SOIL INVESTIGATION REPORT

PROPOSED HOUSING DEVELOPMENT PROJECT
Coral Spring, Trelawny, Jamaica.

Prepared for:

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1.0 Introduction

1.1 Authority

The services of NHL Engineering Ltd. were retained to undertake a geotechnical investigation at the proposed Coral Springs Housing Development project in Trelawney.

The proposed investigation is as shown in the Site and Location Plans (Figure 5.1 and 5.2 respectively). NHL Engineering Ltd., was to arrange:-

i) The SPT and core sample collection, inspection and categorization
ii) The laboratory testing programme, which in our judgment, was necessary to provide a satisfactory basis for evaluating the site for the design of the building foundations and other infrastructural elements on site.
iii) On completion, a report presenting the results obtained, together with our recommendations should be submitted to the Client.

1.2 Site:

The site is located along the northern coastline of Trelawny, approximately 5km east of the Falmoth Town Square. The site forms part of the White Limestone Group, specifically the Coastal Formation. It is therefore expected that the insitu subsoil materials were likely to be dense calcareous Sands and Gravels over-lain by a very thin layer of Silty Clays. The depth to bedrock in most areas appear to be near surface. The rocks are expected to vary in physical characteristics; highly weathered, moderately faulted, fractured and in some locations, could be cavernous (small cavities).

1.3 Superstructure:

According to the information obtained from the client, it is proposed to develop the site as shown in the layout plan below. The indications are that the housing units will be comprised of reinforced concrete elements (beams columns and slab).

PLATE 1 PICTURE SHOWING EXISTING SITE CONDITIONS IN THE VICINITY OF BH #1

PLATE 2- PICTURE SHOWING EXISTING SITE CONDITIONS IN THE VICINITY OF BH #3

PLATE 3- PICTURE SHOWING EXISTING POND IN THE VICINITY OF BH #3

2.0 Proposed Programme

The proposed investigation will seek to establish;

i) The insitu density of the soils on site.
ii) Soil stratification and distribution across the site including depth to bedrock.
iii) The design parameters relevant to the design of the anticipated structural and infrastructural elements required on site.
iv) Liquefaction potential analysis of the susceptible soils on site

The investigation will entail the drilling of at least six (6) boreholes and piezometer installed stand pipes for water sampling and monitoring (total numbers to be determined based on groundwater encounter). The boreholes are to be taken to depths varying from 15m to 30m. The “N” values at the end of each borehole and the soil type and density variations between boreholes will determine whether or not further investigation or termination is to be recommended.

2.1 **Soil Concerns**

Given the nature of the likely superstructures to be constructed on the sites and their accompanying dead, live and dynamic loadings, the foreseeable problems are as follows:

i) Undesirable total and differential deformation problems between the spans due to the presence of hard and compressible soils in close proximity and the possible presence of pockets of very loose/soft sands in the vicinity of the sea shore.
ii) Presence of cavities within the limestone formation
iii) Slope stability of cut embankments

3.0 <u>Data Base</u>

Six boreholes distributed across the site has been assessed. The boreholes were located by the client's surveyors and information on elevation, northing and easting is available from the surveyor upon request. The borings were taken to varying depth; from 9m to 20m (BH3). Coring was done in five of the six boreholes, the sixth borehole (BH3) located in close proximity to the pond (water shed area/low point) encountered weathered limestone and did not require coring.

No ground water was encountered during the sampling exercise, however after overnight rainfall, the pond was recharged and groundwater was observed in Borehole 3 at 17 ft below ground levels. Groundwater was observed flowing into the pond from an apparent aquifer on the southern hills of the site.

The soils generally encountered were predominantly the soft to medium limestone rock formation with the exception of Borehole 3 where the soils were predominantly the dense weathered limestone. The medium hard limestone rock had low RQDs and low recoveries (below 20%).

