Dam Safety Review

Project: Torquay Farm Dam – Horse Bend Shoe Road
Report No: AGTE20249-3 Rev 1

| Geotechnical | Environmental | Residential | Pavements Investigation & Design |
Adelaide, Ballarat, Brisbane, Dingley Village, Warrnambool

Prepared for:

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Contents

Abbreviations

AC	Asbestos Cement (pipe)
AEP	Annual Exceedance Probability
AFC	Acceptable Flood Capacity
AHD	Australian Height Datum
ANCOLD	Australian National Committee on Large Dams
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
AS	Australian Standard
ASCE	American Society of Civil Engineers
BH	Borehole
BOM	Bureau of Meteorology
FSL	Full Supply Level
GIS	Geographic Information System
LL	Liquid Limit
LOL	Loss of Life
LS	Linear Shrinkage
M.G.	Million Gallon
ML	Megalitres
MOL	Minimum Operating Level
MSCL	Mild Steel Cement Lined
NATA	National Association of Testing Authorities, Australia
PAR	Population at Risk
PE	Polyethylene
PGA	Peak Ground Acceleration
PI	Plasticity Index
PL	Plastic Limit
PVC	Poly Vinyl Chloride
RD	Running Distance
TP	Test Pit
UNSW	University of New South Wales
SRWSC	State Rivers and Water Supply Commission
SRW	Southern Rural Water

Torquay Farm Dam: Main Statistics

General

Location	1075 Horseshoe Bend Rd, Torquay VIC 3228
Nearest town	Torquay
River	Off river storage
Catchment Area	Approximately 4ha
Map Reference	-38.303399, 144.348000
History of Construction	◗ Constructed in 1987 ◗ Basic geometry records
Purpose	Irrigation for flower farm nearby
Hazard Category	Significant/High C
Design	Homogenous earth dam with 3H:1V slope, originally farm dam
Construction	Unconfirmed, believed to be combination of original landowner and local earthmoving company Good compaction mentioned in the original report
Original Owner and Operator	Landowner
Current Owner and Operator	Landowner

Reservoir

Total Storage Capacity	Approximately 171ML
Surface Area at FSL	Approximately 3 hectares
Full Supply Level (FSL)	Historic: 15.5m AHD Design & Proposed: 14.0m AHD
Staff Gauge at FSL	Historic: 3.5m Design & Proposed: 2.0m
Minimum Operating Level (MOL)	Not Known

Embankment	
Type	Homogeneous earthfill, no filter, no cutoff
Maximum Height	Approximately 6m Downstream Approximately 9m Upstream
Crest Length	300m x 170m
Crest Width	Approximately 4m
Crest Level as Surveyed	Maximum Level: Approx. 16.6m AHD Lowest Level: Approx.15.5m AHD
Minimum Freeboard	3m currently
Upstream Slope	3H:1V or flatter
Downstream Slope	3H:1V or flatter

Foundation	
Foundation Description	Clay to 5m depth, clayey sand below 5m
Foundation Origin	Torquay Group Marlstone, limestone, mudstone, sandstone, minor lignite

Spillway	
Type	No spillway
Acceptable Flood Capacity *(ANCOLD 2000)*	1 in 1000 AEP

Inlet Works	
Inlet Pipe:	150-250mm diameter pipeline over the embankment
Cutoffs	Unknown, considered unlikely

Outlet Works	
Arrangement:	The outlet works comprise a pump and outlet pipe extending into the reservoir. The outlet pipe travels over the embankment
Cutoffs	Unknown, considered unlikely

1. Introduction

Torquay Farm Dam (the dam) is a shallow 171ML capacity off-stream storage, located 5km north east of Torquay town centre. The reservoir was constructed as a farm storage, used for irrigation of nearby flower farm. A locality plan showing the location of the dam is shown in **Figure 1**. The site is located along Horse Blend Road adjacent to the Sands Golf Course and within agricultural farming.

The storage is filled using recycled water from Black Rock treatment plant operated by Baron Water. Stormwater from the Sands Golf Course and from the farm is also used to reduce the salinity of the recycled water. It has a small natural catchment being the reservoir surface. Water is pumped from this storage into the flower farm.

Mr Charlie Santospirito engaged Australian Geotechnical Testing (AGT) to undertake a safety assessment of the reservoir in order to assess the stability and integrity of the storage embankment and assess a seepage issue previously identified as impacting on two neighbouring property to the south of the site. This report presents the results of the AGT investigations, and options and recommendations for embankment assessment and seepage control.

Figure 1 – Dam Location Plan

1.1 Scope of Work

The following scope of works were undertaken for this study:

- Review existing information on the dam and gaining an understanding of the site history;
- Undertake a feature survey of the site such that a plan of the embankment and basin (including a topographical survey of the site);
- Using information collected during the site investigation in December 2017 and the AGT's targeted site investigation in November 2020 to determine the geology of the site, the condition of the embankment and foundation;
- Using the available information and the targeted site investigation, review the condition of the embankment and comment on the types of material used for its construction, its compaction, moisture content and piping failure potential as well as slope condition;
- Determine requirement for a spillway to pass the design flood/ inflow;
- With reference to ANCOLD guidelines, make recommendations in respect to any works required to provide an acceptable level of risk;
- Make recommendations in respect to the timing for any remediation works;
- Carry out a hydraulic analysis to model dam break and prepare an inundation map;
- Make recommendations in respect of any further investigation or permanent /ongoing monitoring required (seepage monitoring, piezometers, survey control points etc).

2. Review of Available Information and History of Dam

2.1 Collated Site Information

The following site references were collected and reviewed for this study:

- Dam Construction Records (SRWSC 1987)
- Geotechnical Investigation and Dam Stability Analysis (AGT 2017);
- Geotechnical Investigation (AGT 2020)
- Geological Survey of Victoria, 1:63,360 Anglesea Geological Mapsheet, 1980;
- Geological Survey of Victoria, VIMP Report 60 - Hydrocarbon prospectivity of the offshore Torquay Sub-basin, Victoria: Gazettal Area V99-1
- Barwon Water Topography Surveys, CAD files
- Aerial photographs of the dam

2.2 Dam General Description

The embankment was constructed sometime around 1987. It is approximately 300m long, 170m wide and has a crest width of approximately 4m, has a maximum height of 6m on the downstream side and 9m on the upstream side of embankment due to excavation into foundation. It is founded on relatively flat ground. The embankment is of homogeneous earthfill type. Batter slopes are 3H:1V both upstream and downstream.

