Appendix F3 Mine Deformation Study

Appendices

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MINE DEFORMATION STUDY
FINITE ELEMENT ANALYSIS REPORT

for

AGUA MANSA COMMERCE PARK
1500 Rubidoux Boulevard
Jurupa Valley, California

Prepared For:

Crestmore Redevelopment LLC
1745 Shea Center Drive, Suite 190
Highlands Ranch, CO 80129

Prepared By:

Langan Engineering & Environmental Services
32 Executive Park, Suite 130
Irvine, California 92614

18 August 2017
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LANGAN

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1. INTRODUCTION

As requested by Crestmore Redevelopment, LLC (Crestmore) on 26 June 2017, Langan Engineering and Environmental Services, Inc. (Langan) has performed geotechnical and geological engineering services for the proposed project (Aqua Mansa Commerce Park) located at the former Riverside Cement Plant ("site"). This "Mine Deformation Study Finite Element Analysis Report" summarizes the previous document reviews and the results of the deformation study performed using finite element methods. The purpose of the study was to estimate potential changes in stress-strain conditions (i.e., pressure distributions and associated deformations) at the belowground mine chambers and corresponding ground surface deflections due to the proposed development of the Aqua Mansa Commerce Park.

This report summarizes the mine background information including a brief description of the mining at the site and a summary of the proposed development, a description of the finite element analysis, the results of the analysis and a summary of conclusions. Additional details regarding the site geotechnical conditions are presented in the report titled "Preliminary Geotechnical Investigation Report", prepared by Langan, dated 28 April 2017 and the "Mine Study Report" prepared by Langan, dated 25 April 2017.

2. PROPOSED DEVELOPMENT

Based on a review of plans and exhibits provided by Crestmore, including a Draft Preliminary Site Plan dated 7 September 2016 and a April 2017 topographic map prepared by DRC Engineering, the proposed development consists of a commercial/ industrial complex that includes up to 4 single story industrial buildings (identified as Buildings 1 through 4) with potential mezzanine levels totaling a combined footprint of approximately 3.6 million square feet. Site development will require installation of new utilities, and mass grading that could include cuts of up to 35 feet and fills of up to 75 feet.

3. BACKGROUND INFORMATION

The former Riverside Cement Plant is located near the intersection of Aqua Mansa Road and Rubidoux Boulevard in Riverside County, California. The northern part of the site is overlain by fill and is vegetated with shrubs, grass and trees. The remainder of the site contains fill stockpiles including material stockpiles, berms and filled former quarry areas. Ground surface elevations vary from approximately 835 feet above mean sea level (amsl)[1] to approximately 985 feet amsl.

[1] Elevations are based on the National Geodetic Vertical Datum of 1929 (NGVD 1929) as referenced from DRC Engineering, Inc. "Encumbrance Map, Vacant Commercial Property, Jurupa Valley, California" dated 2 March 2016

The Riverside Cement Plant operations included quarries and an underground mining operation (i.e., the Crestmore Mine) that was used to obtain limestone for use in manufacturing cement. The quarries were located south of the proposed buildings; additional information about the location of the quarries is presented in the previously cited reports. Underground mining was initially performed beneath the Chino Quarry, which is located about 700 feet south of the proposed development. Mining progressed north and east as successively lower mining levels were excavated.

3.1. Crestmore Mine

Underground mining at the site began in about 1930. Block caving method was used from 1930 through 1954 in the mine area beneath the Chino Quarry. As the mine progressed deeper, room pillar mining was used from 1955 until about 1986, when the mining ceased and the "rooms" were allowed to fill with water. The limestone formation dips to the east and pitches to the northeast, and the room and pillar mining followed that trend; thus, each successively lower mining level was offset somewhat to the north and east.

Available mapping dated between 1960 and 1970 indicates that ten mine working levels are documented for the Crestmore Mine. The shallowest of those mine workings beneath proposed Building 1 occurs at a mine floor elevation of 440 feet amsl. Shallower mine workings exist at mine floor elevations of 572 feet and 542 feet; however, the mine workings at the elevations of 572 and 542 feet are located outside the proposed Building 1 footprint. Deeper mine workings are mapped at mine floor elevations of 400, 330, 290, 220, 130, 35, and -60 amsl.

3.2. Site Geologic Setting

The site is located on the Perris Block in the eastern end of the Jurupa Mountains on the south side of the San Bernardino Valley, which lies within the Peninsular Ranges geomorphic province of California. The Perris Block is the central block of three major fault-bounded northwest-southeast trending blocks of the northern part of the Peninsular Ranges. The Perris Block is bounded to the east by the San Jacinto Fault Zone, to the north by the Cucamonga Fault Zone, and to the west by Elsinore Fault Zone; and, it is considered to be internally un-faulted and therefore structurally stable.

The Perris Block is underlain by lithologically diverse pre-batholithic meta-sedimentary rocks intruded by plutons of the Cretaceous age Peninsular Ranges batholith. Limestones (aka, the mined "ore bodies") are present as two generally irregular, roughly parallel, lenticular sedimentary members dipping primarily east-northeast and pitching to the northeast The upper and lower limestone bodies are referred to as Sky Blue and Chino Limestones, respectively and are mineralogically similar. However, the upper member was highly fractured and water bearing in contrast to the lower member.

The limestone members are enveloped and cut by intrusive igneous rocks that resulted in alteration due to contact metamorphism of the limestone, which became coarsely crystalline and locally predazzite marble. The country rock within the boundary of the site consists predominantly of quartz-biotite diorite. Although quartz monzonite pegmatites occur commonly as small or thin dikes in the porphyry and country rock and extended generally less than 2 or 3 feet into the limestone. The contact rock predominantly consists of Hornfels. In addition, available Riverside Cement structure logs (taken from diamond drill holes during the original mine investigation) indicate at least 4 predominant joints sets are present in the roof rock mass. The majority of the joints are described as being rough or cemented.

Erosional depositional surfaces are developed on the Perris Block and Quaternary age non-marine sediments of varying thickness discontinuously mantle the basement rock. In particular, the northern portion of the site (i.e., beneath the proposed buildings) is underlain by Holocene to late Pleistocene age alluvial fan deposits consisting of gray alternating layers of mixtures of sands, silts, and clays having varying proportions of gravel and cobbles with occasional boulders. Locally, near the surface are man-emplaced uncontrolled fills consisting of talus materials and intermixed cement materials from the cement manufacturing operations.

4. FINITE ELEMENT MODEL

The finite element analysis was performed using the program Midas GTSNX 2017 v.2.1. Midas GTSNX is a finite element analysis software package that was developed specifically to perform fully coupled analyses for geotechnical applications. The program was developed to analyze 3D models and allows for the use of both hexahedral and tetrahedral mesh elements to assist in the refinement of the analysis around complex surface models. The program includes both linear and nonlinear soil and rock models.

As discussed above, the site geology and mining layout is complex. Therefore, a generalized subsurface conditions model was developed for the basis of the finite element model. The following sections describe subsurface conditions used as the model inputs and the development of the finite element model.

4.1. Subsurface Conditions Model

In general, the mined limestone deposit consists of a steeply dipping and pitching metamorphosed and recrystallized limestone ore body separated and surrounded by the intruding country and contact rock (i.e., diorites and hornfels). Overlying the rock is both naturally occurring and man-emplaced (fill) soils. For the purpose of developing the model, the soil (both fill and naturally occurring) and rock stratum were divided into four stratigraphic units possessing material properties estimated to be representative of each soil or rock unit. The four material units are: soil; hornfels/diorite; limestone; and, diorite (see Figure 1). Based on the potential for variability in the roof materials, the roof materials (i.e., hornfels/diorite) were assigned as a layer separate from the surrounding country rock.

The subsurface conditions model was developed as a generalized profile by interpolating between 13 surficial geotechnical boring logs from the Langan 2016 geotechnical investigation and 38 diamond drill core logs prepared by Riverside Cement Company between 1951 and 1964. The model boundaries were set beyond the boring and drill core locations (model boundaries are further explained in the following section); therefore, the outermost borings and drill cores were used to extrapolate the subsurface conditions laterally and vertically towards the model boundaries. Cross-sections within the area encompassing the proposed Building 1 base using the above data are in included in Figure 1. The proposed Building 4 is located over 3,000 feet from the proposed Building 1; therefore, the proposed Building 4 is not included in the model.

4.2. Model Development

The model boundaries were selected to allow space for potential stress and strain dissipation within the finite element model area of interest. The horizontal extent of the model (i.e., in the X-Y plane) is 3,900 feet in the X direction and 3,500 feet in the Y direction; the location of the X-Y plane origin was chosen 6,217,000 feet east and 2,317,000 feet north from the “NAD 1983 State Plane California VI FIPS 0406 Feet” origin.

The vertical model coordinates (i.e., the Z coordinates) correspond to the NAVD88 vertical datum, and ranged from elevation -150 feet (which is approximately 90 feet below the lowest mine level) to elevation 1,192 feet. The model geometry consisted of a model block with the bottom and side boundaries set as flat surfaces, and the top boundary consisting of an interpolated surface developed from the elevation contours in the April 2017 topographic map prepared by DRC Engineering. Figure 2 presents a screenshot of the FE model showing model boundaries and geometry.

The model boundary conditions were set such that x-direction (east-west) displacements were constrained for the left (west) and right (east) sides of the model, and y-direction (north-south) displacements were constrained for the front (north) and back (south) sides of the model. Additionally, the x-, y-, and z-direction displacements were constrained at the bottom/base of the model.

The in-situ soils were modeled using the Modified Mohr-Coulomb model, which is a nonlinear elastic model based on elasto-plastic formulations, where the axial strain and decrease in material stiffness caused by the initial deviatory stress is similar to the Hyperbolic Constitutive Strength Model. The upper rock units (i.e., hornfels-diorite and limestone) were modeled using the Hoek-Brown material model, which is a nonlinear strength model used for isotropic rock masses. The diorite beneath the limestone was modeled using a linear elastic model.