3.1 Testing:

Soils sampling was predominantly via coring. Preference was therefore generally given to the unconfined compression testing of recovered rock samples. Eighteen samples were tested, their Compressive Strength values ranged from 480psi to 2430psi with an average strength of 1640psi. The rocks can therefore be classified as Medium hard limestone.

Grainsize distribution testing of the SPT samples indicate that the soils generally classified as dense calcareous gravels and sands in a clay/silt sized matrix (powder).

The percolation tests were performed at borehole locations BH2, BH4 and BH7, the detailed results are shown in the appendix. The results indicate that percolation rates varied significantly across the site; values ranged from 0.000015cm/s to 0.0045cm/s.

Piezometer standpipes with slotted lower third was installed in BH 3 where the groundwater was observed.

4.0 Geotechnical Discussion

4.1 Presumptive Soil Profile:

The subsoil layers applicable for evaluating engineering behavior and construction concerns can be characterized as two (2) distinct types (see typical site profiles below). The types are as follows:-

A) TOP 1

1) The Compact to v.Dense Gravelly C-F Sands (weathered limestone) + Clays
   Depth Range; Variable
   Average N_{55} = 25
   Borehole #, 3

B) TOP 2

2) The Soft to Medium Limestone Rock Formation
   Depth Range; Variable
   RQDs (avg.) = 15%
   Borehole #s, 1, 2, 4, 5 and 7

4.2 Depth and Type of Foundations

The Presumptive profiles drawn below are based on the results of the field sampling todate. The profiles are used to illustrate the dominant layers that are likely to significantly impact design and construction, they however are not intended to provide exact information between the boreholes location by extrapolation.

The horizontal distribution of the very dense weathered limestone and the upper rock formation indicates that the use of shallow foundations for the proposed structures is suitable.

In summary, the following are the foreseeable geotechnical issues to contend with on this site:

i) Small Differential deformation problems across the varying soil material on site within the vicinity of BH3 and BH4
ii) Foundation excavation problems within the hard rock formation
iii) The possible existence of unidentified cavernous rocks below building.

iv) The limitations of depth and slope of cuts to form embankments along roadways

With regards to buildings, the use of isolated conventional shallow pad and Beam foundation appears suitable across the site unless evidence of localized solution cavities have been encountered.

For cuts and fills the soil information suggests that a generalized guideline can be recommended however localized areas of loose colluviums could be encountered during construction. These will be location specific and will be addressed accordingly.