Several pipes connect the reservoir to the water supply system which feeds the reservoir from the Sands Golf Course, Black Rock Treatment Plant and stormwater systems; several outlet pipes also connects the reservoir to the irrigation system (see plates 1 and 2, below). All pipes run over the embankment aside from a previously decommissioned Barwon water treatment plant pipe that contributed to a recent leakage incident. There is also one pipe that connects the reservoir to the stormwater sump located to the west of the embankment. This pipe also is located inside the embankment but it is not currently used. The “sump” was excavated in 2017 to assist managing the stormwater and runoff.

The dam does not have a spillway. At the commencement of this study the embankment was not instrumented (i.e. no piezometers or movement markers installed). However, 4 standpipe piezometers were installed during the November 2020 site investigation.

A summary of the main statistics of the dam is included at the beginning of this report under the heading *“Torquay Farm Dam: Main Statistics”*.

Plates 1 and 2: Inlet and Outlet Pipes and Pump House Arrangement

2.3 Regional Geology

The following regional geology summary is based on the Anglesea 1:63,360 geological mapsheet and accompanying geological notes.

The main geological unit is the Torquay Group which includes marlstone, limestone, mudstone, sandstone and minor lignite. The deposition commenced with the onset of the Oligocene transgression, which resulted in calcareous sediments being deposited under widespread marine conditions. The group onlaps onto the King Island – Mornington Peninsula High which, near its crest may be condensed or absent. It is thickest in the basin Depp where approximately 700m of Torquay Group is present. The subunits of Torquay Group is listed below:

- **Batesford Limestone:** This units includes two lithologies: soft calcarenite of sand-sized fragments of marine fossils, white when fresh, weathering to yellow/yellow-brown; and a harder limestone (Moorabool Stone) of closely packed foraminifer tests; hardness due to carbonate cementation.
- **Jan Juc Marl:** this unit includes fine-grained silty glauconitic marl with sandy calcarenite interbeds; coarsens upwards.
- **Point Addis Limestone:** the unit includes yellow sandy bryozoal calcarenite. Ferruginous intraclastic conglomerate with abraded shelly and vertebrate skeletal components.

No major faults have been identified in the vicinity of the dam.

3. Fieldwork Methodology

3.1 General

Two AGT's site investigation, which was conducted separately in December 2017 and November 2020, consisted of the following activities a dam Inspection, borehole Drilling and installation of standpipe piezometers.

In addition, representative samples were selected from the site investigation and tested in a NATA laboratory in order to confirm onsite visual assessments and provide parameters for input into analysis and consideration for safety review.

3.2 Project Briefing and Dam Inspection

The project briefing and condition inspection was undertaken on Monday 5th October 2020 following a recent leak incident. The project briefing was attended by AGT's Mr Amir Farazmand (Senior Geotechnical/Dams Engineer), and Client representative Mr Mark Tomkinson. The project briefing addressed the following issues:

- Dam history;
- Details of people previously and currently involved in the dam, including neighbours and local authorities;
- Onsite location of key issues, underground services and geotechnical investigation works; and site walkover.

At the completion of the project briefing, Mr Amir Farazmand undertook an inspection of the dam in order to:

- Finalise suitable subsurface investigation points;
- Assess the spillway arrangements;
- Assess the overall condition of the dam, including inlet and outlet pipes, embankment erosion and performance;
- Review the composition of downstream properties so that an assessment of potential failure consequences could be determined; and
- Determine potential upgrade works and any site constraints.

The key observations from the dam inspection are presented in AGT reports "AGTE20249 The Dunes Dam Torquay" and "AGTE20249-1 The Dunes Dam Torquay".

4. Information About Dam and Associated Structures

4.1 Type of Dam

The dam is a rectangular excavated tank with the wall raised above the natural surface preventing any surface runoff entering the dam. The embankments are built using materials excavated from the reservoir to approximately 3m below ground. The water is pumped from the Black Rock treatment plant and other sources into the reservoir. Minimal water is obtained from rainfall over the dam due to its small catchment.

4.2 Runoff Estimates

The dam has been raised above the surrounding area about 6m and there is no runoff into the dam and the only source of water is what pumped into storage.

4.3 Catchment Area

The only catchment area is the actual dam reservoir.

4.4 Estimation of Flood Flows

During flooding rains the only impact will be the rain itself. The maximum rainfall according to the Burau of Meteorology Website for the Torquay Golf Club weather station for a day was 90mm in February 2002.

4.5 Water Requirements

The water requirements are for the irrigation of the nearby flower farm.

4.6 Dam Embankment

The dam embankment is homogeneous materials including clay with minor/some sand excavated from the reservoir area. In 2017 some additional Sandy Clay material was added to widen the crest of the dam wall. This material has been well compacted based on the 2017 observations. On the outer edge of the walls there has been some loose material placed. The thickness of this loose material was estimated to be 0.2m to 0.5m. It was concluded the loose material has no impact as the structural integrity of the dam wall.

4.7 Dam Construction

It has been assumed that dam embankment continues the same slope of the observed wall to a depth of 3m below ground levels inside the reservoir. It is believed that after the floor of the dam was stripped of topsoil (no unsuitable material was found in the geotechnical investigation of the walls of the dam, the CLAY was excavated to be used for the walls of the dam.

4.8 Inlet Pipe

Several inlet pipes were observed in front of the western embankment. The water is sourced from the Black Rock Treatment Plant which transfers treated water into the dam, stormwater from the Sands golf course and from 3 other locations away from the dam. The flow of water can be stopped at any time using the valves in the pump house.

4.9 Outlet Pipe

Several outlet pipes transfer the dam water using pumps to the agricultural site.

4.10 Spillway

No spillway is constructed for the dam.

4.11 Field Assessment

A field assessment was undertaken on the 8-9th November 2017 for the purpose of assessing the dam in relation to the structural integrity. The walkover survey viewed the entire dam are and surrounding property. Photos of the site indicating the site area and dam were taken to assist in the assessment. This was repeated in October and November 2020 after the leak incident.

