EARTHTECH CONSULTING LTD

TE ARAI

GOLF COURSE EARTHWORKS

Geotechnical Investigation Report

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1. INTRODUCTION

1.1 Project Description

The Te Arai property is located immediately north of Te Arai Point with a coastal frontage to Te Arai Beach. The property is approximately 5.3*km* long by between 0.8*km* to 1.6*km* wide covering a total area of approximately 620*ha* over rolling sand dune topography. The property is presently managed as a pine forest.

The golf course proposal is located on the northern part of the property.

It is proposed to develop an 18-hole golf course. The golf course requires earthworks for the construction of the golf course, and provision of a clubhouse, access, parking, and maintenance facilities.

This report provides a geotechnical assessment of the property and includes:

i. Geological and topographical conditions.
ii. Surface water catchments affecting the land.
iii. Slope stability and erosion control of dune formations.
iv. Geotechnical conditions and constraints affecting land development.

1.2 Scope of Investigations

The following investigations were completed for an earlier development proposal covering the entire site. Full details are provided in the report titled "The Te Arai Project – Preliminary Geotechnical and Hydrogeological Investigation Report", ref R2590-3 dated 7 August 2006.

i. Property walkover and mapping by a Senior Geotechnical Engineer and Engineering Geologist. The walkover was limited to key features

accessible from tracks, along the beachfront, watercourses and limited access to adjacent properties.

ii. Seven wash drilled boreholes (BHM2A/B, M4A/B, M7 and N6A/B). Monitoring well construction, bore development and permeability testing.

iii. One deep production bore to 150*m* depth.

iv. 26 dutch cone penetrometer profiles (CPT M1 to M12, N1 to N10 and S1 to S6) with 6*m* standpipes.

v. Six hand auger bores (HAM1, M2, M3A, M3B, N4 and S9).

vi. Two scala penetrometer tests (SPTM1 and M2).

vii. Monitoring of groundwater levels within the CPT standpipes and monitoring bores from March 2004 to March 2005.

viii. Groundwater chemistry sampling and laboratory testing of monitoring bores, the deep production bore and a dairy shed bore on the Carter Property.

ix. Surveying of surface water and groundwater spring features on the property and on neighbouring properties to the Te Arai property.

x. Desktop study of aerial photographs, geological maps and local groundwater and surface water users.

An overall location plan of the entire Te Arai property is shown on Figure 1.1. The locations of the above investigations are shown on Figures 1.2 and 1.3. Figure 1.3 incorporates all of the northern part of the property, including the subject site. Detailed field data relevant to the subject site is included in Appendix A.

All levels in this report are given in terms of the NZ Local Circuit Mt Eden 1949 geodetic datum where mean sea level (MSL) = RL0.0*m*. No accurate check on the tidal levels has been made on the land but the true mean sea level is expected to be within ±0.5*m* of the RL0.0*m* given.

2. LAND CONDITIONS

2.1 Topographical Setting

The site is located across extensive rolling dune formations which extend up to 2.0*km* in-land. The dunes vary from short, steep irregular dunes to large, gently undulating dunes which range between RL10*m* and RL35*m* in elevation. There are also large areas of flat to very gently sloping ground. The dunes are predominantly gently sloping with slope angles of less than 15° to the horizontal. Areas of moderately steep to steep topography are generally confined to a

westerly facing dune "front" located near the western property boundary and minor irregular dune slopes. The dune front is approximately 15*m* high with slope angles of up to 33° to the horizontal (angle of repose for uncemented sands) and marks the western extent of the "central" dunes.

A walk over and review of recent aerial photographs indicates that the dune formations are generally stable within vegetated areas covering most of the land. Areas of erosion were observed within the dunes at the following locations:

i. The entire length of beach foredune is mobile and prone to wind, wave and tide erosion and accretion. The foredune is typically 30*m* to 50*m* wide.
ii. Limited areas of unvegetated and poorly vegetated dunes are present within the boundaries of the property. Some of these are 6*m* to 10*m* high and are mobile.
iii. A small area of dune erosion and movement is located in the north west corner where a large dune blowout has occurred on adjacent farmland. This may have been caused by sand extraction from the area.