4.3. Material Properties

Due to the history of mining at the Crestmore Mine, numerous studies were conducted over the years regarding mining techniques and material properties. Testing by Long and Obert (1958) indicates unconfined compressive strength (UCS) values of the limestone to range from 6,700 to 24,000 pounds per square inch (psi). A study done on the limestone in the Crestmore Mine by Heuzé in 1967 reports measured UCS values from core samples taken from mine pillars between the 130, 220, and 330 mining levels ranged from 3,840 to 11,850 psi. The limestone is considered to be relatively strong having an outer fiber tensile strength ranging from about 2,170 to 2,400 psi. Elastic Modulus data from the mine pillar testing done indicates values on the order of 2,500,000 to 11,388,888 psi, while modulus of rigidity values ranged from about 2,290,000 to 4,370,000 psi.

There was no test data available regarding the strength of the igneous and metamorphic country rock. However, regional data for diorites and monzonites (similar chemistry to the hornfels-diorite unit), indicate UCS values on the order of 12,000 to 17,000 psi and elastic moduli on the order of 4,800,000 to 6,666,000 psi. Furthermore, available rock chemistry data for the Crestmore Mine indicates minerals such as sericite, an alteration product of quartz that would reduce strength of the quartz-bearing igneous rocks, is not present in abundance.

The results of the above testing suggest that the limestone and the igneous/metamorphic roof rock can be characterized as an elastic material, and are expected to have a relatively high Geological Strength Index (GSI) on the order of 45 to 65. The results of the above testing suggest that both the limestone and surrounding roof rock are considered to be relatively strong.

The 1967 study by Heuzé concluded that the critical geometric parameter for the mine was the room width. Any room height up to 70 feet was considered safe provided the room width was less than 70 feet. The reported mined room height beneath Building 1 at a working level of 440 feet is roughly 30 feet, and the corresponding room width is 60 feet. Critical stresses were identified by Heuzé to be tensile stress in the mine roof and shear stress near the pillar corners. Studies performed during the Crestmore mining operations concluded that the factored maximum allowable pillar design strength should be just over 4,000 psi. In addition, measured rock jointing identified 3 predominant orthogonal sets oriented near horizontal and vertical; and, therefore were not adversely oriented (i.e., not prone to failure).

Based on criterion developed by Obert and Duvall (1967), the maximum allowable extraction ratio for this site would be roughly 72% to 80%. The calculated extraction ratios were about 60%, which indicates that less material was mined than theoretically could have been while allowing for a factor of safety against the collapse of the overburden.

Engineering properties assigned to the soil layer were derived from the Standard Penetration Test (SPT) N-values reported on the Langan geotechnical boring logs, using the Meyerhof (1956) relationships for relative density, and the strength and stiffness empirical formulas by Brinkgreve, et al., (2010). The engineering properties assigned to each of the rock unit models were obtained from the Langan Mine Study Report, from the rock mass characterization documented on the Riverside Cement Company's diamond core logs, and from the empirical and theoretical correlations in Hoek, et al., (2002) and Hoek & Diederichs (2005). Material model upper- and lower-bound parameters (i.e., range) are shown below in Table 1.

Table 1: Material Model Parameters

	Soil	**Hornfels - Diorite**	**Limestone**	**Diorite**
Unit Weight	120 pcf	170 pcf	165 pcf	170 pcf
Poisson Ratio	0.25	0.14 to 0.18	0.2 to 0.25	0.2
Effective Cohesion	50 psf	---	---	---
Effective Friction Angle	36° to 38 °	---	---	---
Secant Stiffness, E50ref	5,555 to 6,945 psi	---	---	---
Oedometer Tangential Stiffness, Eoedref	5,555 to 6,945 psi	---	---	---
Unloading Modulus, Eurref	15,970 to 20,830 psi	---	---	---
Power of Stress Level Dependency, m	0.5 to 0.45	---	---	---
Rock Mass Modulus	---	2,777,000 to 3,265,000 psi	2,173,000 to 2,500,000 psi	3,472,000 psi
Geologic Strength Index	---	60	60	---
Unconfined Compressive Strength	---	10,000 to 20,000 psi	6,250 to 8,350 psi	---
Hoek-Brown constant mi	---	19	9	---
Disturbance Factor, D	---	0	0.2	---

The soils and rock drainage parameters were set as "Drained", where no excess pore-water pressure is generated and soil stiffness and strength are defined in terms of effective properties. The soil and rock were modeled with a permeability coefficient set to the Midas GTSNX "Drained" default value of 0.000033 feet per second. A global groundwater level was assigned for the model at elevation 825 feet, based on average measurements of the surface water elevation at Crestmore Lake.

4.4. Mine Geometry

The Riverside Cement Company mine level maps from 1955 to 1973 (summarized in the Mine Study Report) were used to create approximate two dimensional (2D) geometries of the bottom of each mine level. Mine levels -66, 35, 120, 210, 290, 440, and 542 feet were used in the finite element model. The mine geometries for levels of 542 and 572 feet were combined into one level (level 542). Each mine level was then referenced into the model's coordinate system. The three dimensional (3D) mine geometries were then created by extruding the 2D mine base geometries upwards a distance equal to the average room height, and then the mine roof corners were rounded to a 6-foot radius as outlined in Table 2 below. Figure 3 presents a screenshot of the mine levels and geometry used in the finite element model.

Table 2: FE-Model Geometries at Each Mine-Level Room

Mine Level	Roof Elevation (feet)	Floor Elevation (feet)	Mine Height (feet)
542	602	542	60
440	470	400	70
290	360	290	70
210	260	210	50
120	160	120	40
35	67	35	32
-66	-30	-66	36

4.5. Mesh Generation

Subsequent to the refinement of the model geometry and the material properties, the geometric volumes were divided into tetrahedron finite elements to perform the mathematical calculations; a composition of finite elements is called a mesh. Due to the large model-boundary extents and the challenging geometrical and material characteristics of this particular FE model, each volume, in areas along the model boundaries and distant from the rooms and pillars, was meshed with a target average element size having dimensions of up to about 100 feet. Elements approaching the rooms and pillars were sized at dimensions of up to 50 feet; however, elements in the room roof and pillar corners, which are the critical areas, were set between 5 and 25 feet.

4.6. Loading Conditions

The proposed site grading was modeled by creating equivalent building pads (rectangular prisms) at each building footprint. The building pads were modeled such the applied pressure at the bottom of each pad was equivalent to the applied pressure from the proposed grading. The pressures from the proposed grading were estimated using an estimated wet unit weight for the soil of 120 pounds per cubic feet (pcf) for the calculated cut and fill volumes from the proposed site grading. The cut and fill weights were modeled by assigning an equivalent unit weight at each building pad. The building pad for Building 1 was set with the top at an elevation of 966 feet; the pad for Building 2 was set with the top at an elevation of 948 feet; and, the pad for Building 3 was set with the top at an elevation of 956 feet. An additional fill volume south of Building 1 was modeled to account for up to 75 feet of fill in this area.

The building pads and the fill south of Building 1 were modeled as drained, isotropic-elastic materials using elastic moduli of 2,880 ksf for the building pads and 1,500 ksf for the fill, and with Poisson's ratios of 0.2 for the building pads and 0.25 for the fill.

The loading from the buildings was modeled as a 500 pounds per square feet (psf), uniformly distributed, static load directly applied at the top of each building pad. The 500 psf loading was derived assuming about 100 psf from about 8 inches of concrete (building floor plus room), plus 300 psf from the American Society of Civil Engineers (ASCE) 7- recommended live load for a storage facility, plus 100 psf from column loads (this assumes large columns spans).

Gravity loading was modeled using the "Self Weight" tool in Midas GTSNX. The gravity loading was applied vertically in the downward direction.

4.7. Staged Construction Modeling

Model finite element calculations were divided into several sequential calculation stages (i.e., Midas GTSNX "Construction Stages"). These model stages were each assigned an element mesh set, calculation type, and load type. The first stage (Stage 1) modeled the initial stresses and initial pore-water pressures. The built-in "Ko – procedure" was used to generate initial soil stresses. All the subsequent stages were modeled utilizing a nonlinear-elastic analysis of stresses and deformation. The order and description of the different model stages are detailed below.

- *Stage 1 –* *Initial Stress Generation (K0 procedure):* The existing ground surface, the subsurface materials, and the ground water were included. The global boundary conditions and gravity loading ("Self Weight" tool) were applied.

- *Stage 2 –* *Clear Displacements from Stage 1:* The calculated displacements from the previous stage were cleared and set at zero.

- *Stage 3 –* *Mining:* The limestone mesh-set that formed the mine openings (rooms) was deactivated.

- *Stage 4 – Clear Displacements from Stage 3:* The calculated displacements from the previous stage were cleared and set to zero.
- *Stage 5 – Proposed Grading:* The building pad and fill mesh-sets were activated.
- *Stage 6 – Building Loading:* The building loads were activated and applied over the building pads.

Figure 4 presents screenshots of stages 1, 3, 5, and 6.

5. RESULTS OF FINITE ELEMENT MODEL

The finite element model results are outlined in the following sections and represent the above described geometry and loading conditions for the model, using the lower-bound soil and rock elasto-plastic parameters shown in Table 1.

5.1. Mesh Generation Ground Surface and Mine Roof Movements

Mine roof and ground surface vertical movements were calculated from the mining stage (Stage 3). The calculated mine roof and ground surface vertical movements ranged from 0.1 to 0.6 inches of downward movement as shown on Figure 5. It is anticipated that such movements (estimated) would have occurred shortly after the mining was completed, which was decades ago. The calculated ground surface and mine roof vertical movements from the effect of grading (Stage 5) and building loading (Stage 6) are summarized in Table 3 below and are shown on Figures 6 and 7.

Table 3: Calculated Incremental Vertical Movements from Stages 5 and 6

Ground Surface Settlement from Grading (Stage 5)	Beneath Building Pad for Building 1	-0.4 to -2.2 inches (Heave)
	Beneath Building Pad for Building 2	0.1 to 1.1 inches
	Beneath Building Pad for Building 3	0.1 to 1.1 inches
Ground Surface Settlement from Building Loading (Stage 6)	Beneath Building Pad for Building 1	0.0 inches (net movement)
	Beneath Building Pad for Building 2	0.2 to 0.5 inches
	Beneath Building Pad for Building 3	0.1 to 0.4 inches
Mine Roof Movement from Grading (Stage 5)	Negligible – The calculated downward movement (estimated) is less than one hundredth of an inch.	
Mine Roof Movement from Building Loading (Stage 6)	Negligible – The calculated downward movement (estimated) is less than one hundredth of an inch.	