4.11.1 Seepage/Leakage

No evidence of seepage or leakage of the dam was observed in 2017. A recent incident occurred in October 2020 with water leaking into two neighbouring properties through a decommissioned pipe. The pipe was used prior to 2015 to transfer the water to a treatment plant immediately southwest of the dam. After the decommissioning of the treatment plan the transfer pipe was left inside the embankment without any capping. After raising the reservoir water level, the pipe collar was submerged directing the reservoir water into the neighbouring properties. This was identified by SRW and the pipe was capped.

4.11.2 Erosion

Minor erosion is observed due to wave action on the internal side of the embankments. The outer surface is mostly grassed.

4.11.3 Deformation/Movement

No evidence of deformation or movement of the dam was observed in 2017 and 2020 inspections which could indicate slope instability or presence of sinkholes in the embankment or foundation.

4.11.4 Shrinkage/Cracking

Occasional shrinkage and cracking are observed in the surface material along the crest of the wall and the outer wall of the dam. This cracking was predominantly observed in the recent material that was placed but has a limited depth of few centimetres.

4.11.5 Trees

Trees were observed along the inner wall of the dam. These trees are estimated to be on the wall for at least 15 years within no detrimental effect on the structural integrity of the dam wall. No evidence is found of the trees having structural detrimental effect on the dam. Some pine trees on the eastern side of the dam were observed either dead or dying. This is due to placement of over 2m of fill against the tree trunk. However, these are outside the embankment and should not have any impact on the dam structure. These trees are recommended to be removed and inspections to be carries out to ensure no leakage is occurring due to dying tree roots.

5. Site Investigation

Two site investigations were carried out in 2017 and 2020. The first field investigation was undertaken on 8 and 9th December 2017 which involved a site inspection and drilling of 8 boreholes to depths ranging between 6.5m and 9.0m from the embankment crest. A second investigation was carried out on 13th November 2020 to obtain more information from the embankment foundation. Four (4) boreholes were drilled to a maximum depth of 6m and standpipe piezometers were installed in the boreholes with screens ranging from 2.8m to 5.8m depth below the ground level. Engineering logs during both investigations are presented in Appendix A. The embankment and foundation materials were found to be fairly consistent across all investigation points.

5.1 Boreholes Profile

Table 3.1 presents a summary of subsurface profile for the 8 boreholes drilled from the crest of the dam in 2017.

Table 3.1 – Summary of Subsurface Profile – Boreholes Drilled from Crest in 2017

Material	Depth (m)			
	BH 1	BH 2	BH3	BH4
Fill, Sandy Clay	0-7.05	0-6.1	0-6.1	0-7.5
Sandy CLAY	7.05-8.0	6.1-6.5	6.1-6.5	7.5-8.5
Total Depth	8.0	6.5	6.5	8.5

Continued - Table 3.1 – Summary of Subsurface Profile – Boreholes Drilled from Crest in 2017

Material	Depth (m)			
	BH5	BH6	BH7	BH8
Fill, Sandy Clay	0-7.5	0-6.8	0-2.9	0-7.1
FILL, Clayey Sand			2.9-3.1	
Fill, Sandy Clay			3.1-6.5	
FILL, Clayey Sand			6.5-8.0	
Sandy CLAY	7.5-8.5	6.8-7.5	8.0-9.0	7.1-7.5
Total Depth	8.5	7.5	9.0	7.5

Table 3.2 presents a summary of subsurface profile for the 4 boreholes drilled at the toe of the embankment in 2020.

Table 3.2 – Summary of Subsurface Profile – Boreholes Drilled at Embankment Toe in 2020

Material	Depth (m)			
	BH 1-2020	BH 2-2020	BH3-2020	BH4-2020
Fill, Silty Sand/Clay	0-0.3m	0-0.8m	0-0.2m	0-0.4m
CLAY	0.3-5.0m	0.8-4.2m	0.2-2.0m	0.4-6.0m
Sandy CLAY	5.0-6.0m	4.2-6.0m	2.0-6.0m	-
Total Depth	6.0m	6.0m	6.0m	6.0m

5.2 Groundwater

Groundwater was not encountered inside the boreholes drilled from the dam crest in 2017. Groundwater was encountered in BH1 and BH4 at between 5.0m and 5.5m below the ground level at the embankment toe in the investigation carried out in 2020. The groundwater raised in BH1 to 3.3m below ground level and stabilised there indicating presence of 2m artesian pressure that could be related to the pressure applied to the groundwater from the reservoir water.

6. Field and Laboratory Testing

Field testing comprised Standard Penetration Tests (SPT) tests at boreholes at various depths. Laboratory testing comprised 35 moisture content tests, 7 sieve analyses, 7 Atterberg Limits tests, 5 Permeability Tests and 10 Emerson Tests. Additional moisture content, Emerson class and fine content laboratory testing was completed on the foundation materials recovered from boreholes drilled in November 2020.

A summary of the results obtained is shown within Table 5.1 below. NATA Test Certificates for each of the laboratory tests are attached as Appendix C.

Table 5.1 – Soil Laboratory Test Results

Location	Layer Depth From (m)	Layer Depth To (mm)	Material	USC (AS1726)	Moisture Content (%)	Permeability ($x10^{-9}$)	Emerson	Maximum Dry Density	OMC	Liquid Limit	Plasticity Index	Linear Shrinkage (%)	(%) Passing			
													0.075mm	0.425mm	2.36mm	19.0mm
BH1	1.0		Sandy Clay		19.1											
	2.0		Sandy Clay		18.7											
	3.0		Sandy Clay		25.4											
	3.0	4.0	Sandy CLAY	CH						58	36	12.5	57	82	93	100
	4.0		Sandy Clay				4									
	5.0		Sandy CLAY		31.8	$2x10^{-10}$										
	6.0		Sandy Clay		22.7											
	6.0	7.0	Sandy CLAY	CI	20.2					39	21	10.0	60	83	94	100
	7.0		Sandy Clay		14.3											
	8.0		Sandy Clay		22.7											
BH2	1.0		Sandy Clay		23.7											
	2.0		Sandy Clay		19.0											
	3.0		Sandy Clay		23.0											
	4.0		Sandy Clay		31.2											
	5.0		Sandy Clay		32.0											
	6.0		Sandy Clay				4									
	8.0		Sandy Clay													
BH3	1.0		Sandy CLAY		20.0											
	2.0		Sandy CLAY		23.2											
	3.0		Sandy CLAY				4									
	3.0		Sandy CLAY		26.7											
	4.0		Sandy CLAY													

