December 21, 2022

Mr. Ruel Tinong Orcajada
Project/ Partnership Coordinator
TAMPEI
234-A Tandang Sora Avenue,
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Dear Mr. Orcajada,

This document was prepared for TAMPEI, containing the preliminary geotechnical assessment of the site's proposed residential complex in Brgy. Coloong 1, Valenzuela City. This preliminary study is a part of the research collaboration between UP ICE - GEG to provide an initial assessment of the site's subsurface conditions and give recommendations for the foundation of the residential complex. All analyses are based on the soil investigation report from Geoscience Technologies, Inc., consisting of three (3) boreholes.

I. EXISTING GEOTECHNICAL CONDITIONS

A. Results of Field Investigation

Geoscience Technologies, Inc. (GTI) conducted the geotechnical investigation program for the project, which consisted of drilling three (3) boreholes with a termination depth of 30 m. The location plan for the boreholes is shown in Figure 1. The details about each borehole are summarized in Table 1.

Figure 1. Borehole Location Plan (Geoscience Technologies, Inc.)

Table 1. Summary of boreholes drilled by GTI

Borehole #	Water Level Above Ground (m)	Date of Drilling	Coordinates
BH-01	3.71	05/02/22	N: 1673489.577 E: 457538.680
BH-02	3.89	05/13/22	N: 1673547.066 E: 457444.655
BH-03	3.94	05/21/22	N: 1673547.066 E: 457444.655

B. Subsurface Idealization

The succeeding tables present the subsurface conditions at each borehole location based on the soil investigation results. Engineering parameters were assigned for each soil layer for the succeeding geotechnical analyses. Table 2 to Table ***4*** show the idealized subsurface conditions for the three (3) boreholes based on field test results.

Borehole data from GTI show that the upper portion of the project site generally consists of soft silts with thicknesses of about 3 to 4.5 meters, followed by medium stiff to stiff clays about 3 to 4.5 meters thick. Under these layers are loose to medium dense sands (about 7.5m thick) in BH-01 and very stiff clays (about 7.5m thick) in BH-02 and BH-03. Competent soil layers (very dense sands and hard clays) were encountered, starting from a depth of 10.5 meters until the termination of boreholes.

Table 2. Idealized subsurface at BH-01 (Geoscience Technologies, Inc.)

Depth, m	USCS	SPT N-value	Relative Density / Consistency
0.0 - 3.0	MH	2 to 5	Soft
3.0 - 6.0	CL	7 to 9	Medium Stiff
6.0 - 7.5	SM	9	Loose
7.5 - 13.5	SM / SW / SP	11 to 19	Medium Dense
13.5 - 18.0	SM / SW / SP	37 to 47	Dense
18.0 - 30.0	SM / SW	‘refusal’	Very Dense

Table 3. Idealized subsurface at BH-02 (Geoscience Technologies, Inc.)

Depth, m	USCS	SPT N-value	Relative Density / Consistency
0.0 - 4.5	MH / CL	3 to 5	Soft
4.5 - 7.5	CL	12 to 15	Stiff
7.5 - 10.5	CL	21 to 24	Very Stiff
10.5 - 19.5	CL	37 to 'refusal'	Hard
19.5 - 30.0	SM	'refusal'	Very Dense

Table 4. Idealized subsurface at BH-03 (Geoscience Technologies, Inc.)

Depth, m	USCS	SPT N-value	Relative Density / Consistency
0.0 - 4.5	MH	3 to 5	Soft
4.5 - 6.0	MH	9	Medium Stiff
6.0 - 9.0	CH	12 to 16	Stiff
9.0 - 13.5	CH	19 to 28	Very Stiff
13.5 - 19.5	CH	41 to 'refusal'	Hard
19.5 - 30.0	SM	'refusal'	Very Dense

Figure 2 presents the SPT N-value vs. depth chart for the three boreholes, clearly showing the increase of N-values with depth. It indicates the presence of soft soils in the upper layers and hard and very dense soils starting at depths between 10 and 15 meters.