5.2. Induced Stresses on Mine Pillars

The calculated maximum induced stresses in the mine pillars from the effect of grading (Stage 5) and building loading (Stage 6) are summarized in Tables 4 below. The net induced stresses from the grading plus building loading resulted in an estimated net unloading (i.e., a reduction in the in-situ stresses caused by the soil removal) of the pillars directly beneath the Building 1 footprint. Figure 8 illustrates the effective stress diagrams depicting this stress unloading condition. The highest calculated induced stresses, as a percentage increase of the average in-situ stress, from Stages 5 and 6 were calculated at Level 120 in the pillars closest to the proposed fill south of Building 1. The maximum average effective in-situ stress at pillars was about 1,415 psi at Level -66.

Table 4: Calculated Mine Pillar Induced Stresses from Stages 5 and 6

Mine Level	Avg. Effective In-Situ Stress at Pillars	Maximum Induced Stresses from Grading (Stage 5)		Maximum Induced Stresses from Grading Plus Building Loading (Stage 6)	
		Stress	% of in-situ	Stress	% of in-situ
542	655 psi	1.2 psi	0.2%	1.5 psi	0.2%
440	725 psi	1.4 psi	0.2%	2.0 psi	0.3%
290	840 psi	5.5 psi	0.7%	5.9 psi	0.7%
210	935 psi	7.0 psi	0.7%	7.4 psi	0.8%
120	1,185 psi	9.4 psi	0.8%	10.3 psi	0.9%
35	1,250 psi	10.2 psi	0.8%	10.9 psi	0.9%
-66	1,415 psi	6.6 psi	0.5%	7.3 psi	0.5%

5.3. Model Verification/Calibration

The finite element calculations were performed using the range in material strength parameters shown in Table 1 to attempt to understand the resulting stress/strain relationship with respect to the material input parameters. Additional tasks were also performed to attempt to verify and/or assess the veracity of the model results. The additional tasks performed are outlined below.

1. Different model sizes (boundary extents) and configurations were evaluated to attempt to confirm that the stress and strain dissipation within the finite element model area of interest from the proposed grading and building loading was consistent with expectations.

2. As previously mentioned, the proposed site grading was modeled by creating equivalent building pads (rectangular prisms) at each building footprint and the expected building loading was applied at the top of each building pad. The proposed approximate cut and fill volumes were estimated and the approximate applied pressures from the proposed grading were hand calculated to confirm that the applied pressure beneath each building pad was similar to the pressure from the proposed grading. Additionally, the stiffness of the building pads was confirmed by checking the induced stresses from Stage 6 at the base of each building pad.

3. The horizontal roof stress was calculated for a 56-foot wide room at mine level 210 to validate the finite model results with the results published in the 10 September 1982 publication by Francois E. Heuzé titled "Geomechanics in Hard Rock Mining: Lessons from Two Case Histories". The calculated total horizontal (shear) stresses at the roof, using lower-bound parameters, varies between 260 and 320 psi, which are similar to the published horizontal longitudinal and transverse stresses of 275 and 330 psi, respectively, for the same room width at the same level (see Figure 9).

4. As previously mentioned, mine roof vertical movements were calculated from the mining stage (Stage 3) to range from 0.1 to 0.6 inches of downward movement, which are similar to the vertical room closures (i.e., pillar shortening and room downward movement measured using extensometers) on the order of less than 0.6 inches reported by Heuzé in 1967, 1974, and 1982. The measured room closures were considered the result of blasting-induced damage and dilation from the mine excavation

5. A simplified analysis was also performed to estimate the settlement beneath Building 2 from the proposed building loading. The results of the hand-calculations were within ±10% from the estimated settlement from the finite element model.

6. CONCLUSIONS

The results of the document review, literature review and the finite element modeling indicate that the presence of the former mine workings will not impact the proposed development, consisting of multiple warehouse distribution buildings. The results of the modeling indicate that a loss of soil support is not anticipated in the proposed new building foundation bearing zone. The above conclusions are based on the following:

1. The proposed grading and new building loads will not induce significant increases in stress or deformation within the former mine workings. Based on the current grading plan, significant earthwork removal is required at Building 1, which is the only proposed new building to be located directly above the former mine workings. Note that mine level 440 is closest to Building 1 and is approximately 420 feet beneath the building's proposed pad grade. The earthwork removal or "cuts" will result in a future lower overburden pressure than currently exists.

2. In room and pillar mining, as a room chamber is excavated, a portion of the overburden load is shed to the adjacent pillars, resulting in a concentration of stress at the pillar corners and sidewalls. As previously mentioned, studies performed during the Crestmore mining operations concluded that the factored maximum allowable pillar design strength should be just over 4,000 psi. The calculations performed during our modeling indicate

that the maximum vertical pillar stress, after the proposed new surface development (with the anticipated warehouse loading); will be 1,600 psi at mine Level -66 (see Figure 10). A comparison of the allowable strength and calculated maximum stress indicates sufficient capacity remains in the pillars, including a safety factor. This means that a pillar would have to suffer 80% loss of strength before collapse becomes imminent. Strength loss on this order for limestone of the quality measured during is not anticipated.

3. The greatest calculated induced stresses in a mine pillar will come from the deepest proposed fills. The location of the deepest fill is to the south of the proposed Building 1. However, the maximum calculated grading-induced stress is less than 0.8% of the calculated existing in-situ stress, and occurs at Mine Level 120, at about 800 feet vertical from the proposed Building 1 pad elevation and about 400 feet south of Building 1. For comparison, the maximum grading plus building load-induced stress is less than 0.9% of the calculated existing in-situ stress, and also occurs at mine level 120. Stress increases of below 1% are considered numerically insignificant.

4. The results of the finite element model calculated grading and building load inducted deformations on the order of 0.01 inch or less, which is consistent with a stress increase of about 1% or less. Estimated stress increases of this magnitude are not expected to result in surface deformations sufficient to materially impact geotechnical stability under Building 1.

7. LIMITATIONS

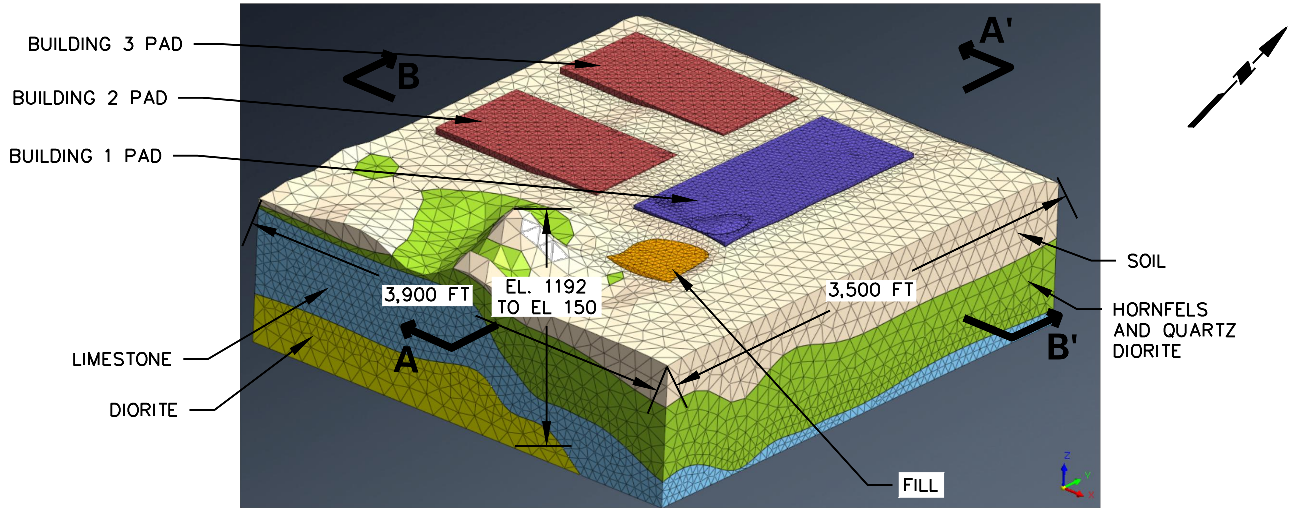
The above study was performed using data obtained from the geologic and engineering literature, from the results of the preliminary geotechnical investigation conducted by Langan and from the diamond core logs provided by the Riverside Cement Company. Strength parameters for the limestone were obtained from 1967 testing by Hueze; strength parameters for the hornfels diorite were obtained from the cited literature and not confirmed in the field by drilling and testing. The model profile was also estimated from the cited literature and the diamond borehole logs and not confirmed in the field by drilling and testing.

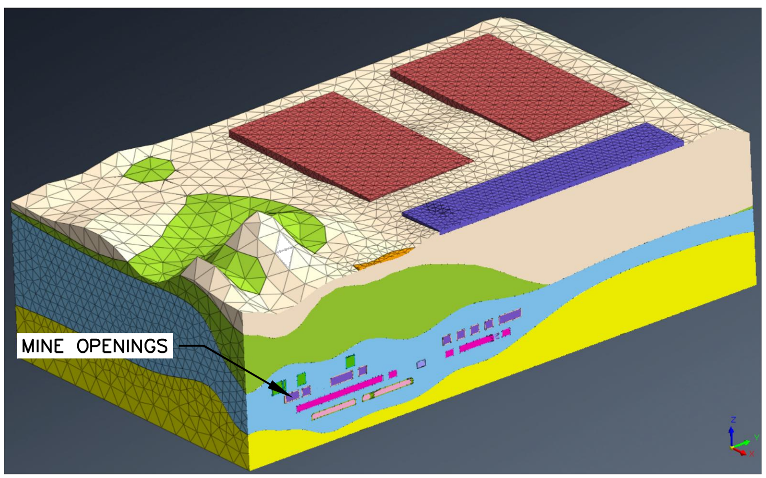
The services were performed in accordance with the standard of care and peer reviewed by the following peer reviewers.