Location	Layer Depth From (m)	Layer Depth To (mm)	Material	USC (AS1726)	Moisture Content (%)	Permeability ($x10^{-9}$)	Emerson	Maximum Dry Density	OMC	Liquid Limit	Plasticity Index	Linear Shrinkage (%)	(%) Passing			
													0.075mm	0.425mm	2.36mm	19.0mm
BH3	5.0		Sandy CLAY		29.5											
	6.0		Sandy CLAY		27.9											
BH4	1.0		Sandy CLAY		18.6											
	2.0		Sandy CLAY				4									
	3.0	4.0	Sandy CLAY	CI	27.5		4			55	31	14.0	72	87	93	100
	4.0		Sandy CLAY		13.4	$4x10^{-11}$										
	5.0		Sandy CLAY		23.9											
	6.0		Sandy CLAY		27.4											
	7.0		Sandy CLAY		32.3											
	8.0		Sandy CLAY													
BH5	1.0		Sandy CLAY		20.6											
	2.0		Sandy CLAY		7.0											
	3.0		Sandy CLAY				4									
	4.0		Sandy CLAY		21.6											
	5.0		Sandy CLAY		29.0											
	6.0		Sandy CLAY				4									
	7.0		Sandy CLAY		28.4	$3x10^{-10}$										
	6.0	7.0	Sandy CLAY	CH						52	29	12.5	75	91	98	100
	7.0		Sandy CLAY													
	8.0		Sandy CLAY		20.7											
BH6	2.5	6.0	Sandy CLAY	CH						51	32	14.0	65	88	96	100
	6.6	8.0	Clayey Sand	SC		$5x10^{-6}$	4	1.904	10.7	31	19	7.0	32	77	100	100
BH8	1.0		Sandy CLAY		15.4											
	2.0		Sandy CLAY				4									
	2.5	4.0	Sandy CLAY	CH						50	32	14.0	58	81	92	100
	3.0		Sandy CLAY		23.3.	$1x10^{-10}$										
	4.0		Sandy CLAY		18.0											
	5.0		Sandy CLAY		26.1											
	6.0		Sandy CLAY				4									
BH8	7.0		Sandy CLAY		32.3											

Notes: DCP: Dynamic Cone Penetrometer; CBR: California Bearing Ratio; OMC: Optimum Moisture Content

7. Rainfall Data

The following is a summary of the rainfall data for the Torquay Golf Club.

Year	Month	Maximum Daily Rainfall
2002	2	90
2005	2	88.4
2001	4	70
1987	12	61.2
1978	11	58.6
2001	3	56
1981	5	55.4
2001	4	50
2010	3	48
1988	11	45
1988	1	42
1989	3	40.6
1981	10	40.4
1987	10	39.2
2005	8	39.2
1977	5	38.6
2004	11	38.2
1989	4	38
2000	10	38
2008	12	37.4

8. Inundation Mapping

A hydraulic modelling was carried out to estimate the extent of the inundated area in a dam breach event. This is presented in detail in AGT's report "AGTE20249-4 Torquay Farm Dam - Dam Break Analysis" where the depth and velocity of the flood was calculated on the downstream of the dam.

Based on the guidelines prepared by Victorian state government - Department of Environment, Land, Water and Planning (DELWP) in "Guidelines for Development in Flood Affected Areas February 2019":

People attempting to enter or leave a property during a flood should not be endangered by deep or fast-flowing water. This includes emergency response personnel, property occupants and visitors.

The areas of most interest are:

- around building envelopes
- at entrance and exit points to buildings
- along driveways and internal connecting routes to outbuildings and car parking
- along external connecting routes leading to safety.

Table 1 shows the thresholds applying for the three categories.

Table 8.1: Thresholds for safety of children, small cars and light buildings

Source: Adapted from Australian Rainfall and Runoff

Category	Maximum depth (D), velocity (V) and product (VD)		
	D max metres	Vmax Metres/second	VD max Metres²/second
Children	0.5	3.0	0.4
Small cars	0.3	3.0	0.3
Light buildings	2.0	2.0	1.0

The dam breach and subsequent inundation were analysed using HEC-RAS 2D finite element modelling. Two scenarios were considered including:

- A dam breach at the centre of south embankment with water level at RL14 mAHD
- A breach at the southwest corner of the dam with a reservoir water level of RL12 mAHD.

Figure 2 shows the extend of inundation area with maximum water depth for the Scenario with RL14m AHD reservoir water level. The water level reaches a maximum of 800mm in this scenario.

Figure 3 shows additional modelling where the breach location is on the southwest corner of the dam and the operating level is at RL12 mAHD. The maximum depth of flood in the nearby properties reaches 350mm in this scenario.

Based on the above map there are between 400 to 600 properties that could be affected due to a dam break with a reservoir water level of RL14 mAHD.

Figure 2 –Maximum Depth of Flood Water Level (metres)- Reservoir Water Level at RL14