Active sand dunes are located on the northern edge of the property, extending northwards along the coastal margin to the shores of the Mangawhai Harbour. These dunes have not moved significantly since the 1961 aerial photographs but do encroach onto the property boundary.

The Mangawhai Spit to the north of the property is listed in the Inventory of Important Geological Sites and Landforms in the Auckland Region (Geological Society of NZ, Publication no. 48, 1996). The barrier spit is classified as a well-defined landform of scientific/educational value. Hazards to this landform are listed as sand extraction and stabilisation efforts. Prior to 1961, the Te Arai property would have been classified in a similar manner.

The majority of the land is planted in pines intermixed with recently cleared areas which are presently covered with grasses and scrub. Access through the pine forest is via a series of metalled and sand based tracks which run off a metalled ring road around the property. The road/track locations and names are shown on Figures 1.2 and 1.3.

The western property boundary is located on or close to extensive alluvial flats which extend to the base of foothills located to the west and the Mangawhai Harbour to the north. The alluvial flats typically range between RL 5m and 15m in elevation. Portions of the flats are covered with older, fixed dunes which typically follow a north-south line halfway between the western property boundary and Black Swamp Road.

2.2 Surface Water and Drainage Features

Surface water drainage across the land is predominantly to ground soakage within the dunes. A number of small excavated water supply ponds and swampy/wet areas are located along the coastal margins and close to the western property boundary. These features are fed from groundwater seeps and are more fully described in section 5.1. A larger wetland area is located in the northwest corner of the property as sketched on Figure 1.3.

A series of culverts beneath Canal Road drain ponds located near the coastal margins on the middle portion of the property. Approximate measurements of the flow rates during February and March 2004 indicated total volumes in the order of $300m^3$/day. This did not increase during the winter months as expected. Water from the culverts soaks away into the coastal foredunes.

The site has similar wet areas immediately behind the foredunes.

A similar flow rate of $300m^3$/day was observed in January 2005 in the wetland areas located in the northwest corner of the property.

The extensive alluvial flats located to the west of the property drains via a series of ditch drains to either the Mangawhai Harbour to the north or to the Te Arai Stream to the south which outlets via a natural channel cut through the dunes between the southern and middle blocks.

There are no permanent watercourses on the land apart from the groundwater seep areas and the Te Arai Stream itself.

2.3 Aerial Photographs

A review of the 1961 aerial photographs of the property and surrounding topography indicates the following:

- The majority of the land (approx. 70%) was covered with unvegetated sand dunes. The large sand dune front along the western edge of the central dunes has not moved significantly since the 1961 photographs. The extent of the active dunes shown in the 1961 photographs is plotted on Figures 1.2 and 1.3.
- Small pockets of vegetation and what appear to be wet swampy areas are located along the coastal margins in similar locations to the present day.

- Much of the alluvial flats to the west of the property are vegetated with grasses and shrubs indicative of swampy ground. The topography to the west of Black Swamp Road is in farmland.
- A large pond located between Black Swamp Road and the western property boundary can be observed in the 1961 photographs and forms the present day Conservation Lake.

The aerial photographs emphasise the importance of the pine tree cover in stabilising the dunes and the risks of leaving an area of exposed sand for any length of time. Without vegetation cover, the land would revert to shifting dunes similar to that on the Mangawhai Spit.

3. SURFACE CATCHMENTS AND YIELDS

3.1 Catchment Boundaries

Figure 3.1 indicates the extent and nature of the surface water catchments that abut or drain through the land. Only the Black Swamp Catchment is relevant to the site. Boundaries have been determined from public vantage points and published maps. In some areas the catchment divides are very subdued and have been affected by farm drainage systems. In particular, the Black Swamp catchment to the north does not appear to coincide with the Auckland/Northland Regional Council Boundaries which are usually determined by surface water catchment divides.

3.2 The Black Swamp Catchment

On the north western boundary, the Black Swamp Drain provides an artificial drainage system for the original Black Swamp. Gradients are extremely low and some of the drains are expected to flow in both directions under different conditions. The two water supply ponds in the North Block connect to the Black Swamp Drain. The Conservation Lake off Black Swamp Road is also reported to overflow into the drain. The main drain parallels the western property boundary and flows through a large culvert under Tern Point Road to the north. Available drain invert levels are provided in Figure 1.3.