1. Professor Tim Stark, PE Professor of Geotechnical Engineering at the University of Illinois, Urbana-Champagne, Illinois.
2. Edward Wellman, Principal Geologist, SRK Consulting, Denver, Colorado

Enclosures: Figures 1 through 10; Appendix A

FIGURES





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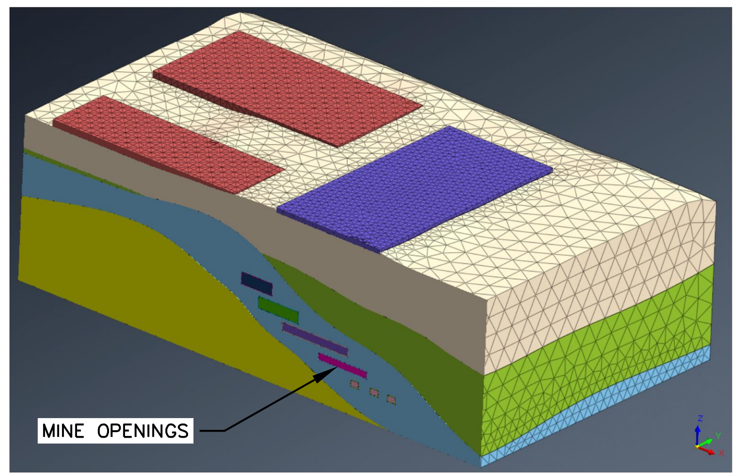

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Project

AGUA MANSA COMMERCE PARK

JURUPA VALLEY
RIVERSIDE COUNTY CALIFORNIA

Drawing Title

FINITE ELEMENT MODEL BOUNDARIES AND CROSS-SECTIONS

Project No.	700045406
Date	18 AUGUST 2017
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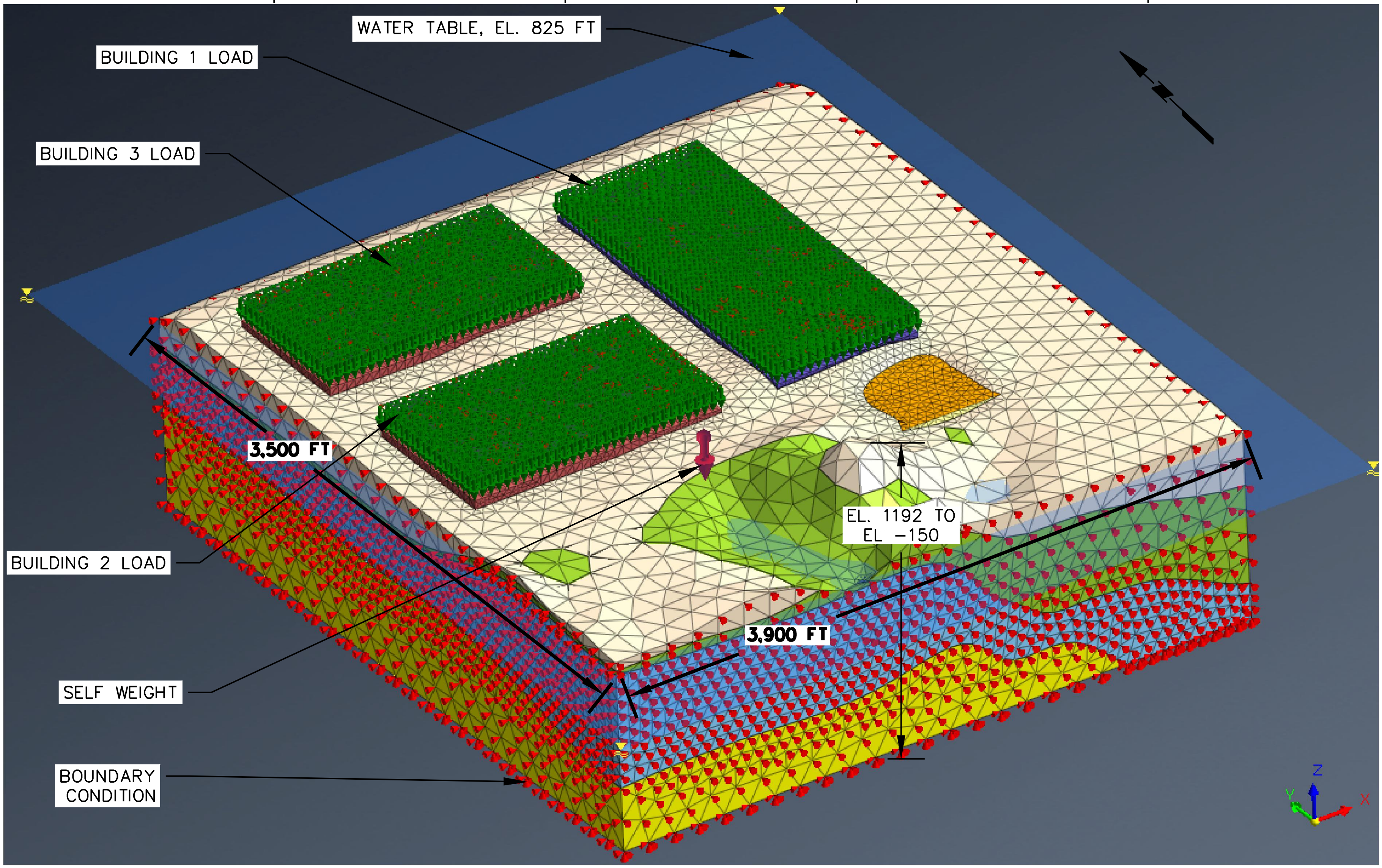
Drawn By	IH
Checked By	LB
Figure No.	1

1	2	3	4	5



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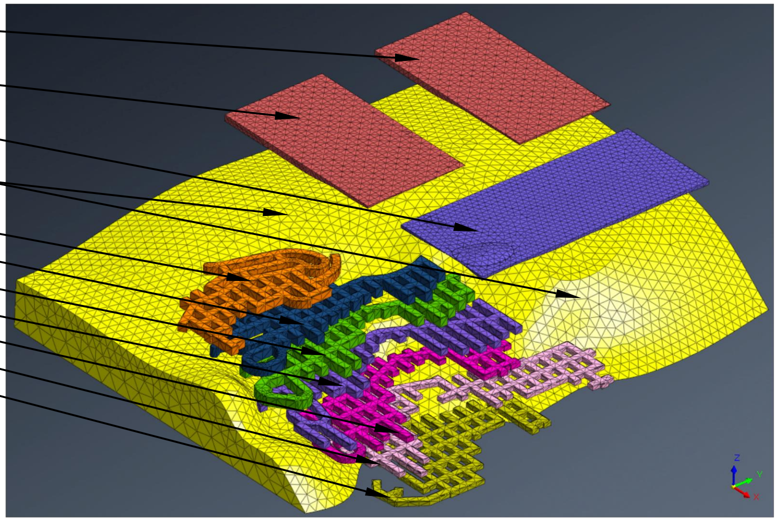
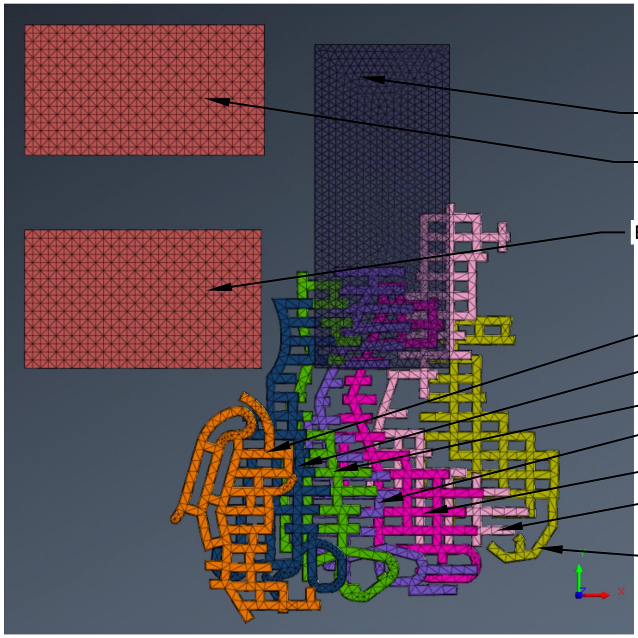
Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 2.dwg Date: 8/7/2017 Time: 09:23 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL

1 2 3 4 5

A B C D



Isometric View



Plan View

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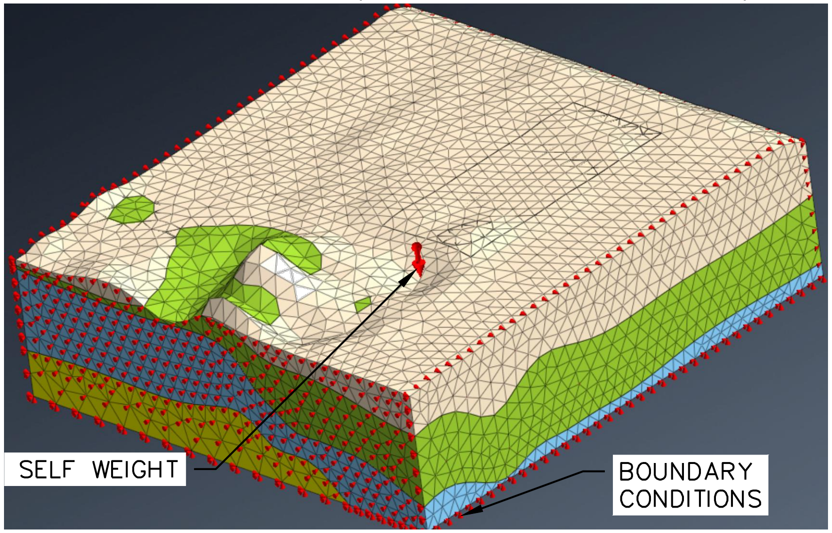
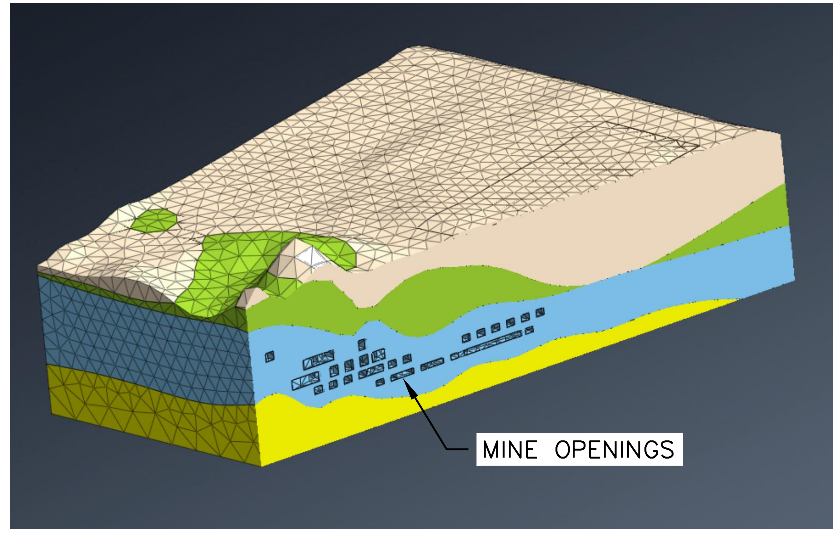
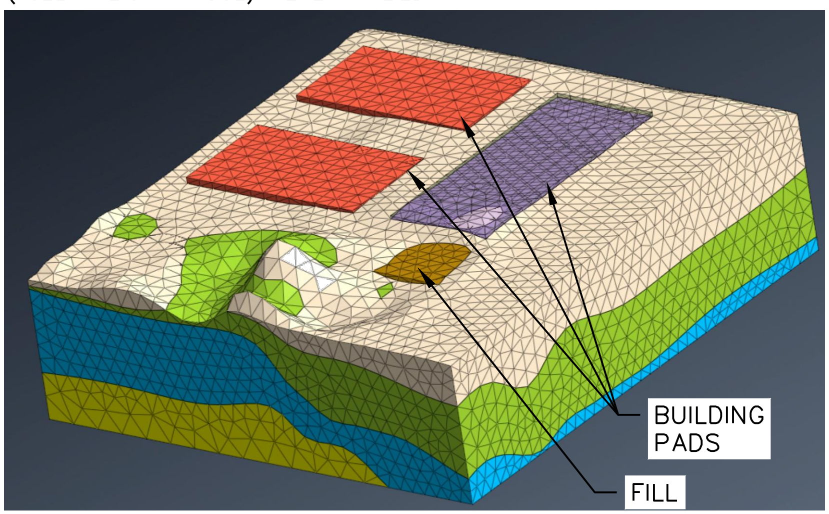
Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 3.dwg Date: 8/18/2017 Time: 13:20 User: ywangare Style Table: Langan.stb Layout: ANSIA-BL



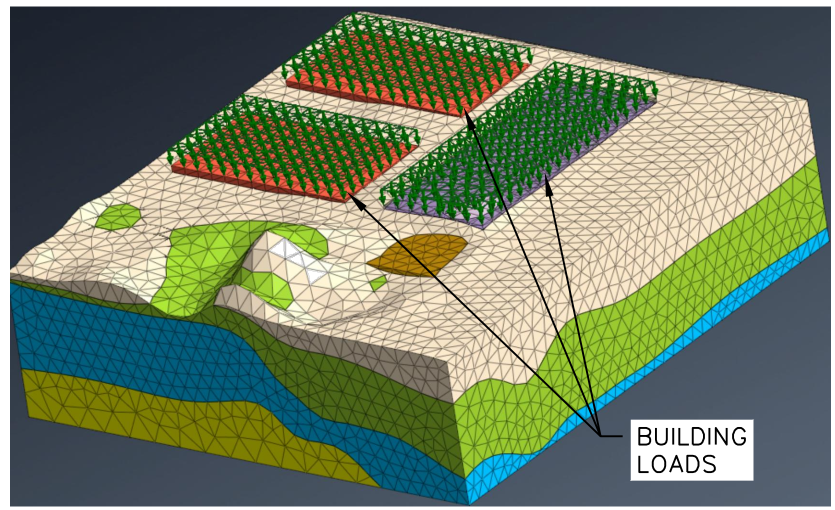
STAGE 1: INITIAL STRESS GENERATION: THE EXISTING GROUND SURFACE, ALL THE SUBSURFACE MATERIALS, AND THE GROUND WATER WERE INCLUDED. THE GLOBAL BOUNDARY CONDITIONS AND GRAVITY LOADING ("SELF WEIGHT" TOOL) WERE APPLIED.



STAGE 3: THE LIMESTONE MESH-SET THAT FORMED THE MINE OPENINGS (ROOMS) WERE DEACTIVATED.



STAGE 5: THE BUILDING PAD AND FILL MESH-SETS WERE ACTIVATED.



STAGE 6: THE BUILDING LOADS WERE ACTIVATED AND APPLIED OVER THE BUILDING PADS.

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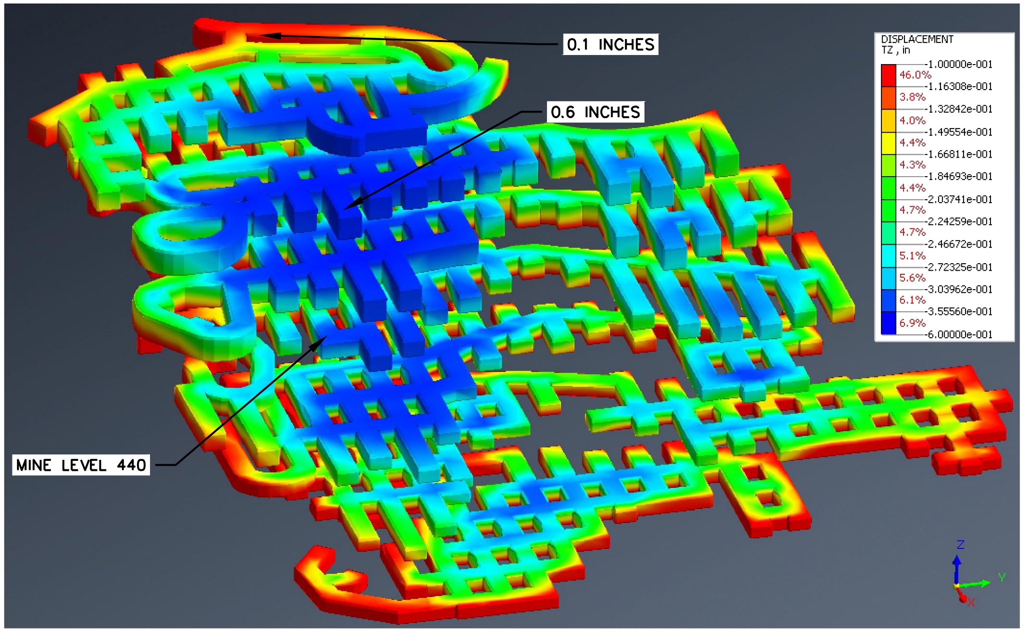
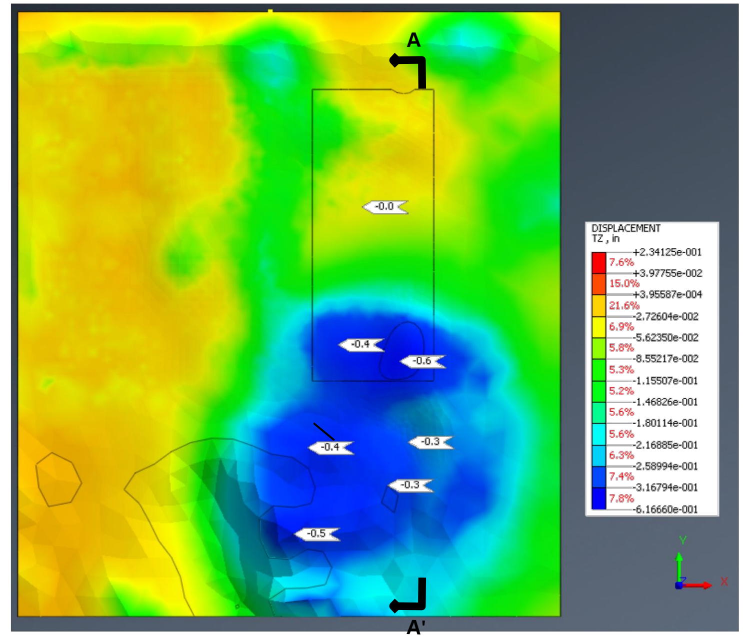
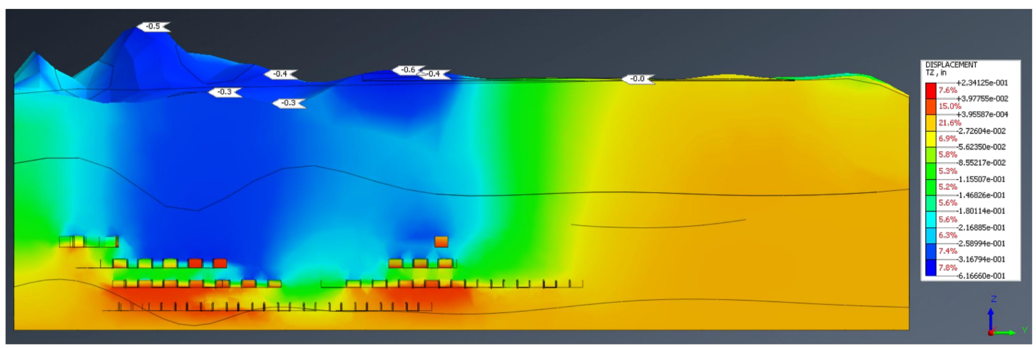
Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0103 - Fig 4.dwg Date: 8/4/2017 Time: 13:02 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL



MINE ROOF VERTICAL DISPLACEMENT



GROUND SURFACE VERTICAL DISPLACEMENT STAGE 3 (TOTAL)



VERTICAL DISPLACEMENTS STAGE 3 A–A'