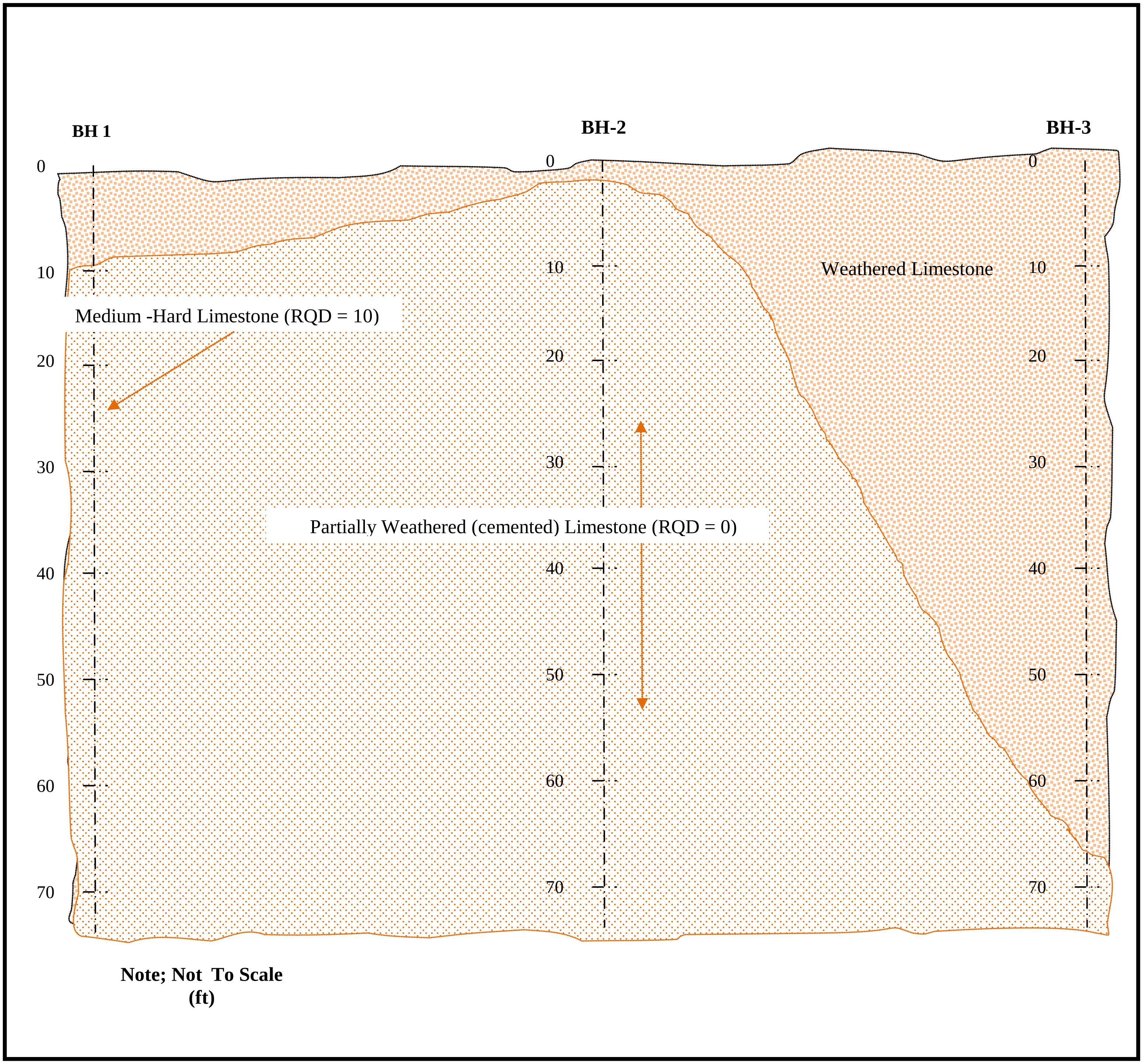

FIG. 4.1 PRESUMPTIVE PROFILE ; BHs# 1, 2 & 3

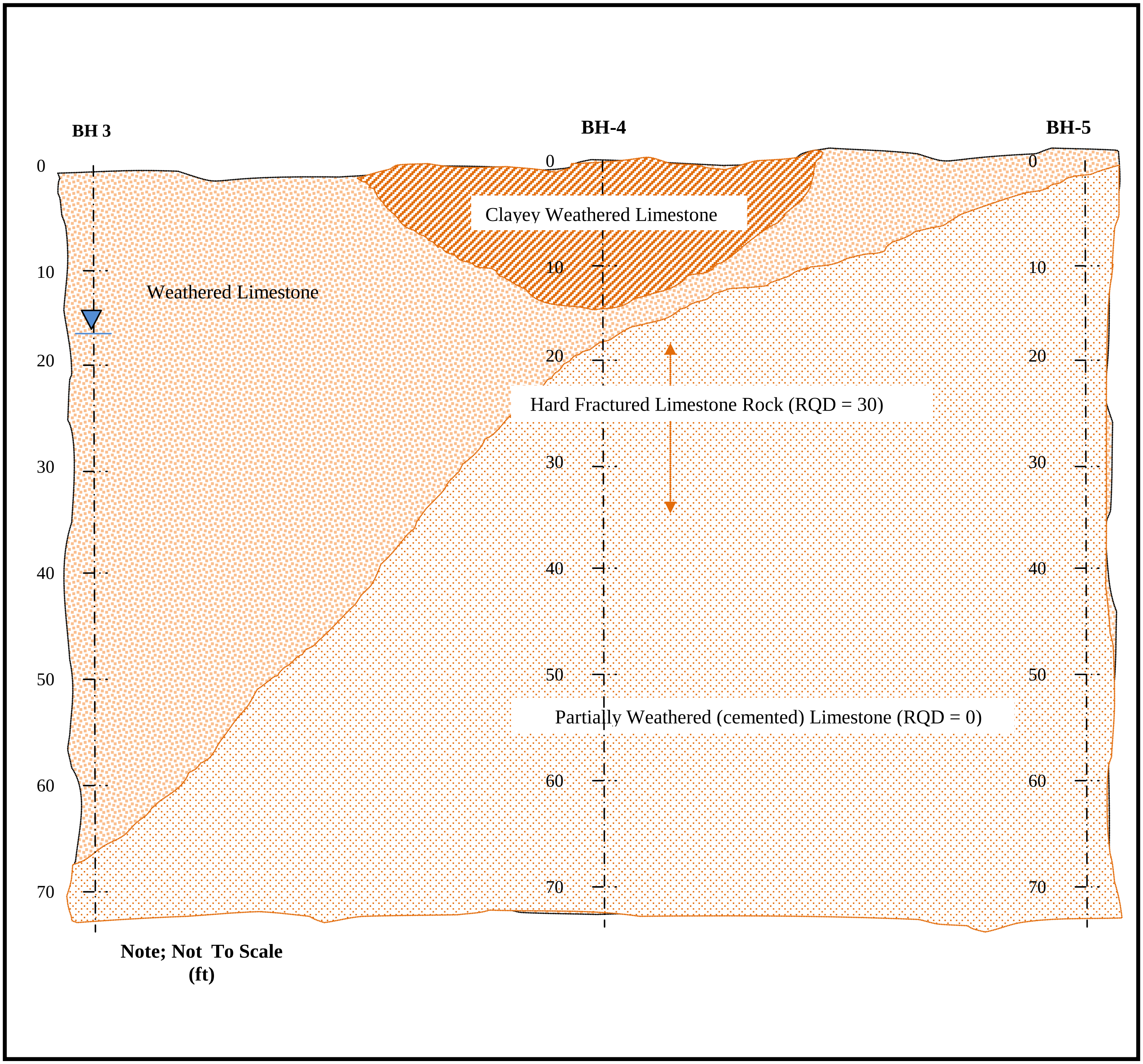

FIG. 4.2 – PRESUMPTIVE PROFILE ; BHs#3, 4 & 5

4.3 Bearing Capacity

4.3.1 Shear Considerations:

Note that Ultimate values are given for the insitu soils. A Factor Of Safety of 2.5 for maximum safe load capacity is recommended.

TOP1 and TOP2 (highly fractured & soft - modelled as Top1 Soils):

Raft/Beam/Pad Foundation

For this alternative, the Modulus of Subgrade Reaction (Ks) is the parameter of relevance for design. The recommended value for this parameter is :-

i) Ks = 39116*(1-0.4*B/L)*B KN/m^3

Raft/Beam/Pad Foundation

For shallow spread/strip footings, the maximum Ultimate Bearing Capacity (please apply FOS) and other relevant parameters recommended for this soil type:-

i) Q_{ult}. = 762.52*(1+0.47*B/L)*(1+0.22*D/B) KPa

Where,

Q_{ult} is the Ultimate Bearing Capacity
Ks is the Vertical Modulus
D is the Depth of footing,
B is the Width of footing (or span for raft),
L is the Length of footing (or span for raft)

TABLE 4.1 SUMMARY OF SOIL PARAMETERS

LAYER IDENTIFICATION	TOP2 Soil Rock	TOP1 Soil Gravel/Sand		
Bulk Unit Weight (KN/m^3)	21.0	18.5		
Submerged Unit Weight				
Compression Index				
Void Ratio				
Undrained Cohesion (KPa)				
Drained Cohesion (KPa)				
Effective PHI/PHI (Deg)	39.0	37.1		
Relative Density (%)		81.0		
Ka	0.203	0.235		
Kp	4.920	4.263		
Elastic Modulus (KPa)	71820.2	50274.1		
Percolation (cm/s)	$3.7x10^{-3}$	1.6x10-2		