Flow volumes are low (but reported to be continuous throughout the summer) and water quality is poor due to the peat substrate and intensive dairy and dry-stock farming in the catchment. No surface water takes have been reported.

3.3 The Catchment

Most of the subject site has no defined surface watercourse and rainfall infiltrates the dune land. The western portion of the lot forms part of the Black Swamp Catchment.

4. GROUND CONDITIONS

4.1 Published Geology

The NZMS 290 Sheet R09 maps the property as being underlain by active sand dune deposits. Greywacke bedrock is mapped to the south of the property underlying Te Arai Point and alluvial deposits are mapped to the immediate west of the property underlying the alluvial flats. Mudstone deposits are mapped underlying the foothills to the west of the property and alluvial flats. Pockets of Pleistocene fixed dune sands are mapped to the west and south-west of the property. The investigations and topographical information are consistent with the published geology.

Figures 1.2 and 1.3 show the geology from mapping and the published geology. Figure 4.1 shows geological sections A-A and B-B through the middle and northern portions of the property respectively. The ground conditions underlying the Te Arai property consists of the following units:

4.2 Topsoil

Essentially non-existent with only a thin pine needle organic blanket or thin layer of organic SANDS covering the dune sands. Topsoil does not appear to have developed in any of the large depressions – reflecting the young age of the dunes.

4.3 Upper Dune Sands

The upper dune sands are extensive across the land and consist of wind-blown sand deposits. CPT testing shows that the sands extend from the ground surface to typically between RL10*m* and RL12*m* along the western property sloping down to between RL6*m* and RL8*m* along the coastal margins where they merge with the coastal foredunes. The upper dune sands have a considerable range in thickness of between 3*m* and 50*m*.

The upper sands consist predominately of medium dense (cone resistance >4*MPa*) to dense (cone resistance >10*MPa*), fine to medium SANDS. A zone of loose to medium dense sands is typically present at the surface. Scala penetrometer tests SPT M1 and M2 provided blow counts per 50mm of between 1 and 3 to depths of up to 1.55*m*.

4.4 Middle Organics

An organic layer is situated at the base of the upper sands and appears to be present across the majority of the property. The organic layer was not encountered within CPT's M3, M7, N7 and S6. Other CPT's which show no signs of the organics are typically at levels too high or too low to intersect the middle organics layer. CPT profiles indicate the organic layer has an overall thickness of typically 4*m* to 6*m* near the western property boundary thinning to between 1*m* and 2*m* near the coastal margins.

The middle organics consist of interlayered PEATS, sandy PEATS and organic fine to medium SANDS. The CPT profiles indicate the PEATS typically have a cone resistance of 1*MPa* to 5*MPa* where overlain by significant depths of dune sands (e.g. M2). However, where the dune sand cover is thin, the cone resistance is less than 1MPa (e.g. N4). The CPT data indicates significant strength variations in the organic layer – probably as a result of dune preloading effects.

A deeper organic layer is shown in CPT's M4, N9 and N10 at depths of between RL0.4*m* and RL-1.3*m*. This layer appears to be confined to small areas along the coastal margins and is less than 1.0*m* thick.

4.5 Lower Dune Sands

The lower dune sands are interpreted to underlie the entire property and consist largely of wind-blown sand deposits. CPT testing shows that the sands extend down to levels of between RL-0.8*m* and RL-10.6*m* with an overall thickness of between 5*m* and 15*m*.

The lower sands consist predominantly of medium dense to dense, fine to medium SANDS. Monitoring bore sets M2 and N6 indicate that the lower dune sands are heavily iron stained and mineralised with some organics immediately below the middle organics decreasing with depth. A 300*mm* diameter tree trunk was intersected within BH N6B at RL-1.0*m*.

4.6 Green Sands

The green sands were encountered in all deep monitoring bores to depths of at least RL-19.0*m* (overall thickness of greater than 18*m*). The green sands consist typically of dense to very dense, medium to coarse SANDS with occasional fine gravels and clays.

Two SPT tests completed within bores M4B and N6B provided counts of N = 40 and 35 respectively.

