AGEC

Applied GeoTech

September 5, 2013

Church Properties, LLC
c/o David Whitehead
2167 Jacob Drive
Santa Clara, Utah 84765

Attn: David Whitehead

Subject: Addendum to Geotechnical Investigation
Micro-Pile Design Parameters and Updated Geotechnical Recommendations
Joshua_s at Southgate Phase 1, Lots 10-15, Phase 2, Lots 25-34, 36, 37, 43, 45, 46, 48-56, 58-63 and 67
St. George, Utah
AGEC project No. 2130793

Gentlemen:

Applied Geotechnical Engineering Consultants, Inc., was requested to provide additional engineering analysis, consultation and recommendations for design and construction of the proposed residences to be constructed on lots listed above in St. George, Utah.

AGEC was requested to perform the following tasks:

1. Review the referenced geotechnical documents (referenced below) and provide revised recommendations for design of deep foundation elements to support the proposed residences.

2. Provide revised slab support recommendations.

PREVIOUS STUDY/REFERENCES

AGEC reviewed the following previously prepared studies:

Ref. No. 1. „Geotechnical Recommendations, The Joshuas„, AGEC project No. 981745 in a report dated September 16, 1999.

Ref. No. 2. „Geotechnical Recommendations, The Joshuas, Phase III„, AGEC project No. 2052082 in a report dated October 7, 2005.

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PROPOSED CONSTRUCTION

We understand it is proposed to construct single family residences on the subject lots. We understand it is proposed to support the residences on drilled and grouted micro-piles with reinforced concrete grade beams designed to span the distance between micro-piles. We understand raised structural floors will also be utilized.

Based on observation of the site, it also appears that the building pads are currently pre-graded and roadways are paved within the subdivision. We also understand that the proposed residences will be constructed near the existing grade.

If the proposed construction, loading conditions, or grading are significantly different than what is described above, we should be notified so that we can reevaluate our recommendations.

SUBSURFACE CONDITIONS

Based upon review of the referenced reports, subsurface conditions at the site generally consist of expansive mudstone bedrock to the maximum depth investigated, approximately 24 feet. We anticipate the surficial site grading fill will also be present on portions of the lots.

GROUNDWATER

Based on our experience in the area, we anticipate groundwater may be encountered perched on top of the bedrock or within fractures in the bedrock and may be encountered during drilling of micro-piles.

FINDINGS

The following conclusions are provided:

1. The subsurface investigation indicates expansive bedrock is present beneath all the building pads listed above.

2. The presence of potentially expansive mudstone bedrock typically warrants special foundation considerations which are implemented during design and construction of residences supported above expansive mudstone bedrock.

UPDATED RECOMMENDATIONS

AGEC has provided the following revisions for the referenced report:

A. Slab Support

Prior to placing site grading fill or concrete, soil containing roots and organics should be removed the full depth. We anticipate this will require removal of 4 to 6 inches of soil.

We also recommend on the order of 8 feet of non-expansive, low permeable cover soil be maintained over the underlying mudstone to reduce potential for wetting of the underlying mudstone and heave of surface improvements such as CMU fences and flatwork. Pools are not recommended.

The estimated potential surface heave associated with corresponding non-expansive overburden depths are provided in the following table. The estimate varies depending on the swell potential of the underlying mudstone and the wetting depth or "active" zone.

Depth to Expansive Mudstone Bedrock (feet)	Estimated Potential Differential Slab Heave (inches)
0	3½ - 4½
2	2½ - 3½
4	2 - 2¾
6	1¾ - 2⅓
8	1⅓ - 2
10	1¼ - 1¾
12	1 - 1½
14	¾ - 1⅓
16	½ - 1

The potential impact of the expansive characteristics of the underlying mudstone bedrock can be reduced by protecting the bedrock from becoming wet. Placement of relatively low permeable fill above the bedrock can help reduce the possibility of water coming in contact with the expansive bedrock. Low permeable fill used to replace removed mudstone should meet one of the following set of criteria.

