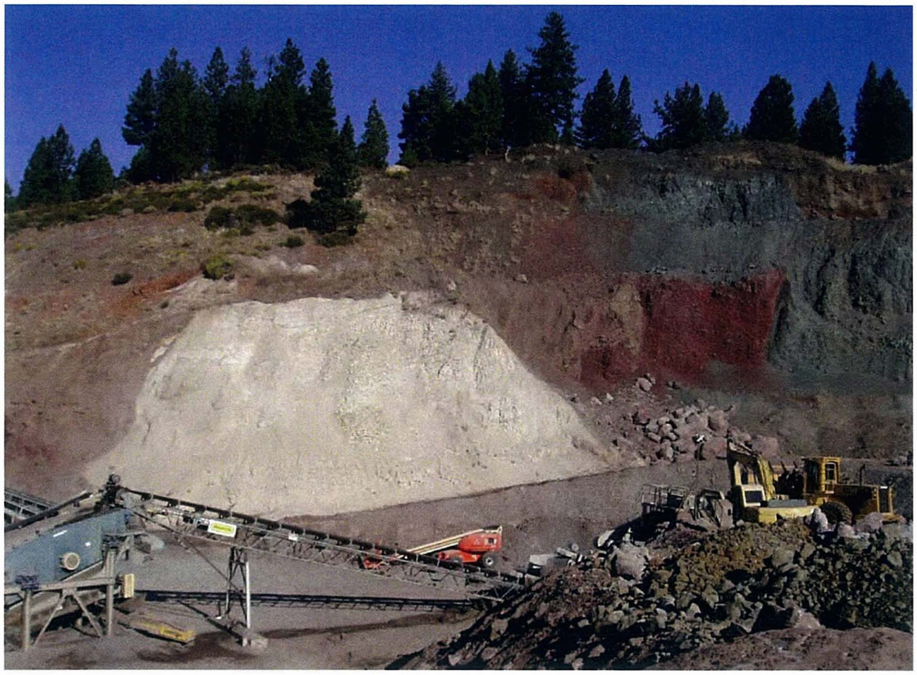
Teichert/Boca Quarry West Pit /CA Job No. 103-91727

PHOTOGRAPH 9. Bedding in ash in DOB08DH-01

PHOTOGRAPH 10. Slickensides in clay-altered ash in DOB08DH-01

PHOTOGRAPHS 9 & 10

Teichert/Boca Quarry West Pit /CA Job No. 103-91727



PHOTOGRAPH 11. 45-ft high exposure of ash in northwest wall of East Pit

APPENDIX A
RMR CALCULATIONS FOR BASALT FLOWS

RMR Calculations for Basalt Flows

DHID	Lith	From (ft)	To (ft)	Length (ft)	Strength Rating	RQD Rating	Spacing Rating	JCR		StrxL	RQDxL	SpacxL	JCRxL	Total
DOB08DH-01	Basalt	103	105	2	12	10	7	12		24	20	14	24	82
DOB08DH-01	Basalt	105	108	3	12	13	7	10		36	39	21	30	126
DOB08DH-01	Basalt	108	112.5	4.5	9	11	7	12		40.5	49.5	31.5	54	176
DOB08DH-01	Basalt	112.5	115	2.5	9	13	5	10		22.5	32.5	12.5	25	93
DOB08DH-02	Basalt	41	44	3	7	7	10	16		21	21	30	48	120
DOB08DH-02	Basalt	44	45.5	1.5	7	12	10	16		10.5	18	15	24	68
DOB08DH-02	Basalt	45.5	50.5	5	7	8	7	16		35	40	35	80	190
DOB08DH-02	Basalt	56.5	61.5	5	9	11	7	16		45	55	35	80	215
DOB08DH-02	Basalt	61.5	64	2.5	12	19	9	16		30	47.5	22.5	40	140
DOB08DH-02	Basalt	64	69	5	12	14	13	16		60	70	65	80	275
DOB08DH-02	Basalt	69	74	5	12	9	10	16		60	45	50	80	235
DOB08DH-02	Basalt	74	79	5	12	8	10	16		60	40	50	80	230
DOB08DH-02	Basalt	79	84	5	12	15	10	16		60	75	50	80	265
DOB08DH-02	Basalt	84	89	5	7	19	10	16		35	95	50	80	260
DOB08DH-03	Basalt	64	69	5	7	16	6	20		35	80	30	100	245
DOB08DH-03	Basalt	69	74	5	7	14	9	20		35	70	45	100	250
DOB08DH-03	Basalt	74	76.5	2.5	7	13	11	20		17.5	32.5	27.5	50	128
DOB08DH-03	Basalt	76.5	79.5	3	7	14	11	20		21	42	33	60	156
DOB08DH-03	Basalt	79.5	84	4.5	7	11	9	20		31.5	49.5	40.5	90	212
DOB08DH-03	Basalt	84	86.5	2.5	7	10	9	20		17.5	25	22.5	50	115
DOB08DH-03	Basalt	86.5	90.5	4	7	9	9	20		28	36	36	80	180
DOB08DH-03	Basalt	90.5	94	3.5	7	18	9	20		24.5	63	31.5	70	189
							Weighted Averages:			**9**	**12**	**9**	**17**	**47**

Note: Core logging data provided by Teichert