4.4 <u>Vertical Deformation</u>:

Settlement considerations are insignificant in most location based on the field and laboratory data collected thus far. Moderately Compressible soils (clays and gravels) was encountered at Borehole 4. Vertical deformation is likely to be less than 50mm for the anticipated loads. Differential settlement could however be problematic (up to 35mm) in this location and a granular pad could be required below isolated footings.

4.5 <u>Slope Stability of Cut Embankments</u>

The following considerations are required for analysis and rehabilitations:

i) Estimation of effective cohesion and friction angle based on field and laboratory results

ii) Iteration of Saturation levels, cohesion and friction angles using established theoretical guide for failure criteria in analysis.

iv) Estimation of the possible initiation and exist point of critical slip surfaces based on the results of the analysis (software search for critical Janbu Slip Circle by running 25 circles at four specified points along the slope).

To maintain an acceptable Factor of Safety on the slopes will involve;

a) Limiting the effective height of the embankment by using cutbacks and steps. This also minimizes the effects of stormwater erosion along slope face.
b) Implementation of stormwater drainage elements to channel water in designated disposal facilities. Also the use of slope protective vegetation to minimize stormwater erosion and surface infiltration.
c) Remove pockets of areas identified as colluviums wherever they are exposed; these areas are susceptible to slope failure and erosion.

In summary, the generalized results were as follows:

1) For Cal. Gravels and Sands on Slopes of 1:2, 5m+ high; FOS = 1.460
2) For Cal. Gravels and Sands on Slopes of 1:3, 5m+ high; FOS = 1.310

<u>Factor of Safety Guidelines</u>

Factor of Safety	General Guidelines
< 1	UNSAFE
1.0 – 1.25	QUESTIONABLE
1.25 – 1.4	SATISFACTORY FOR CUTS AND FILLS (Not for Dams etc.)
> 1.4	SATISFACTORY FOR DAMS/LEVEES

The results indicate that the weathered limestone formation encountered satisfies the acceptable guidelines for cuts and setbacks up to 5m. Surface protections however will be critical to long term erosion control. Embankments or cuts with soil typical of the colluviums (not encountered so far) are highly susceptible to erosion and slope failure. This material should be excavated and removed where encountered.

The locations tested were along temporary access roads and not necessarily along the direct path of proposed highway. As a consequence the tested soils are not necessarily representative of those under construction. There can be significant changes in the formations after exposure along roadways.

4.6 <u>Liquefaction Considerations</u>:

Liquefaction considerations are insignificant based on the field and laboratory data collected thus far.

4.7 Hydrology Considerations

The collection of rainfall data is critical to drainage on site. Percolation rates appear fairly good (3x10-3cm/s to 1.6x10-2cm/s); in one location (where fractured rocks were encountered at 8ft) testing was done (hole was done to eight feet for the purpose of testing the upper soils only) and was abandoned due to the high rate of infiltration observed (possible fractures in rock). This location was approximately 5m south of BH3.

4.8 Site Material Use:

The calcareous gravels and sands encountered so far have acceptable Fines content and are in some locations suitable for structural fill. These areas have to be sampled and tested at the locations required because of the high variability observed.

4.9 Construction Considerations:

The rock formation, will limit the choice and suitability of equipment required to carry out the preliminary site preparation. The construction of all the infrastructural elements on site will require very strict monitoring given the high possibilities of cost over-runs (some of the required work may necessitate the use of explosives for blasting). Generally however the rocks are soft enough to be ripped by a front end loader and/or an excavator.