Liquid Limit (%)	Percent Passing the No. 200 Sieve
45+	15-20
30-45	20-40
0-30	30-100

B. Foundations

We recommend the proposed residences be supported on deep foundation elements due to the presence of the underlying potentially expansive mudstone. The deep foundation elements should be designed by a structural engineer according to the parameters provided in this report. Grade beams should be utilized to span the distance between piers and support a structural floor with a crawl space below.

The following recommendations should be followed for the deep foundation system.

1. The deep foundations (proposed to be micropiles) should extend at least 20 feet into the underlying expansive mudstone with a minimum total length of 25 feet.

2. End bearing should not be considered for micro-pile capacity. Micro piles should be of sufficient diameter to allow for placement of grout around reinforcing steel.

3. Micropiles should be designed and reinforced by a licensed structural engineer using the parameters provided in the attached Table 1, Drilled Micro-pile Design Parameters.

4. The piles should be structurally reinforced to resist tensile forces on the pile due to negative skin friction. The tensile force may be calculated utilizing at least 10 feet of pier length with a skin friction of 2,000 psf. A greased PVC bond breaker may also be considered to reduce uplift forces on the micro- piles, but should be verified by load testing.

5. Due to the presence of expansive mudstone bedrock, the piles should be designed and spaced so that a minimum dead load pressure of 10,000 psf is sustained based on the pier bottom end area of each pile. If the minimum dead load cannot be met and piles are spaced as far apart as practical, the length should extend beyond the minimum penetration to make up the dead load deficit. This can be accomplished by assuming 6,000 pounds per square foot of skin friction (½ the ultimate value provided in Table 1 for firm mudstone) for the portion of the pier below the minimum penetration depth.

6. Piles should be placed as far apart as practical in order to achieve minimum dead load recommendations and a minimum of three diameters apart center to center.

7. Care should be taken to assure the drilled piles are not over-sized (mushroomed) at the ground surface, which could provide an area where swelling soil/rock could exert uplift forces on the piles. If a „PVC bond breaker„ or a „steel pipe„ are placed at the surface to provide a straight pile, the uplift from a potential surface „mushroom„ should not be a concern.

8. Grout should be placed using a tremmie extended to near the bottom of the drill hole to ensure the drill hole is filled without voids. The water cement ratio of the grout should be on the order of 0.45 to 0.50. This should be verified during construction using a grout scale to verify the grout has a specific gravity on the order of 1.8 to 1.9. The grout volume should be recorded for each micro pile constructed.

9. Grout should be placed in the piles the same day they are drilled using a tremmie. If water enters the pile holes, it would be necessary to place grout immediately after the pile hole is completed using a tremmie. Failure to place grout the day of drilling may require re-drilling for additional bedrock penetration.

10. Micro pile holes should also be inspected to verify caving does not occur below the ground surface which could also result in additional uplift forces. Casing the drill hole may be necessary if the caving occurs.

11. Centralizers„ should be used on the steel reinforcing bar at approximately a 7 to 10 foot spacing to ensure the appropriate grout cover on the reinforcing.

C. Floor System and Construction

1. <u>Structural Floor/Beams/Crawl Space</u>
Raised structural floors (including porches and patios) , supported on the grade beams, should be used in conjunction with deep foundation systems. The grade beams should be designed and reinforced to span the distance between the piers/piles.

We recommend that a minimum 24 inch crawl space be provided below structural floors. Proper ventilation of the crawl space it critical and the ventilation system should be designed by a licensed professional. This is beyond AGEC„s scope of services.

A minimum 10-inch void space should be provided below the grade beams to allow the expansive mudstone to swell without exerting uplift forces on the grade beams. Subsequent to removing concrete forms from grade beams, the void should be inspected by AGEC to ensure the proper void space is provided. The void space should also be protected prior to backfilling the grade beams to ensure the void space is not compromised. We also recommend low permeable fill be used as backfill around the beams to reduce the potential for infiltration and migration of water to the crawl space. Proper compaction and moisture conditioning of the backfill is critical.

2. Vapor Barrier

A vapor barrier should be placed in the bottom of the crawl space, attached to the interior of the perimeter grade beams using a water resistant attachment system and covered with pea gravel to reduce moisture in the crawl space.