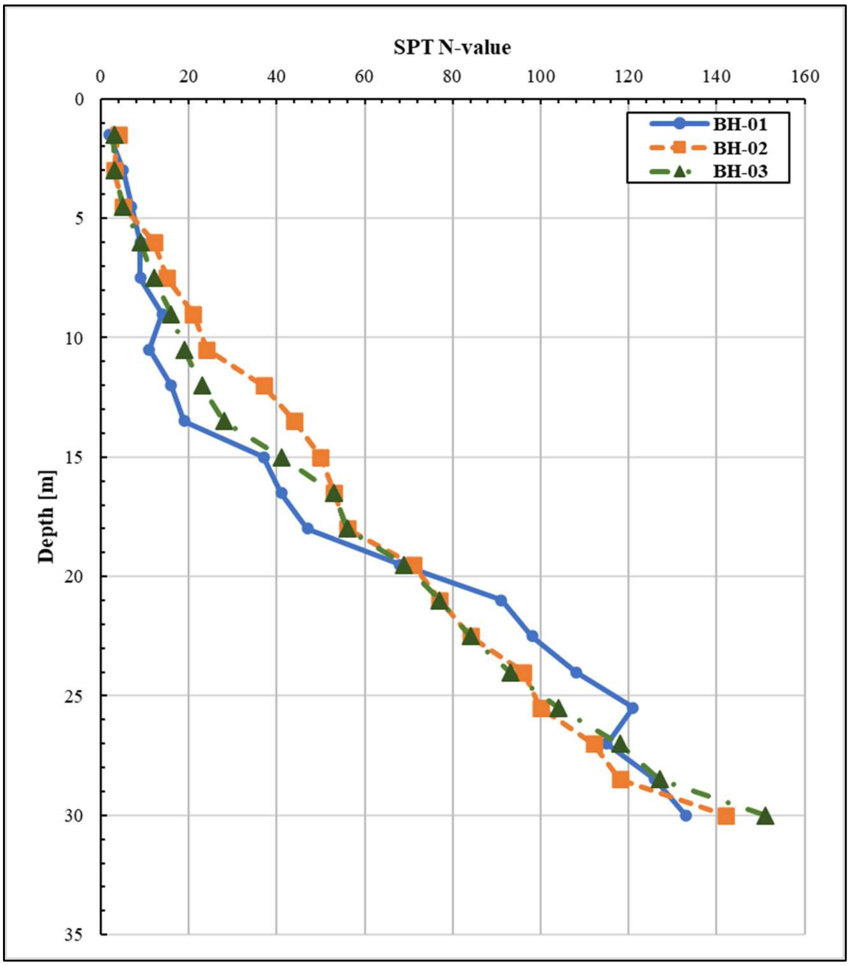

Figure 2. SPT N-value vs Depth chart (Geoscience Technologies, Inc.)

II. SETTLEMENT ANALYSIS

A. Analysis Model

Based on the field investigation, the current water level is around 3.71 to 3.94 m high, above the ground surface. Hence, the preliminary construction works at the proposed residential complex are embankment filling to provide a relatively flat, stable, and dry subgrade for the structures.

According to the soil investigation results, up to a 4.5m-thick compressible layer, mainly consisting of soft silty materials is found below the water table. With these types of soil, long term consolidation is expected due to the very low permeability of cohesive soils. It is anticipated that the most significant amount of settlement will occur in this layer.

To address this geohazard and improve the strength characteristics of the underlying soft layer, ground improvement by means of preloading with granular backfill can be implemented. Preloading will induce settlement, therefore allowing for the compaction or densification of soil. This improvement technique is considered in the subsequent analysis.

The models were based on idealized subsurface conditions. Settlement and consolidation parameters were estimated using correlations from the results of the available laboratory tests conducted on the soil samples. The required minimum fill height is determined based on the current water level and the resulting settlement. In the model, a 3m-high embankment was applied at the beginning, and the remaining fill height was added in the succeeding month. Dense to very dense sands and very stiff to hard clays were no longer considered in the models.