NOTE: ALL MEASUREMENTS SHOWN ARE IN INCHES

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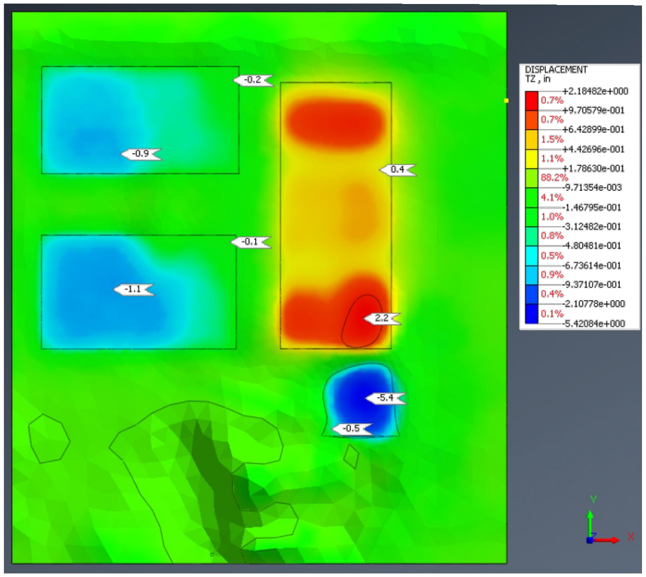
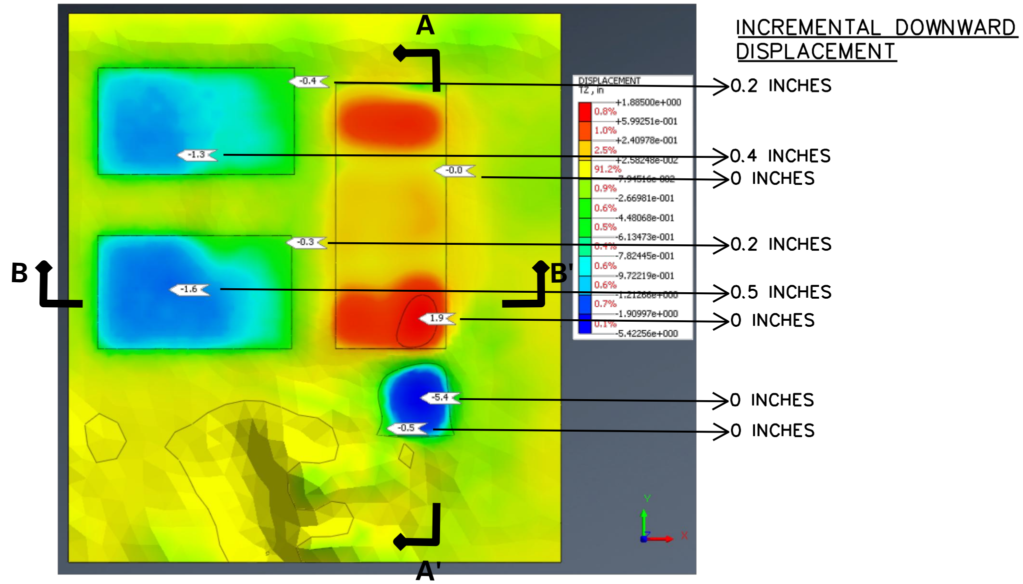
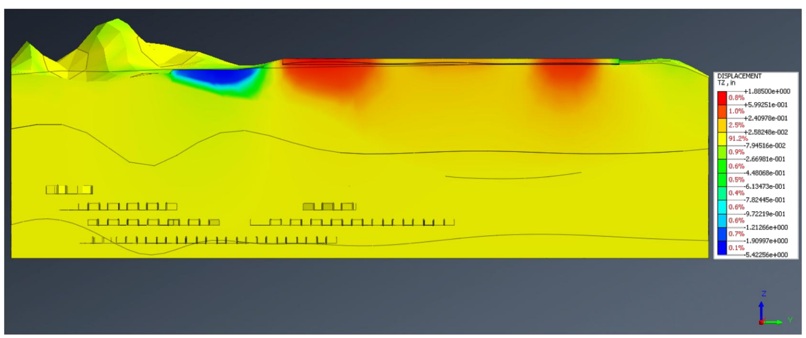
1 2 3 4 5



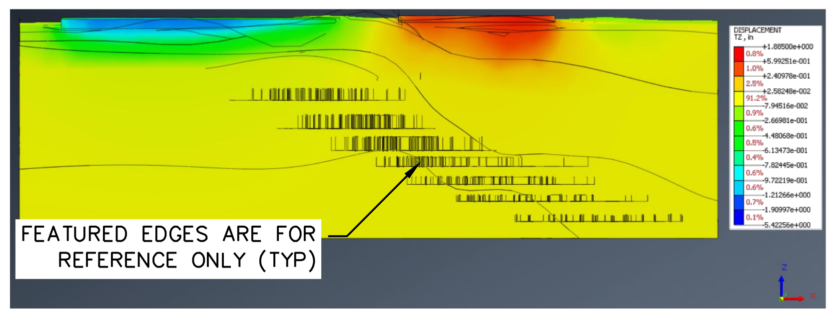
GROUND SURFACE VERTICAL DISPLACEMENT STAGE 5 (TOTAL)



GROUND SURFACE VERTICAL DISPLACEMENT STAGE 6 (TOTAL)



VERTICAL DISPLACEMENTS STAGE 6 A–A'



VERTICAL DISPLACEMENTS STAGE 6 B–B'

NOTE: ALL MEASUREMENTS SHOWN ARE IN INCHES

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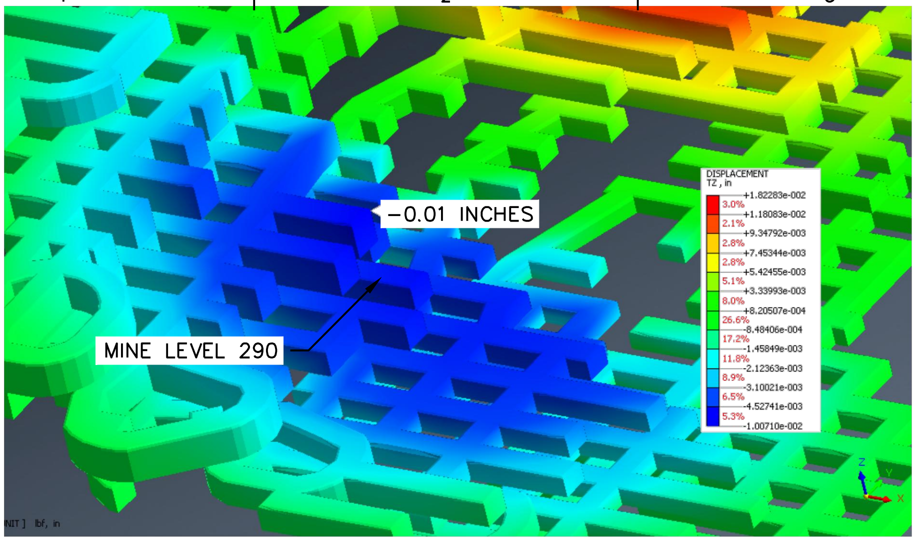
JURUPA VALLEY
RIVERSIDE COUNTY CALIFORNIA

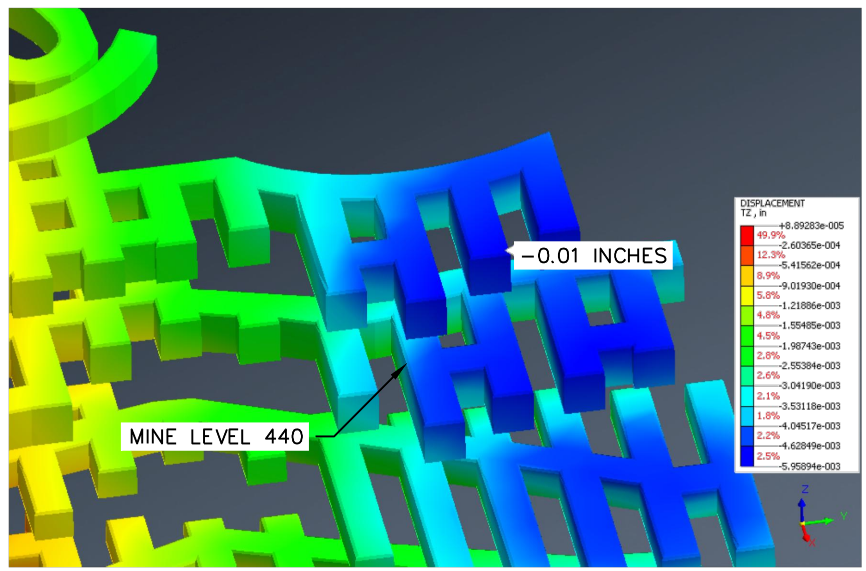
Drawing Title
GROUND SURFACE VERTICAL DISPLACEMENTS

Project No. 700045406	Figure No. 6
Date 18 AUGUST 2017	
Scale N.T.S.	
Drawn By IH	Checked By LB

Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 6.dwg Date: 8/7/2017 Time: 12:19 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL



MINE ROOF VERTICAL DOWNWARD MOVEMENT: STAGE 5



MINE ROOF VERTICAL DOWNWARD MOVEMENT: STAGE 6

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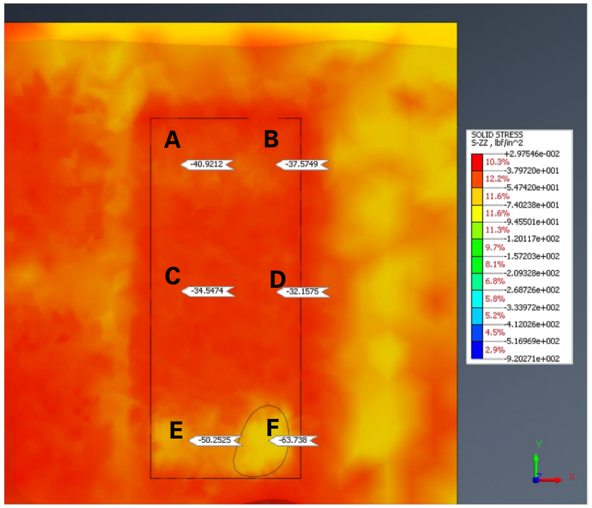
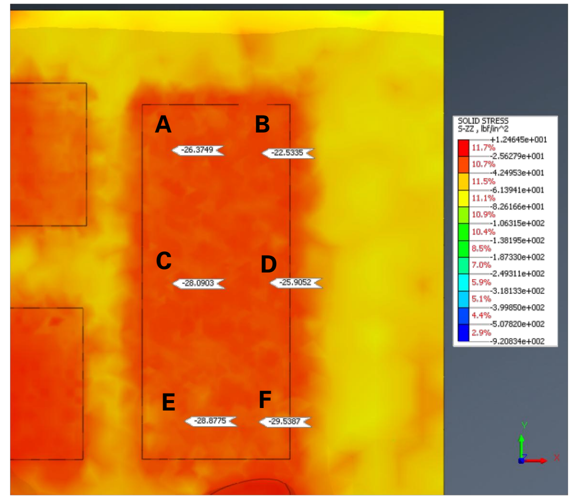
Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 7.dwg Date: 8/7/2017 Time: 13:17 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL

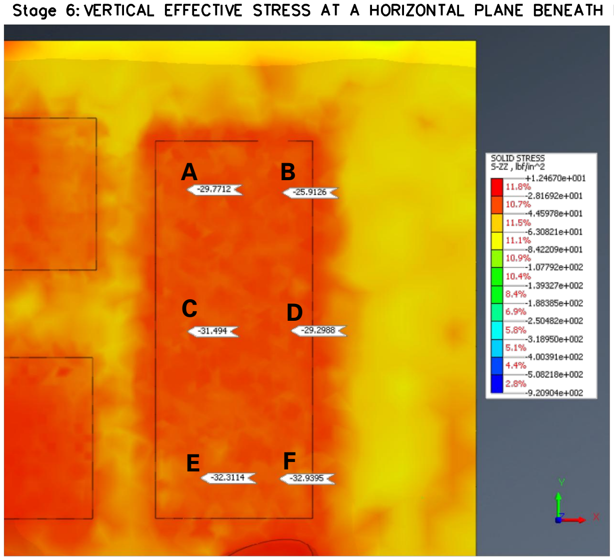
Stage 4: VERTICAL EFFECTIVE STRESS AT A HORIZONTAL PLANE BENEATH BUILDING 1



Stage 5: VERTICAL EFFECTIVE STRESS AT A HORIZONTAL PLANE BENEATH BUILDING 1



Stage 6: VERTICAL EFFECTIVE STRESS AT A HORIZONTAL PLANE BENEATH BUILDING 1



NET EFFECTIVE VERTICAL STRESS BENEATH BUILDING 1 – UNLOADING

POINT	STAGE 5 MINUS STAGE 4	STAGE 6 MINUS STAGE 4
A	14.5 psi	11.2 psi
B	15.0 psi	11.7 psi
C	6.5 psi	3.1 psi
D	6.3 psi	2.9 psi
E	21.4 psi	17.9 psi
F	34.2 psi	30.8 psi

NOTE: ALL MEASUREMENTS SHOWN ARE IN POUND PER SQUARE INCH (psi)

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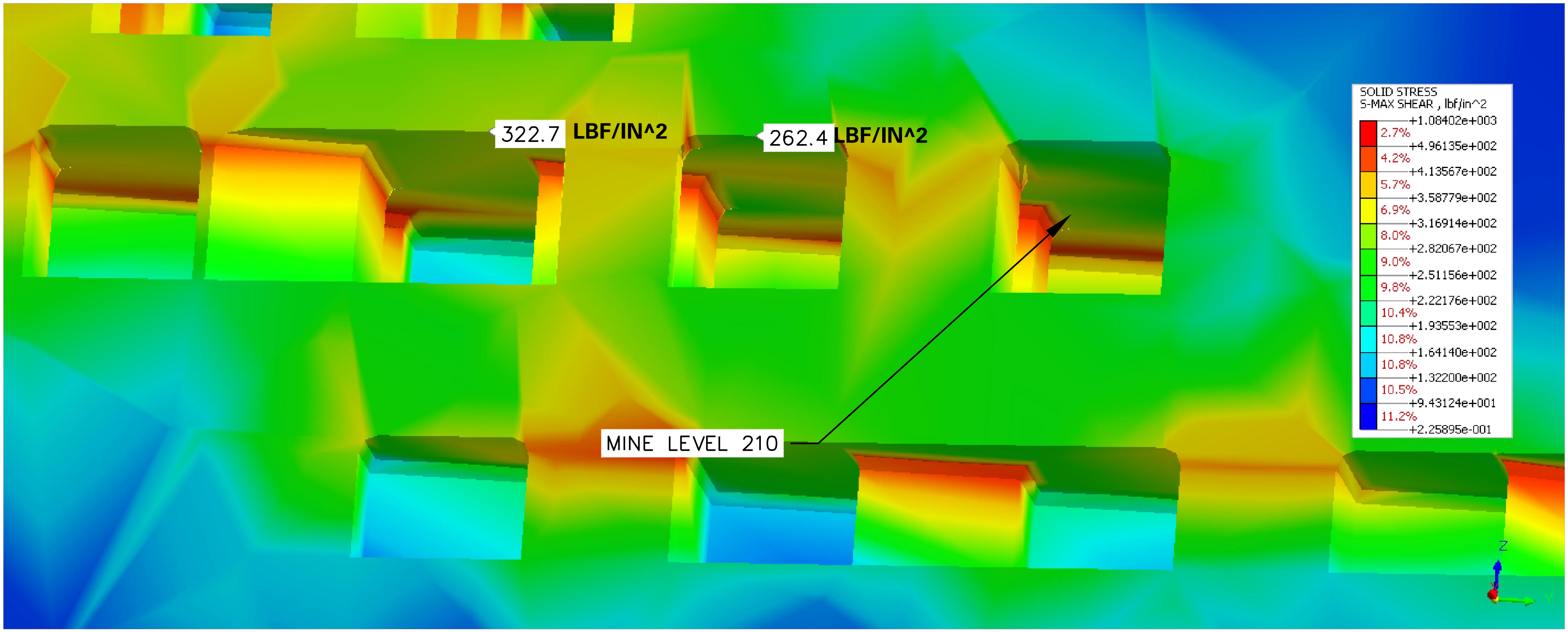
AGUA MANSA COMMERCE PARK
JURUPA VALLEY
RIVERSIDE COUNTY CALIFORNIA

Drawing Title
EFFECTIVE STRESS DIAGRAMS - UNLOADING CONDITIONS

Project No. 700045406
Date 18 AUGUST 2017
Scale N.T.S.
Drawn By IH
Checked By LB
Figure No. 8

Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 8-IJH.dwg Date: 8/7/2017 Time: 12:20 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL

1 2 3 4 5



NOTE: ALL MEASUREMENTS SHOWN ARE POUNDS FORCE PER SQUARE INCH (LBF/IN^2)

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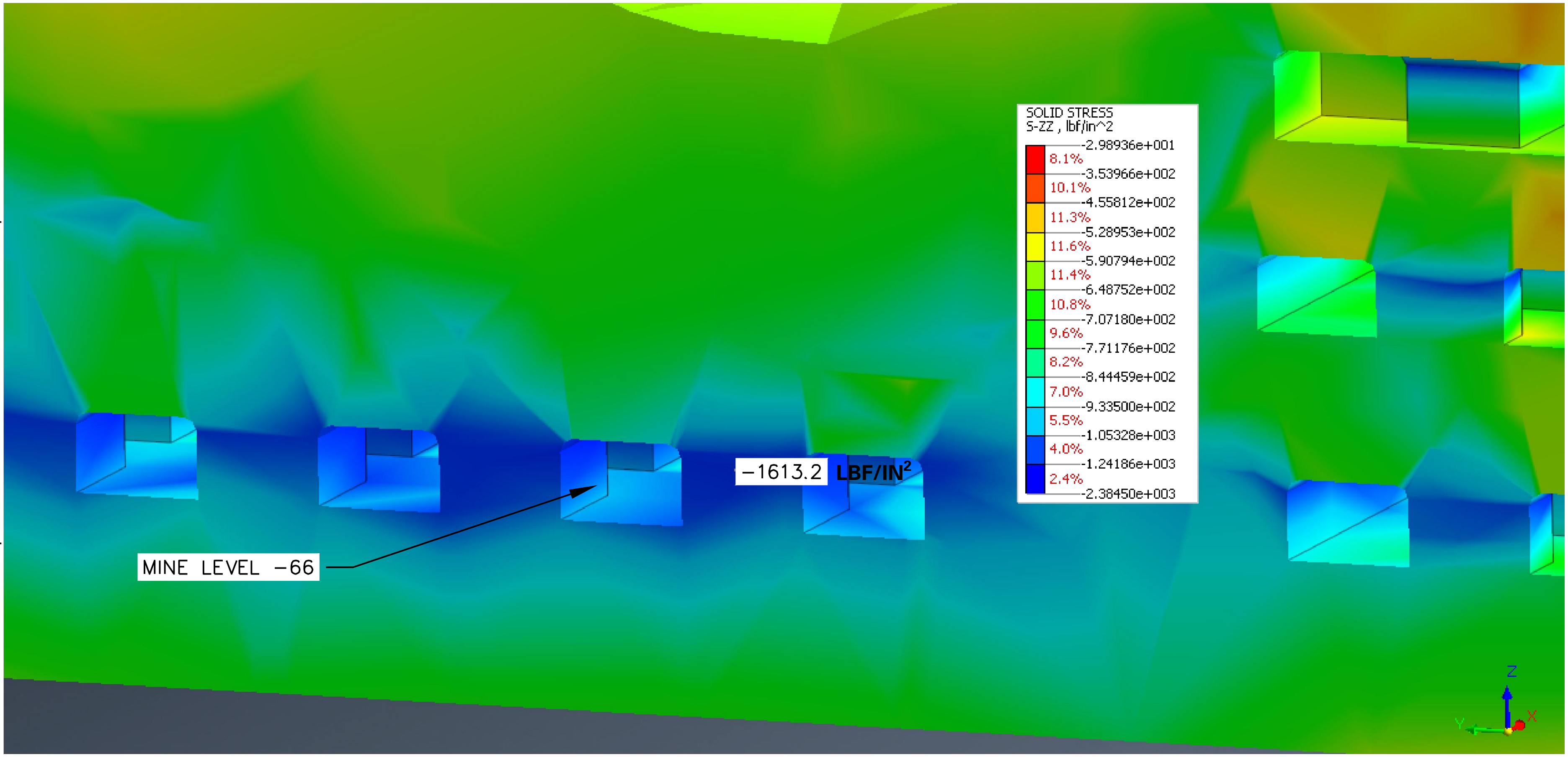
Project	Drawing Title	Project No.	Figure No.
AGUA MANSA COMMERCE PARK JURUPA VALLEY RIVERSIDE COUNTY CALIFORNIA	STAGE 6 HORIZONTAL ROOM-ROOF STRESSES AT MINE LEVEL 210	700045406 Date: 18 AUGUST 2017 Scale: N.T.S. Drawn By: IH Checked By: LB	9