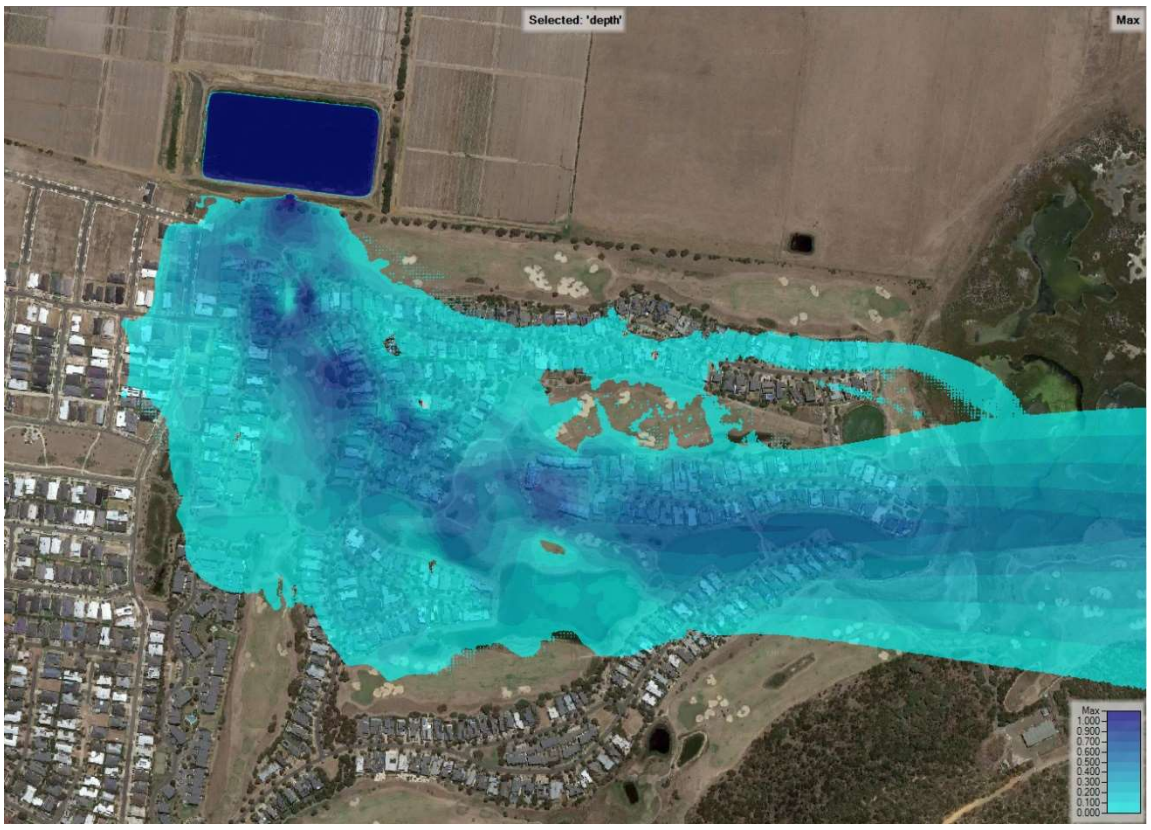
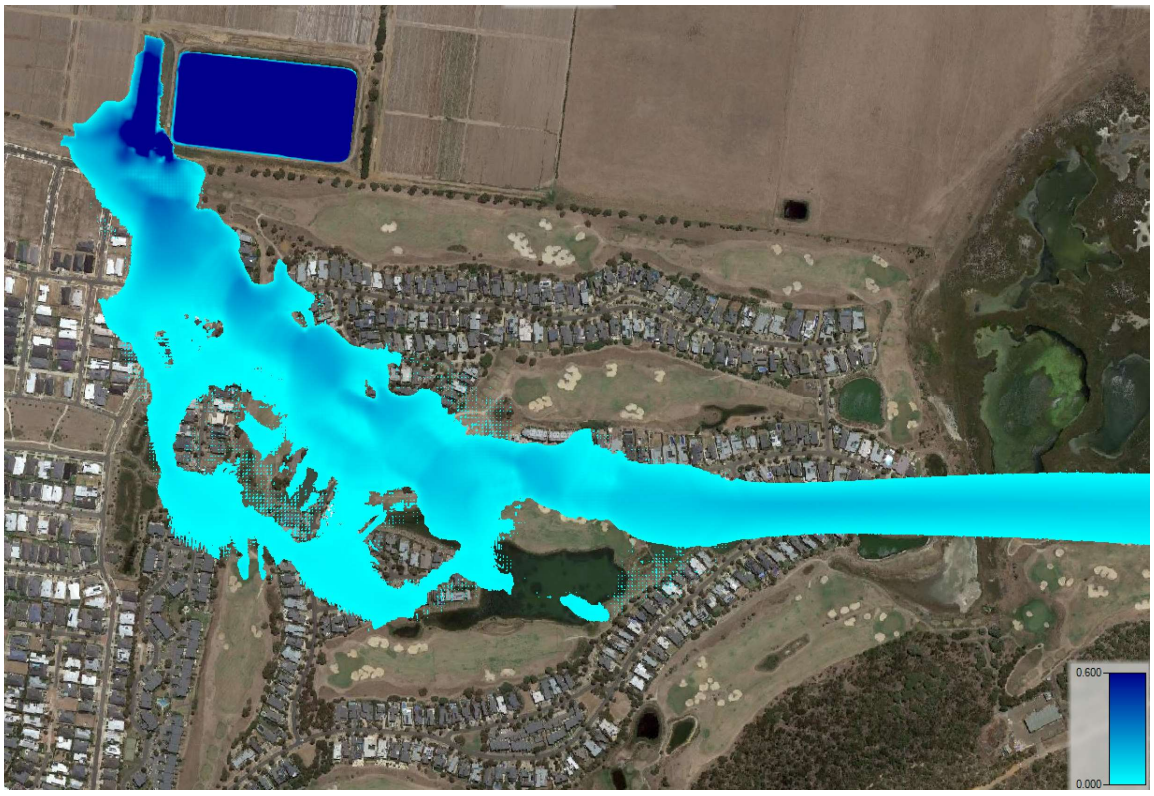


Figure 3 –Maximum Depth of Flood Water Level (metres) - Reservoir Water Level at RL12



9. Dam Safety Assessment

9.1 Modes of Failures

The initial failure mode analysis based on ANCOLD Guideline is undertaken as per following table.