4.7 Waitemata Group Bedrock

The deep production bore (DB1) drilled near the western boundary (Figure 1.3) by Kiwi Well Drillers indicates a bedrock contact at 70*m* depth (RL-54*m*). The bore continued in the sandstone/mudstone rock to a depth of 150*m* (RL-134*m*). The bore log is attached in Appendix A – note that soil and rock descriptions are of cuttings brought to the surface by rotary flush-drilling and hence are not accurate descriptions of the in-situ conditions.

4.8 Geological Model

The middle organic layer identified across the land is at similar levels to the alluvial flats located to the west of the property. It is likely that at some stage the alluvial flats extended up to the present day coastal margin and was later buried with wind-blown sand forming the upper dune sands.

The lower dune sands may form an extension of the Pleistocene fixed dune sands mapped to the immediate west of Black Swamp Road and which are considered to underlie some or all of the existing alluvial flats area.

The green sands belong to an older formation and a different depositional environment. The green sands have been proven to RL-19.0*m* depth and possibly to RL-54*m* in the deep production bore. It is not known whether they underlie the organics to the west or overlie the greywacke to the south.

A conceptual geological section through the Northern Block (the subject site) is provided in Figure 4.2.

5. GROUNDWATER SYSTEMS

5.1 Conceptual Model of the Groundwater Systems

A conceptual east-west hydrogeological section through the Northern Block of the property is shown on Figure 5.1. The section has been formed from available geological information, mapping of spring features and groundwater level monitoring of CPT standpipes and boreholes.

The groundwater system consists of three distinct zones: an upper or perched groundwater system contained within the upper sands; a middle groundwater system contained within the lower dune and green sands; and a deep system within the underlying Waitemata Group bedrock.

- The Upper Groundwater System

Groundwater within the upper dune sands is considered to be perched above the "middle" organic layer which is characterised by low permeability peats and organic sands. Monitoring of groundwater levels within monitoring bore sets M4 and N6 show a sharp drop in measured groundwater heads within the upper and lower sands of between 3.0*m* and 5.0*m* respectively. This indicates a hydraulic separation between the two systems, with downward leakage controlled and restricted by the organics.

The upper groundwater system is recharged from rainfall. Groundwater which does not "leak" through the middle organics typically flows from west to east above the very gently sloping middle organics contact and outlets via a number of seeps located along the coastal margins. As the "spring line" is not continuous it is likely that large portions of the perched system are "lost" to depth near the coastal dunes. Minor groundwater springs and ponds along the western boundary are also considered to be recharged from the perched groundwater system.

The upper groundwater system ranges between 1*m* and 10*m* thick.

- The Middle Groundwater System

The groundwater system within the lower dune and green sands is characterised by a gentle west to east groundwater flow with discharge to the Te Arai coastal margins and to the Te Arai Stream below sea level. The groundwater system is expected to be restricted in the south by the Te Arai Point greywacke headland.

The groundwater system to the west of the property is poorly defined as limited information is presently available on the depth of the alluvial deposits which

mantle the alluvial flats area and groundwater levels. The presence of the green sands is inferred but has not been proven by drilling. Groundwater levels measured within a few drainage ditches across the flats may not be representative of the local groundwater system at depth due to the confining nature of the low permeability alluvial deposits. The underlying sand aquifer could extend to the mudstone hills which outcrop to the west of the property and alluvial flats, resulting in a larger groundwater catchment area than the property itself.
Over the northern portion of the property, groundwater flows at depth are also expected to flow towards the Mangawhai Harbour to the north and northwest.

The base of the aquifer has only been defined at the deep bore location at RL-54*m*.

- The Deep Groundwater System

The deep production bore intercepted good flows in the sandstones and minor mudstones at depths of 70*m* to 150*m* below the surface. Local well drillers report that the sandstone surface is commonly intercepted at these depths, generally providing good flow rates but variable quality. Bore DB1 was airlift tested at a rate of 28.8m^3/hr (690m^3/day) – limited by the flow rate in the 100*mm* riser pipe.

Water quality is poor with elevated salinity and high boron levels.