3. Plumbing and Utility Lines

Plumbing lines and utility lines should be hung from the floor when a pier/pile foundation system is utilized. Plumbing lines should have flexible joints where connections are made. A 10-inch void space should also be provided below plumbing where it crosses below grade beams.

4. Exterior and Garage Flatwork

Flatwork should be supported on a properly prepared subgrade as recommended in the Subgrade Preparation Section of this report. The owners should be aware that exterior flatwork will likely move where expansive soil/bedrock is present. To reduce concerns for flatwork movement causing distress to the structures, the flatwork should be separated from the main structure and allow for unrestrained vertical movement. This generally is accomplished by providing a construction joint between the concrete flatwork and the wall/slab with a heavy felt board.

A 4-inch layer of properly compacted base course should be placed below slabs to provide a firm and consistent subgrade and to promote even curing of the concrete.

Use of pavers or crushed gravel in lieu of concrete flatwork may also be considered. Pavers will allow for some movement if the supporting subgrade soil heaves and can be re-leveled. Our experience has shown that this system performs relatively well.

5. Exterior Porches/Garage Walls

Exterior porches, overhangs, and garage walls that are structurally tied to the remainder of the residence should be supported by the same foundation system as the remainder of the residence.

D. Surface Drainage

The following drainage recommendations should be implemented to reduce the potential for wetting of the underlying support soils.

- Positive site drainage away from the residence should be maintained during the course of construction.

- After construction has been completed, positive drainage of surface water away from the residence should be maintained throughout the life of the structure. We recommend a minimum slope of 6 inches in the first 10 feet from the perimeter of the structure.

- Desert landscaping, which require no water, should be implemented due to the expansive characteristics of the underlying bedrock

- In no case should water be allowed to pond adjacent to foundations.

- Rain gutters should be utilized and roof down spouts should be piped horizontally to discharge away from the residence and preferably off site.

- We also recommend that desert landscaping, which requires no water, be used adjacent to foundations, slabs and masonry walls or other concrete elements to reduce the potential for wetting of the support soils and to reduce salt migration into cement containing elements. CMU walls which are backfilled with soil should be protected with an impermeable membrane. A gravel covered, perforated PVC drain pipe should also be placed at the base of the wall to carry water to a discharge point. This is intended to reduce the potential for salt weathering and sulfate attack on concrete/masonry.

- Further, the gravel areas and planters adjacent to the residence should be underlined by a impermeable membrane which extends into a membrane lined trench which is excavated around the perimeter of the residence. The trench should extend at least 12 inches into the bedrock and be on the order of 7 to 10 feet outside of the perimeter of the residence. A 4 inch PVC pipe should be placed in the bottom of the trench and sloped so as to drain by gravity. The trench should be filled with clean free draining gravel. The gravel should be covered with a filter fabric prior to backfilling with a cover soil. The PVC pipe should be sloped at a 2 percent minimum grade and outlet to the storm drain.

E. Seismicity, Liquefaction and Faulting

Seismicity

Listed below is a summary of the site parameters for the 2009 International Building Code using a latitude of 37.0705 degrees and a longitude of -113.6038 degrees.

a.	Site Class	C
b.	Short Period Spectral Response Acceleration, S_s 0.50g	
c.	One Second Period Spectral Response Acceleration, S_1	0.16g
d.	PGA = 0.21g (2% probability of exceedance in a 50 year recurrence interval)	
e.	Fa = 1.200 (Site Class D factor)	
f.	Fv = 1.641 (Site Class D factor)	

Liquefaction

Based on subsurface soil and groundwater conditions encountered in the explorations, the subsurface soils are non-liquefiable during a severe seismic event to the depths investigated.

Faulting

Based on review of available geologic literature, there are no mapped faults extending through the site.

F. Soil Corrosion

Based on our experience in the area, the on-site soils likely contain sulfates in sufficient concentration to present a "moderate to severe" sulfate attack potential for concrete. Therefore, we recommend concrete used at the site contain Type V sulfate resistant cement and be designed in accordance with provisions provided in the American Concrete Institute Manual of Concrete Practice (ACI) 318 Section 4.3 and the 2009 International Building Code. Table 4.2.1 of ACI 318-08 should be referenced utilizing a sulfate exposure category of "severe" and Class S2.