Failure Mode	Initiating Event	Mechanism or sub event
Overtopping	*Flood*	*Inadequate spillway – design failure, human error or mechanical failure of pump control* *Spillway blockage,* *Spillway flow erodes embankment toe, resulting in slope failure loss of freeboard.*
	Earthquake	*Liquefaction - slope failure,* *Slope failure - loss of freeboard.*
	Fire, snow, ice, power failure	*Prevents operation of spillway or reservoir outlet.*
	Intrinsic	*Slope failure reduces freeboard,* *Excessive consolidation of embankment or foundation material.*
	Wind	*Seiche and inadequate freeboard,* *Inadequate riprap, waves erode through embankment crest and no monitoring,* *Prevents operation of spillway gates.*
	Reservoir rim slope failure	*Landslide generated wave.*
	Impact of an object	*Removes part of crest.*
	Human error	*Maloperation of reservoir.*
	Terrorism, sabotage	*Removes part of crest.*
Sliding / overturning	*Flood*	*Load exceeds sliding resistance at base or at joints of structure,* *Erosion at toe reduces base width.*
	Earthquake	*Load exceeds sliding resistance at base or at joints of structure.*
	Intrinsic	*Load exceeds sliding resistance at base or at joints of structure.* *Drain blockage, increased pore pressure, no surveillance.*
Internal Erosion	*Flood*	*Increased hydraulic gradient, inadequate filters.*
	Seismic	*Cracking,* *Differential settlement,* *Liquefaction,* *Opening of interface between construction materials, e.g. concrete / earthfill,* *Outlet pipeline rupture.*
	Intrinsic	*Internal cracking, hydraulic fracture, differential settlement and lack of adequate filters,* *Dispersive soils and lack of adequate filters,* *Outlet pipeline failure,* *Open foundation joints and lack of adequate filters.* *Root channels and animal / insect holes from pipes through embankment.*
	Operation	*Sudden rise in reservoir level causes flow through transverse cracks in earthfill.*
Erosion	*Flood*	*Spillway channel erodes back into reservoir.*

The applicable modes of failure for the dam are further assessed in the following sections.

9.2 Potential for Piping Failure

9.2.1 Piping Failure Factors

The main details of the Torquay farm dam are presented at the front of this report. Based on the AGT site investigation results, it is evident that the embankment is essentially composed of homogeneous earthfill and does not include any filters or cutoffs. The location of the inlet and outlet pipes in the embankment above full supply level results in a low risk of piping failure along the pipeline / backfill interface under normal operating conditions. However, during times of high reservoir level, above FSL, the risk could be high, depending on the details of the pipework and the backfill details. These pipes include the one that was the cause of the leakage incident in October 2020. The other pipe is located in the middle of west embankment that is not currently used. No details of the pipework are available. Ideally the pipework should have welded joints within the embankment and be concrete encased.

It is unknown what compaction control existed during the construction of the dam, however initial SRWSC report indicates good compaction of embankment. The site investigation did identify the embankment consistency typically ranging between stiff to very stiff clay with no evidence of any wet materials/layer in the embankment. The wet materials in the foundation were also at least 5m deep.

The embankment is constructed from a medium plasticity clay with varying quantities of sand (the sand content is not high to make the soil permeable). No depressions such as “jug and tunnel” or other signs are visible that may indicate susceptibility to piping. The Emerson Crumb and Percent dispersion laboratory test results identified the embankment materials as being “Partially Dispersive” and “marginally susceptible to dispersion” to “susceptible to dispersion” respectively.

With regards to assessing the likelihood of major piping failures, the embankment materials were assessed in terms of *Sherard et. al.* (*1963*). The plasticity index varied from 19-36% and linear shrinkage from 7.0-14.5%, indicative of a low to moderate potential for transverse cracking to occur through the embankment due to shrinkage or drying out. According to *Sherard et. al.* (*1963*, the grading of the embankment material generally falls outside the danger envelope for susceptibility to strain-induced cracking. The embankment did not show any sign of differential settlement.

The foundation of the dam to 5m depth is clay. Clayey sand/sandy clay is present below this depth where wet layer is encountered.

Small trees were observed during the site inspection to be growing on the embankment. If the trees continue to grow and the tree root system develops there is potential for the roots to provide paths for potential pipes at a time when the trees are removed and the roots die leaving voids. It recommended to prevent any further trees growing on the embankment.

9.2.2 Assessed Piping Potential

As discussed above, evidence of piping and related dispersive processes were not identified during the AGT site investigation both in the dam foundation and within the embankment. However, as the embankment does not have a filter zone to control piping nor even a foundation cutoff, an assessment has been carried out to estimate the likelihood of piping failure .

In addition, depending on the nature and condition of the outlet and inlet pipework through the embankment crest, piping failure could be initiated by increased seepage during high reservoir levels along the pipeline / backfill interface. If piping were to occur along the interface it is more likely to occur below the lower quadrant of the pipeline where compaction of clay fill is difficult.

A further risk, again depending on the location, nature and condition of the outlet and inlet pipework, is a burst pipe joint during normal pumping operation which could lead to an embankment breach.

Piping failure of the embankment, whether due to the piping through the foundation, embankment or along the inlet or outlet pipework is most likely during elevated reservoir levels. For this reason the normal operating level should be reduced.

The calculation takes into account the historic probability of piping failure for various types of dams as presented below.

Average probabilities of failure of embankment dams by internal erosion and piping (Foster et al., 1998, 2000a).

	Embankment			Foundation			Embankment into foundation		
		Average annual P_e ($\times 10^{-6}$)			Average annual P_f ($\times 10^{-6}$)			Average annual P_{ef} ($\times 10^{-6}$)	
Zoning category	Average P_{Te} ($\times 10^{-3}$)	First 5 years operation	After 5 years operation	Average P_{Tf} ($\times 10^{-3}$)	First 5 years operation	After 5 years operation	Average P_{Tef} ($\times 10^{-3}$)	First 5 years operation	After 5 years operation
Homogeneous earthfill	16	2080	190						
Earthfill with filter	1.5	190	37						
Earthfill with rock toe	8.9	1160	160						
Zoned earthfill	1.2	160	25						
Zoned earth and rockfill	1.2	150	24						
Central core earth and rockfill	(<1.1)	(<140)	(<34)	1.7	255	19	0.18	19	4
Concrete face earthfill	5.3	690	75						
Concrete face earthfill	(<1)	(<130)	(<17)						
Puddle core rockfill	9.3	1200	38						
Earthfill with corewall	(<1)	(<130)	(<8)						
Rockfill with corewall	(<1)	(<130)	(<13)						
Hydraulic fill	(<1)	(<130)	(<5)						
All dams	**3.5**	**450**	**56**	**1.7**	**255**	**19**	**0.18**	**19**	**4**

1. P_{Te}, P_{Tf} and P_{Tef} are the average probabilities of failure over the life of the dam.
2. P_e, P_f and P_{ef} are the average annual probabilities of failure.

Table 9.2.2 presents a detailed risk assessment for piping with the details presented in Appendix B.