5.2 Groundwater Levels

Groundwater level monitoring of monitoring bores and CPT standpipes across the property has been carried out during the summer lows of 2004 and 2005 and the winter high of 2004. During this period groundwater levels remained fairly steady with any changes typically less than 80*cm*.

Groundwater levels measured within CPT standpipes situated within the upper dune sand system show a gradual groundwater gradient towards the coastal margins with the highest levels measured within the central and western portion of the property indicating minor mounding of groundwater within the upper dunes. The groundwater levels tend to follow the base of the upper dune sands/organics contact. Surface water levels measured within the ponds along the coastal margins closely match the groundwater levels and confirm the perched nature of the groundwater seeps which feed the ponds and swampy areas.

Groundwater spring levels surveyed along the coastal beach range between RL3.0*m* and RL4.5*m* with a typical level of about RL3.5*m* (MSL = 0.0*m*).

Groundwater levels measured within the lower dune and greens sands aquifer from the monitoring bores indicate a gentle groundwater gradient towards the coastal margins. Bore set N6 shows falling groundwater head with depth indicating possible groundwater impedance within the lower dune sands from the partial iron cementing observed. Monitoring bore sets M2 and M4 do not show this.

The deep production bore has a static level 8*m* below the surface or RL8*m*.

6. CONCLUSIONS AND RECOMMENDATIONS ON LAND RESOURCES AND CONSTRAINTS

6.1 Geological and Ground Conditions

- Upper Dune Sands

The land is located on windblown sand dunes. These were stabilised by the planting of pines during the 1960's. There is no topsoil, other than a thin layer of recently developed organic matter. The dunes are prone to active movement if the vegetation cover is removed and large blowouts and smothering with sand can occur rapidly.

Active dune erosion and accretion is present along the foredune area. The upper dune sands vary in thickness with the topography and overlie an organic layer which is interpreted as an extension of the Black Swamp area located along the western boundary. A thin layer of lower dune sands is then sandwiched between the organic layer and the green sands which extend to depths of at least RL –19m.

No bedrock is present on the surface of the land.

6.2 Groundwater Systems

Three groundwater systems have been identified on the land.

The upper system has formed within the upper dune sands and is perched on top of the organic layer. The system is fed by rainfall infiltration of the dune sands. Discharge is via small seeps and ponds around the perimeter of the property with significant leakage to depth through the organic layer. The upper system is unlikely to yield a reliable water supply but it does supply existing wetland areas which could be developed further.

The middle system extends well below sea level within the lower dune sands and green sands. The system may extend west of the property as far as the higher ground beyond Black Swamp Road.

The deep system lies within the Waitemata Group bedrock at depth of $60m+$ below the land. The single bore drilled to date indicates high flow rates but with elevated salinity and a high boron level. A "sustainable" yield of $400m^3/d$ has been estimated. Treatment to drinking water standards could be difficult.

6.3 Surface Water Systems

The Te Arai Stream is the only significant surface water body on the property. It does not extend to the subject site. The stream is sourced from the Spectacle Lakes and local watercourses which have been heavily modified by farm drainage works.

6.4 Geotechnical Engineering Assessment

Earthworks should be straightforward in the sand dune conditions and would suit a winter construction programme. Effective controls will need to be taken to protect exposed areas against wind erosion.

Large areas of the land are flat to very gently sloping and could be developed with minimal or very minor earthworks. Care and appropriate setbacks will be required where active erosion is present.

High groundwater levels are present around the perimeters of the property and specific investigations and design of an appropriate drainage system will be required if these areas are built on. Most of these areas would be better suited to development as a "managed wetland area" or simply left as is.

Surface water controls from impermeable areas need to consider run-off effects on slopes and also any effects on groundwater levels if piped systems discharge to surface ponds and soakaways.

7. DEVELOPMENT PROPOSALS AND ASSESSMENT OF EFFECTS (GEOTECHNICAL)

7.1 Project Concept

The project team has developed a concept for the northern part of the property. This includes an 18-hole golf course, clubhouse, associated facilities and parking.

7.2 Earthworks details

7.2.1 General

Only minor earthworks are anticipated. The works can be scheduled to ensure that areas and times that the sand is exposed to erosion are kept to a minimum. Protective surfaces include temporary measures such as mulch, wind nets, geotextile mats and short-term cover crops (e.g. lupins). Long-term protection will be provided by the revegetation programme and erosion resistant surfaces such as metalling of the sand access roads and carpark areas.