B. Results

Settlement analysis was conducted for each borehole. The total settlement of soil includes the immediate settlement of sandy soils and the consolidation of clayey soils. The resulting settlement, assuming that 95% consolidation is achieved, is presented in Table 5. The estimated total settlement is about 900 mm to 1250 mm, which will occur in 1 to 2.5 years.

Table 5. Summary of Settlement Analysis Results

Borehole	Backfill Height (m)	Time for 95% Consolidation (months)	Immediate Settlement (mm)	Consolidation (mm)	Total Settlement (mm)
BH-01	5	11.7	39	860	899
BH-02	5.5	29.8	33	1046	1079
BH-03	5.5	30.9	36	1197	1233

The required minimum fill height around the area of BH-01 is 5 m, while the required minimum fill height around the areas of BH-02 and BH-03 is 5.5 m. These backfill heights are just enough to provide a dry platform for the residential complex to be developed.

III. BEARING CAPACITY ANALYSIS

The objective of this analysis is to conduct an initial evaluation of the safe bearing capacities that may be considered in the structural design of the houses in the residential complex. The foundation scheme chosen is primarily determined by the magnitude of the structural loads that must be transmitted by the foundations into the underlying ground.

Due to land filling works, a significant amount of fill material will be placed on top of the existing ground. If the backfill is properly compacted, the utilization of a shallow foundation system is feasible. It is therefore anticipated that structures on shallow foundations will rest on the fill material. The height of backfill required based on the settlement analysis was considered.

To calculate the safe bearing pressure, a factor of safety of 3.0 was adopted in the analysis. Deformation criteria were considered in coming up with the allowable bearing capacity.

For housing projects, the typical type of foundation used is strip or wall footing, with a typical width of 0.35 m and an embedment depth of 0.6 m. An allowable bearing capacity of 90 kPa for wall footings may be adopted. This bearing capacity considers the housing units to be resting on backfill.

For other low-rise structures that are isolated from the housing, an integrated foundation system composed of spread footings with tie beams is recommended. The depth of the foundation shall be at least 1.0 m from the top of the backfill to ensure adequate footing embedment. The allowable bearing capacities for various footing widths at each borehole are shown in Figure 3. The allowable bearing capacity for isolated footing is at least 130 kPa.