Table 9.2.2 Piping Risk Assessment for Foundation, Embankment And Their Interface

Torquay Farm Dam - AGTE20249

Piping Failure of Torquay Dam

Dam Type: **Homogeneous Earthfill**

Type of Failure: **Embankment**

Average Probability of failure over the life of the dam
All Years of Operation = 2.07E-02

Average Annual Probabilities of Failure

First 5 Years of Operation = 2.70E-03

After 5 Years of Operation = 2.46E-04

Piping Characteristics	
Embankment Filter WE (filt)	*No embankment filter (for dams which usually have filters)*
Core Geology Origin WE(cgo)	*Alluvial*
Core Soil Type WE (cst)	*High plasticity clays*
Compaction WE(cc)	*Rolled, modest control*
Conduits WE(con)	*Conduit through the embankment - some poor details*
Foundation Treatment WE(ft)	*0*
Observations of Seepage WE(obs)	*Leakage measured none or very small*
Monitoring and Surveillance WE(mon)	*Inspections Monthly*

Associated Multiplier incorporated into above Failure Probabilities= **1.296**

Type of Failure: **Foundation**

Average Probability of failure over the life of the dam
All Years of Operation = 8.81E-03

Average Annual Probabilities of Failure

First 5 Years of Operation = 1.32E-03

After 5 Years of Operation = 9.85E-05

Piping Characteristics	
Filters WF (filt)	*No Foundation filter present when required*
Foundation Type (below cutoff) Wf (fnd)	*Soil Foundation*
Cutoff Type (Soil foundation) (cts)	*Shallow or no cutoff trench*
Soil Geology Types (below cutoff) WF(sg)	*Alluvial*
Observations of Seepage WE(obs)	*Leakage steady, clear, or not observed*
Monitoring and Surveillance WE(mon)	*Weekly - monthly seepage monitoring, weekly inspections*

Associated Multiplier incorporated into above Failure Probabilities= **5.184**

Type of Failure: **Embankment through Foundation**

Average Probability of failure over the life of the dam
All Years of Operation = 6.07E-05

Average Annual Probabilities of Failure or Accident

First 5 Years of Operation = 6.40E-06

After 5 Years of Operation = 1.35E-06

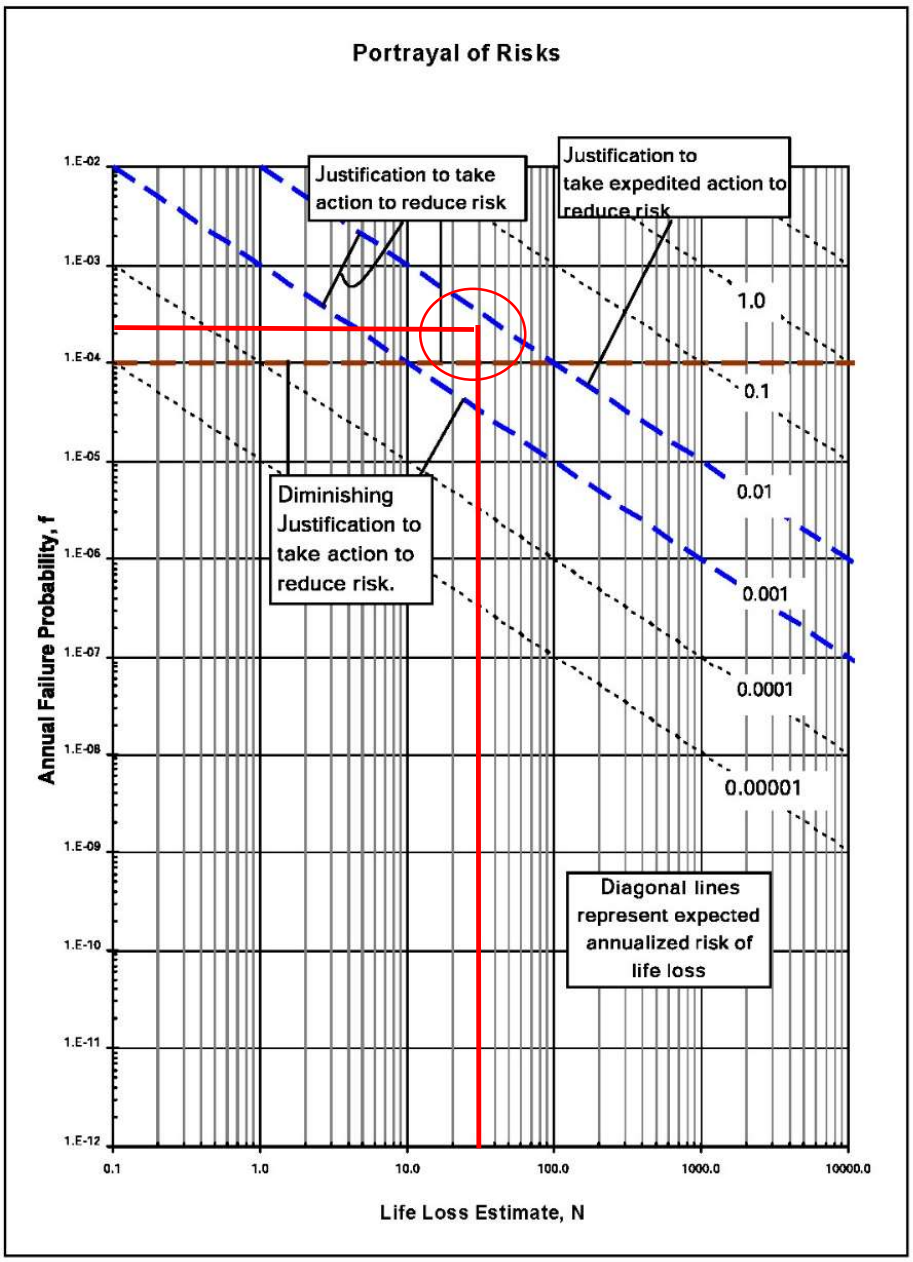
Piping Characteristics	
Foundation cutoff trench WEF (cot)	*Average cutoff trench width and depth*
Foundation Type WEF(fnd)	*Founding on or partly on rock foundations*
Erosion Control Measures of Core Foundation WEF(ecm)	*Good erosion control measures present and good foundations*
Grouting of Foundations	*No grouting on rock foundations*
Soil Geology Types (below cutoff) WF(sg)	*Granite, Andersite,Gabbro,Gneiss*
Core Geology Origin WE(cgo)	*Aeolian, Colluvial*
Core Soil Type WE (cst)	*Low Plasticity clays (CL)*
Foundation Treatment WE(ft)	*Careful slope modification by cutting, filling with concrete*
Observations of Seepage WE(obs)	*Leakage steady, clear or not monitored*
Monitoring and Surveillance WE(mon)	*Weekly - monthly seepage monitoring, weekly inspections*