7.2.2 Geotechnical Design Parameters

The proposed earthworks involve only minor reshaping of the upper dune sands. Minimal undercutting of unsuitables is anticipated although there may be small pockets of organics in depressions and mixed sand fills from previous forestry operations.

Design parameters for the sands are recommended as follows:

- Loose dune sands (in-situ or landscaping fills).

  $c' = 0, \varnothing' = 30°, \gamma = 17kN/m^3$

- Medium dense dune sands (in-situ or compacted fills).

  $c' = 0, \varnothing' = 33°, \gamma = 17kN/m^3$

Road construction in the sands involves stripping any vegetation and tree roots, trimming and shaping to the design subgrade levels and proof rolling of the subgrade surface. A design CBR value of 4 is recommended for the sand

subgrade for the metalled roads. If roads are to be permanently sealed, the subgrade should be compacted to achieve a design CBR value of 10.

Where buildings are located, the in-situ sands should be checked and/or recompacted to provide a design CBR value of at least 4. This will allow standard footing designs to be specified with an ultimate bearing capacity design value of $300kPa$ (allowable bearing capacity value = $100kPa$).

Buildings and soakaway areas should be located to ensure that groundwater levels on these sites are at least $0.6m$ below the surface. If necessary, subsoil drains can be installed to lower areas with a high water table.

Compaction of the loose sands is generally best achieved by spreading in thin layers ($<100mm$) with a dozer and compacting with continuous passes of a tractor drawn levelling bar. The sand must be compacted to achieve a minimum scala penetrometer value of >2 blows/$50mm$ over depth of $600mm$ for metalled roads.

No density or compaction requirement is specified for landscaping areas.

7.2.3 The Access Road (Figure 8.1)

The existing perimeter access road is metalled and was formed as part of the forestry operations. The existing formation width is $7m$ with a $3.5m$ to $4.0m$ metalled width. No further earthworks are required on the existing perimeter road. Where vegetation has encroached on the road formation width this needs to be sprayed off, trimmed and dressed with road metal. Minor upgrading is required, together with a new dressing of road metal.

- Length = $1500m$
- Formation width = $7m$
- Metalled width = $3.5m$ to $4.0m$, increase to $5.0m$
- Metal quantity
  - GAP65 for road widening = $300m^3$
  - GAP40 for final surface = $400m^3$

The final $300m$ follows an existing sand track on near level ground. This requires upgrading to provide all weather two-wheel drive access. Construction involves minor shaping, removal of pine tree stumps, short

sections of swale drain and placement of a subgrade and metalled surfacing layer.

- Length = $300m$
- Earthworks volume = $400m^3$ (allow for small dune cuts)
- Required formation width = $7m$
- Required metal width = $5m$
- Metal quantity
  - GAP65 subgrade = $250m^3$
  - GAP40 for final surface = $250m^3$

7.2.4 Carparking Area (Figure 8.2)

The parking area is shown on Figure 8.1. It is located on gently sloping dune topography.

Construction requires removal of tree stumps, minor shaping and placement of road metal.

	Cut/Fill Volumes	GAP65	GAP40
Club Parking	$200m^3$	$60m^3$	$60m^3$

7.2.5 Club House Building and Ancillary Structures

A $100m^2$ clubhouse is to be located as shown on Figure 8.2.

Construction requires removal of tree stumps and shaping of the sands to the proposed contours. Compaction of the loose sands is required.

- Cut and fill volume = $150m^3$
- Spoil volume (landscaping fill) = $200m^3$

Building foundations may be designed for an ultimate bearing capacity of $300kPa$ ($100kPa$ allowable) in the in-situ and/or compacted sand areas.

7.3 The Golf Course (Figure 8.3)

The design of the golf course utilises the existing dune topography for the fairways and no additional earthworks are proposed for these areas.

Greens, tees and bunkers will require minor earthworks to form the desired land profiles. Greens and tees have been located on existing natural features and minimal earthworks is required. For the bunkers, cut and fill depths of less than $1m$ is anticipated and the sands will simply be reshaped and then stabilised with grass (or bunker sand).