NHL ENGINEERING LIMITED

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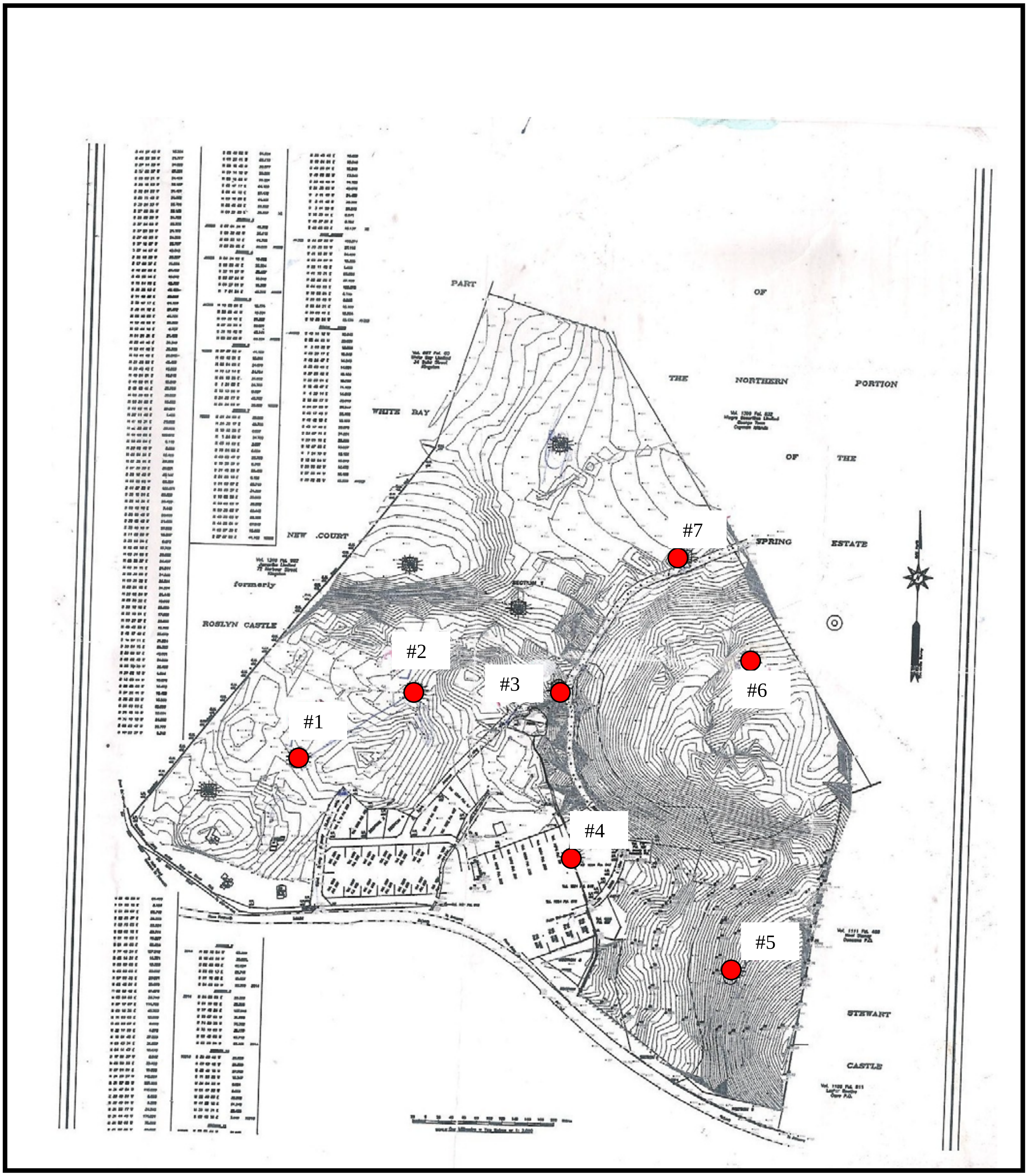
5.0. APPENDICES

Appendix I - Figures

SITE PLAN - Coral Spring Development



TEST LOCATION PLAN - Coral Spring Development