Filename: \\langan.com\data\IRV\data4\700045406\Cadd Data - 700045406\SheetFiles\Geotech\700045406-BI001-0101-Fig 9.dwg Date: 8/7/2017 Time: 10:37 User: ihajjar Style Table: Langan.stb Layout: ANSIA-BL



NOTE: ALL MEASUREMENTS SHOWN ARE POUNDS FORCE PER SQUARE INCH (LBF/IN^2)

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APPENDIX A
Reference Documents

Drawings and Maps

- CGS, (2010), Fault Activity Map of California, Geologic Data Map (GDM) 6, scale 1:750,000, Compilation and Interpretation by C. Jennings and W. Bryant, Digital Preparation by M. Patel, E. Sander, J. Thompson, B. Wanish, and M. Fonseca.
- Dibble, T.W. (2004), "Geologic Map of the Riverside West/South ½ of Fontana Quadrangle, San Bernardino and Riverside County, California", DF 128.
- RGA Office of Architectural Design (2015), Riverside Cement Site-East Jurupa Valley, 28 September 2015.
- United States Geologic Survey, (1999), "Preliminary Geologic Map of the Fontana 7.5' Quadrangle, San Bernardino and Riverside Counties, California, Version 1.0, Open-Field Report 03-418.
- United States Geologic Survey, (2003), Preliminary Geologic Map of the San Bernardino 30' x 60' Quadrangle, California.
- United States Geologic Survey, (2003), List of Units in the San Bernardino 30' x 60' Quadrangle, Sheet 3 of 5 of Open-File Report O3-293.
- United States Geologic Survey, (2006), Geologic Map of the San Bernardino and Santa Ana 30' x 60' Quadrangles, California, Open-File Report OFR-2006-1217.

Publications and Plant/Quarry-Related Engineering Documents

- Daly, John W., (1931), The Geology and Mineralogy of the Limestone Deposits at Crestmore, Riverside County, California, dated 1931.
- Ely II, Marion F (1989), Mining & Reclamation Plan, Crestmore Quarry, dated 15 December 1989, revised most recently 24 February 1992.
- ERM-West, Inc., (1991), Technical Evaluation 9/30/90 EPA FIT Report, Riverside Cement Company, Crestmore Plant, dated November 1991.
- Gary S. Rasmussen & Associates, Inc. (1990), Engineering Geology Investigation of Slope Stability, Crestmore Quarry, Crestmore Area, Riverside County, California, dated 22 March 1990 included as Appendix E in Willdan Associates (1992), Crestmore Quarry Expansion, County of Riverside, Surface Mining Permit No. 180, Draft Environmental Impact Report, Riverside County No. 352, State Clearinghouse No. 90020118, dated 5 February 1991.
- Heuzé, Francois (1967), Mechanical Properties and In Situ Behavior of the Chino Limestone, Riverside, California, Master of Science in Engineering Thesis, dated June 1967.
- Long, Albert E. and Obert, L. (1958), Block Caving in Limestone at the Crestmore Mine, Riverside Cement Co., Riverside, Calif.

- Paul Martin, TXI Riverside Cement, Crestmore Plant, (2013), Mining History, Geology and Rare Minerals at the TXI Crestmore Sky Blue and Chino Hills Mines Presented at the WIM Chapter Meeting at Crestmore, 26 September 2013.

- United States Geologic Survey (2003), Preliminary Geologic Map of the San Bernardino 30' x 60' Quadrangle, California.

- United States Geologic Survey (2006), Geologic Map of the San Bernardino and Santa Ana 30' x 60' Quadrangles, California", Open-File Report OF-2006-1217.

- United States Geologic Survey (2003), List of Units in the San Bernardino 30' x 60' Quadrangle, Sheet 3 of 5 of Open-File Report O3-293.

- Willdan Associates (1991), Crestmore Quarry Expansion, County of Riverside, Surface Mining Permit No. 180, Final Environmental Impact Report, Riverside County No. 352, State Clearinghouse No. 90020118, dated December 1991 and Comments and Responses, dated 29 January 1992.

- Willdan Associates (1992), Crestmore Quarry Expansion, County of Riverside, Surface Mining Permit No. 180, Final Environmental Impact Report, Riverside County No. 352, State Clearinghouse No. 90020118, dated 6 May 1992.

- Woodford, A. O., Crippen, R. A., and Garner, K. B., (1941), Section Across Commercial Quarry, Crestmore, California, American Mineralogist, Volume 26, pages 351-381.

Mine Level Maps

MINE LEVEL MAP	DATE OF MOST RECENT MAP
Level 572	1955-09-23 Progress Map
Level 542	1956-03-22 Progress Map
Level 440	1957-03-26 Progress Map
Level 400	1958-08-28 Progress Map
Level 330	1959-09-16 Progress Map
Level 290	1961-05-23 Progress Map
Level 220	1962-05-17 Progress Map
Level 130	1964-10-20 Progress Map
Level 35	1970-05-18
Level 35	1972-01-17
Level 35	1973-12-06
Level -60	1971-11-10
General Mine Map	1968-11-25

Riverside Cement Company, Diamond Drill Photo Logs

HOLE NO.	DIRECTION	ELEVATION (FEET)
200	Vertical (Dip 90º)	595 to 922
204	Dip 70º	0 to 854
205	Vertical (Dip 90º)	138 to 524.5
207	Dip 48º	137 to 453.5
209	Vertical (Dip 90º)	38.5 to 453.5
213	Vertical (Dip 90º)	819 to 1011
214	Dip 70º	567.58 to 709
218	Vertical (Dip 90º)	294 to 495
219	Vertical (Dip 90º)	208 to 1118
222	Vertical (Dip 90º)	537 to 847
224	Vertical (Dip 90º)	539 to 895
225	Vertical (Dip 90º)	701.5 to 1007
227	Vertical (Dip 90º)	761 to 1068
229	Dip 45º to 30º	58 to 920.5
231	Vertical (Dip 90º)	69 to 893.5
233	Vertical (Dip 90º)	378 to 486
238	Vertical (Dip 90º)	422 to 831.5
247	Dip 10º	0 to 201

Riverside Cement Company, Diamond Drill Logs

HOLE NO.	DIRECTION	DATE DRILLED
200	Vertical (Dip 90º)	10 May to 14 June 1951
201	Vertical (Dip 90º)	9 to 31 May 1951
202	Vertical (Dip 90º)	31 May to 12 June 1951
203	Vertical (Dip 90º)	14 to 29 June 1951
204	Dip 70º	15 June to 16 July 1951
205	Vertical (Dip 90º)	29 June to 21 July 1951
206	Dip 89º	17 July to 23 August 1951
207	Dip 48º	21 July to 2 August 1951
208	Dip 64º	23 July to 8 August 1951
209	Vertical (Dip 90º)	2 to 21 August 1951
210	Vertical (Dip 90º)	8 August to 6 September 1951
211	Vertical (Dip 90º)	22 to 30 August 1951
212	Vertical (Dip 90º)	31 August to 11 September 1951
213	Vertical (Dip 90º)	5 September to 19 October 1951
214	Dip 70º	7 to 26 September 1951
215	Vertical (Dip 90º)	17 to 26 September 1951
216	Vertical (Dip 90º)	27 September to 29 October 1951
217	Vertical (Dip 90º)	20 to 29 October 1951
218	Vertical (Dip 90º)	30 October to 5 November 1951

HOLE NO.	DIRECTION	DATE DRILLED
219	Vertical (Dip 90º)	31 October to 28 November 1951
220	Vertical (Dip 90º)	5 to 6 November 1951
221	Vertical (Dip 90º)	7 November to 17 November 1951
222	Vertical (Dip 90º)	19 November to 3 December 1951
223	Vertical (Dip 90º)	29 November to 19 December 1951
224	Vertical (Dip 90º)	3 December to 12 December 1951
225	Vertical (Dip 90º)	15 December 1951 to 17 March 1952
226	Vertical (Dip 90º)	22 December 1951 to 15 January 1952
227	Vertical (Dip 90º)	22 December 1951 to 17 January 1952
228	Vertical (Dip 90º)	16 January to 5 February 1952
229	Dip -45º30'W	18 January to 15 February 1952
230	Vertical (Dip 90º)	5 February to 6 March 1952
231	Vertical (Dip 90º)	15 February to 12 March 1952
232	Vertical (Dip 90º)	28 February to 4 March 1952
233	Vertical (Dip 90º)	12 to 25 March 1952
234	Vertical (Dip 90º)	18 April to 15 May 1952
235	Vertical (Dip 90º)	21 January to 6 March 1953
236	Vertical (Dip 90º)	10 to 27 March 1953
237	Vertical (Dip 90º)	10 March to 21 April 1953
238	Vertical (Dip 90º)	1 to 17 April 1953
239	Vertical (Dip 90º)	23 April to 22 May 1953
240	Vertical (Dip 90º)	22 April to 21 May 1953
240-A	Deflect	5 to 23 June 1953
241	Vertical (Dip 90º)	23 April to 15 May 1953
242	Vertical (Dip 90º)	19 May to 11 June 1953
243	Vertical (Dip 90º)	25 May to 25 June 1953
244	Vertical (Dip 90º)	15 June to 7 July 1953
245	Horizontal	17 to 22 September 1953
246	Dip -5º	23 September to 1 October 1953
247	Dip -10º	2 to 7 October 1953
248	Vertical (Dip 90º)	29 May to 29 June 1964
249	Vertical (Dip 90º)	10 to 28 July 1964
250	Vertical (Dip 90º)	3 August to 3 September 1964
251	Vertical (Dip 90º)	10 September to 29 October 1964
252	Vertical (Dip 90º)	2 to 30 November 1964