A cut/fill volume of no more than $575m^3$ is anticipated for each fairway based on:

- 1 x Green = $300m^3$
- 3 x Tee Blocks = $75m^3$
- 4 x Bunkers = 4 x 50 = $200m^3$

Tree felling is currently underway. All slash, stumps and undergrowth should be left in place as wind protection until development of each fairway is undertaken in accordance with the Revegetation Management Plan.

7.4 Earthworks Summary

Estimated earthworks volumes are summarised as follows:

	Dimensions	Earthworks	Roading Metal
Perimeter Access Road	1500*m (existing)*	Nil	$700m^3$
Clubhouse Access Road	$1500m^2$	$375m^3$	$500m^3$
Carpark Area	$615m^2$	$154m^3$	$154m^3$
Clubhouse Building	$150m^2$	$37.5m^3$	-
Golf Course	$19,800m^2$	$10350m^3$ (@ 575m³ per hole) see inserted table below	-
Practise Area	-	Nil	-
Totals	$22,065m^2$	**$10,920m^3$**	**$1320m^3$**

Proposed earthworks figures – Average golf hole							
	Length (m)	Width (m)	Subtotal (m^2)	# per hole	Subtotal (m^2)	Depth (m)	**TOTAL (m^3)**
Tee Block	12.5	8	100	3	300	0.25	75
Bunker	10	5	50	4	200	1	200
Green	30	20	600	1	600	0.50	300
TOTAL			750m²		1100m²		575m³

7.5 Effects of Earthworks

The principal geotechnical constraint is the high risk of erosion if the dune sands are left exposed and without adequate vegetation.

The concept recognises these constraints and development is proposed to be undertaken with a minimum of earthworks. Careful attention to re-vegetation details is proposed at all stages.

Setback requirements for steep slopes and active erosion/accretion areas have been identified and recognised in the concept plan. Detailed design has taken account of these requirements and thereby avoids or mitigates any adverse erosion effects.

7.6 Effects on Groundwater Resources

The upper aquifer is limited in depth and very sensitive to level changes i.e. deep cuts or subsoil drains could drain the system below the current wetland levels. Care is required to maintain the flows to those wetland areas that are to be preserved (and enhanced).

With careful detailing of drainage systems a balance can be achieved whereby the existing natural systems are enhanced via infiltration galleries, rain gardens and control of runoff from impervious areas.

The upper system is vulnerable to contamination and treated wastewater disposal areas should be located well clear of wetland areas and potential take sources.

The middle aquifer is "protected" to some extent by the upper system. It is advisable to separate treated wastewater disposal areas from any bore take areas – a minimum separation distance of $50m$ is recommended. However, no bore take is proposed as part of the earthworks application.

The deep aquifer is not well understood and water quality and quantity appears to be variable.

The change in land use from pine plantation to golf course plus extensive planting is not expected to significantly alter the groundwater systems. Infiltration of rainfall is likely to increase due to lower evapotranspiration rates after removal of the pines – this would enhance the wetland systems. Irrigation water is not expected to have any effect on the aquifers if managed correctly.

7.7 Effects on Surface Water Resources

There are no surface water bodies except for the small fire-fighting ponds and wetland areas. The earthworks are a sufficient distance from these waterbodies such that the waterbodies are not affected.

The ponds can be enhanced with the infiltration measures proposed for runoff controls and remain available for fire-fighting purposes if required.

7.8 Summary of effects of earthworks on the environment

The earthworks require to construct the 18 hole golf course at Te Arai are minimal in scale and will not adversely affect the environment, including the surface materials, and the groundwater and surface water, provided that suitable erosion protection measures, and a re-vegetation programme, are adopted. These measures are addressed in the *Earthworks and Revegetation Management Plan* proposed as part of the application for earthworks.

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This report has been prepared solely for the benefit of you as our client with respect to the particular brief given to us, and data or opinions contained in it may not be used in other contexts or for any other purpose without our prior review and agreement.

APPENDIX A

FIELD INVESTIGATION DATA

Borehole, CPT, Hand Auger and Scala Penetrometer Logs
Deep Production Bore DB1 (Kiwi Well Drillers Log)