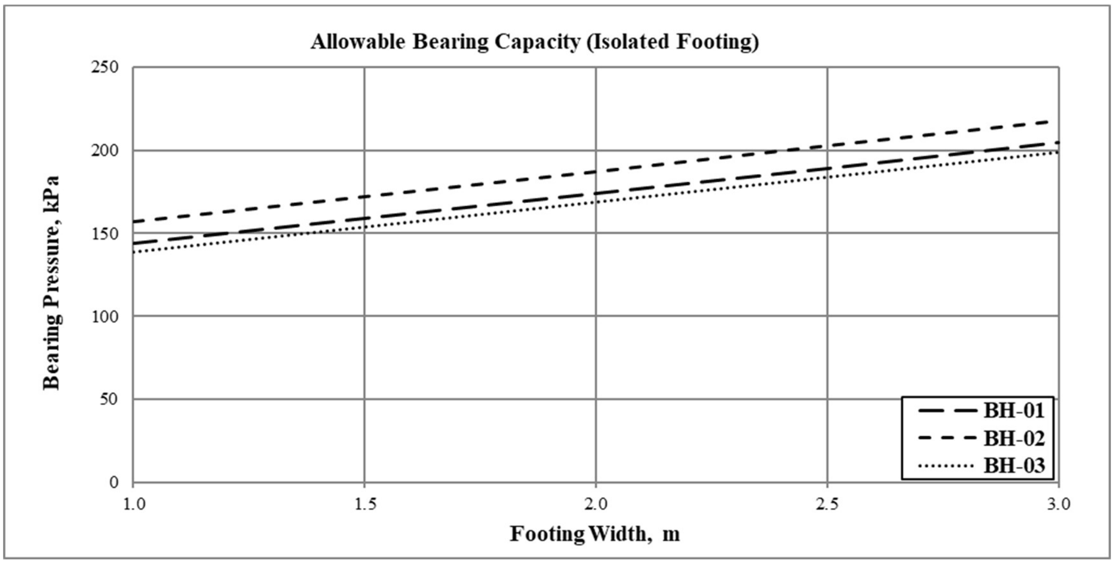

Figure 3. Allowable Bearing Capacity for Spread Footing of Various Widths

IV. FINDINGS AND RECOMMENDATIONS

1. Results of Field Investigation

   The results of the soil investigation, consisting of 3 boreholes, show that the site is generally underlain by an upper layer of soft silts consisting of clay materials (thickness up to 4.5 meters). There is a thin layer of loose sand (1.5 m thick) found at BH-01. But aside from this, the deeper layers are composed of dense to very dense sands and very stiff to hard clays. The area is also submerged in water, with the groundwater level encountered at around 3.71 m to 3.94 m above ground.

2. Settlement Analysis

Since the site is currently flooded, it is expected that embankment filling will be done to provide a relatively flat, stable, and dry subgrade for the housing. Embankment filling can also be considered a ground improvement technique because it preloads the existing ground. Preloading will induce settlement, therefore allowing for the compaction and densification of soil.

The total settlement of soil, which includes immediate settlement of sandy soils and long-term consolidation of clayey soils, was computed. The estimated total settlement at 95% consolidation ranges from about 900 mm to 1250 mm, which will occur in 1 to 2.5 years.

The recommended minimum fill height around the area of BH-01 is 5 m, while the recommended minimum fill height around the areas of BH-02 and BH-03 is 5.5 m. These backfill heights are just enough to provide a dry platform for the residential complex to be developed.

Note that the granular backfill was used in the settlement analysis. Generally, suitable fill material for reclamation is granular with limited fines and stone-sized fragments. To give guidance to the type of fill material that can be used in the area, the Department of Public Works and Highways Standard Specifications Volume II, 2013 provides the following criteria:

Suitable backfill materials are soils of such gradation that all particles will pass a sieve with 75 mm (3 inches) square openings and not more than 15 mass percent will pass the 0.075 mm (No. 200) sieve. The material shall have a plasticity index of not more than 6 and a liquid limit of not more than 30.

Organic soils, such as peat and muck, and materials that contain detrimental quantities of organic materials such as grass, roots and sewerage are not normally suitable for use as fills. Unsuitable materials also include soils with liquid limit exceeding 80, plasticity index exceeding 55, natural water content exceeding 100%, and natural density lower than 800 kg/m^3.

Proper steps in fill formation should be observed during construction to densify and compact the sand appropriately. The existing topsoil layer containing vegetation and possible organic materials at the project site shall be cleared first before filling.

The computed settlements are highly dependent on the consolidation properties of the soil. Note that the soil parameters used in the analysis were just derived from existing correlations from published literature due to the lack of consolidation test results.

3. Shallow Foundation Analysis

   Because a substantial amount of fill will be placed on top of the existing soil, structures with shallow foundations must be supported by the upper fill material. For the housing units, strip footing with a width of 0.35 m and embedment depth of 0.6 m is recommended. The strip footing shall have a safe bearing capacity of 90 kPa. For other low-rise structures, an integrated foundation system composed of spread footings with tie beams may be used with a safe bearing capacity of 130kPa.

The above assessment was based on the results of three boreholes at different project site locations. Given the significant distances between boreholes, the profiles presented in this report may not represent the actual conditions of the entire site. If actual subsurface conditions vary on the site, the researchers must be informed so that further geotechnical evaluation may be conducted.