G. Lateral Earth Pressures

1. Lateral Resistance for Footings

Lateral resistance for spread footings is controlled by sliding resistance developed between the footing and the subgrade soil or rock. An ultimate friction value of 0.35 may be used in design for ultimate lateral resistance of footings bearing on clay. The friction value may be increase to 0.50 for compacted structural fill.

2. Retaining Structures

The following equivalent fluid weights are given for design of subgrade walls and retaining structures. The active condition is where the wall moves away from the soil. The passive condition is where the wall moves into the soil and the at-rest condition is where the wall does not move. We recommend the basement walls be designed in an at-rest condition.

The values listed below assume a horizontal surface adjacent the top and bottom of the wall.

Description	Active	At-Rest	Passive
Imported granular backfill (sand or gravel)	35 pcf	55 pcf	300 pcf
Imported granular backfill - Earth pressure coefficient	0.28	0.44	-
On-site Clay Soil/Processed Mudstone	55 pcf	70 pcf	200 pcf
On-site Clay soil/Processed Mudstone - Earth pressure coefficient	0.48	0.61	--

It should be recognized that the above values account for the lateral earth pressures due to the soil and level backfill conditions and do not account for hydrostatic pressures or surcharge loads.

Lateral loading should be increased to account for surcharge loading (using the appropriate earth pressure coefficient) and a rectangular distribution if structures are placed above the wall and are within a horizontal distance equal to the height of the wall. If the ground surface slopes up away from the wall, the equivalent fluid weights should also be increased.

Care should be taken to prevent percolation of surface water into the backfill material adjacent to the retaining walls. The risk of hydrostatic buildup can be reduced by placing a subdrain behind the walls consisting of free-draining gravel wrapped in a filter fabric.

3. Seismic Conditions

Under seismic conditions, the equivalent fluid weight should be modified as follows according to the Mononobe-Okabe method assuming a level backfill condition:

Lateral Earth Pressure Condition	Seismic Modification (2% PE in 50 yrs)	
	Granular Backfill	Clay Backfill
Active	9 pcf increase	11 pcf increase
At-rest	no increase	no increase
Passive	23 pcf decrease	16 pcf decrease

The seismic increases and decrease assume a peak ground acceleration of 0.21g using the Mononobe-Okabe pressure distribution. The resultant of the seismic increase should be placed up ⅓ from the base of the wall.

4. Safety Factors

The values recommended assume mobilization of the soil to achieve the assumed soil strength. Conventional safety factors used for structural analysis for such items as overturning and sliding resistance should be used in design.

H. Previous Reports

The geotechnical recommendations provided in the referenced report should also be referred to and followed during design and construction of the subject residence.

I. Geotechnical Recommendation Review

The client should familiarize themselves with the information contained in this letter. If specific questions arise or if the client does not fully understand the conclusions/recommendations provided, AGEC should be contacted to provide clarification.

LIMITATIONS

This letter has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the referenced report, engineering analysis, our experience in the area and the currently adopted building codes. Variations in the subsurface conditions may not become evident until excavation is conducted. If the subsurface conditions or groundwater level are found to be significantly different from those described above, we should be notified to reevaluate our recommendations.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

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Applied Geotechnical Engineering Consultants, Inc.

Table 1

Drilled Micro Pile Design Parameters

The Joshua's Lots

Project No. 2130793

Layer Depth (Feet)		Soil Properties			Lateral Design Parameters		Axial Design Parameters		
Top	Bottom	Effective Unit Weight (pcf)	Cohesion (psf)	Friction Angle (Degrees)	Horizontal Modulus (pci)	Ultimate Passive Resistance (psf)	Ultimate Skin Friction (psf)	Ultimate Uplift Skin Friction (psf)	Soil or Bedrock Description
0	10	120	6,000	0	500	45,000	4,000	2,700	Mudstone bedrock (active)
10	>10	140	17,000	0	2,500	15,000	12,000	8,000	Mudstone bedrock (firm)

Note: iIf surficial fill is encountered, it should be ignored when determining capacity.