Associated Multiplier incorporated into above Failure Probabilities= **0.33696**

NOTE: No dams of this design have failed, average probabilities are used

As shown in Table 8.2.2 the highest piping risk is in the embankment and calculated to be 2.46 x 10^{-4} after 5 years of operation. USBR provides the following graph to provide guidance on relating the risk and potential loss of life to the actions required to improve the safety of the dam. With a potential loss of life of 30 or more and considering the probability of embankment piping failure of 2.46 x 10^{-4} the action is deemed to be between "Take Action" and "Take expedited action" to reduce risk.

- The f-N Chart for Displaying Probability of Failure, Life Loss, and Risk Estimates



9.3 Liquefaction Assessment of Foundation

One of the primary issues relating to the effect of earthquakes on dams is whether liquefaction of the dam or foundation may occur, and if so, what the consequences may be. Historically, liquefaction has been the major cause of dam failures due to earthquake.

Liquefaction (or cyclic mobility) denotes a condition where a soil deposit will undergo continued deformation at a constant low residual stress, due to the build up and maintenance of high pore water pressures. The three primary factors controlling the development of cyclic mobility or liquefaction are:

- character of ground motion (the intensity, number of cycles, duration);
- soil type (gradation, relative density etc); and
- in situ stress conditions (confining pressure).

In general terms, uniformly graded cohesionless soils have a higher susceptibility to liquefaction than the well graded materials. Saturated sands, silty sands, silts and gravelly sands are known to be susceptible to liquefaction. Generally the presence of fines (silt and clay passing 0.075 mm sieve) reduces the liquefaction potential of materials.

9.3.1 Liquefaction Potential of Materials

The AGT boreholes encountered thick layers of dry clay in the embankment and foundation. The investigation results indicate that a significant proportion of the embankment foundation consists of very low permeability clay layer with insignificant liquefaction potential.

9.3.2 Liquefaction Assessment

The potential for liquefaction to occur within the soil horizons of the dam foundation was assessed in accordance with the procedures recommended by ANCOLD. This is a preliminary assessment based on one representative sample soil consistency. The site investigation found that the clay content was high and consistent across the embankment and foundation of the dam. This liquefaction assessment has been undertaken using the following methods:

- Geological Considerations;
- The so-called 'Chinese Criteria', as defined by Seed and Idriss and reported in Youd et al were used to assess a laboratory test result of a representative sample for the saturated sands. These criteria state that liquefaction cannot occur unless all three of the following conditions are met:
  - The clay content (particles smaller than 5μm) is less than 15% by weight;
  - The liquid limit is less than 35%; and
  - The natural moisture content is more than 0.9 times the liquid limit.

9.3.3 "Chinese Criteria" Assessment

All representative samples from boreholes were selected for laboratory testing for comparison with the three criteria listed above.

The results of the assessment show that in accordance with the Chines Criteria, the gradings of the materials within the embankment were not susceptible to liquefaction.

9.4 Slope Stability Assessment (Embankment Failure Mode)

An extract of the AGT 2017 is presented below for slope stability analysis.

9.4.1 Geotechnical Material Properties

Table 5.1 presents geotechnical material properties for slope stability. Table 5.2 also presents the safety factor calculated in the analysis indicating slope instability is unlikely. The Slope/W Assessment were undertaken on the existing and worst case scenario with the water raising to the top of the crest level.

Table 5.1 Geotechnical Material properties

Material	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (°)
Sandy CLAY	20	10	25
Clayey Sand	18	2	30

Table 5.2 Slope/W Results

Material	Section	Dam Level	Embankment Slope	Factor of Safety	Assessment
Sandy Clay	A-A	Existing	1:3.5	2.772	Stable
Sandy Clay	A-A	Crest	1:3.5	2.772	Stable
Sandy Clay	B-B	Existing	1:3.7	2.999	Stable
Sandy Clay	B-B	Crest	1:3.7	2.977	Stable
Sandy Clay	C-C	Existing	1:3.3	2.975	Stable
Sandy Clay	C-C	Crest	1:3.3	2.923	Stable
Sandy Clay	D-D	Existing	1:2.6	3.367	Stable
Sandy Clay	D-D	Crest	1:2.6	3.367	Stable
Sandy Clay/Clayey Sand	E-E	Existing	1:1.9	1.953	Stable
Sandy Clay/Clayey Sand	E-E	Crest	1:1.9	1.963	Stable

9.5 Overtopping of Embankment

Although there is no natural catchment for the dam, there is risk of overfilling resulting in overtopping of the dam and embankment failure. This could be due to miscommunication, equipment failure and unforeseen scenarios where the overfilling may occur. Currently there is no spillway to prevent this. Two options is proposed as spillway:

- Using the sump pipe and extend it to a desired level inside the reservoir to act as an overflow spillway.
- Excavation of a channel on the embankment to act as a traditional spillway.

10. Hazard - Consequences Assessment

A formal consequence assessment had not been carried out on the dam. AGT inspected the potential downstream inundation zone and has estimated the consequences of failure of the dam. A worst case scenario, where a large breach in the south embankment forms in 15 minutes, was considered which takes the flow into the new developments around the Sands golf course. It was estimated the Population At Risk (PAR) to be greater than 100. The severity of Damage and Loss from a breach is estimated as being Medium. A Hazard Category of **'High B'** is therefore estimated for the dam based on "ANCOLD Guidelines on Assessment of the Consequences of Dam Failure" (as detailed in the table blow). An uncontrolled release has the potential to cause loss of life.

Applicant Name	*I. C. & J. SANTOSPIRITO*					
Stream Name	*NA*					
Estimated Capacity at FSL	*140*					
Dam ID. No. (If existing dam)						
Dam Height (metres)	*8* **M**					
Location	*1075 Horseshoe Bend Road, TORQUAY*					
Damage and Loss	**Estimate**	**Severity Level**				
		Minor	*Medium*	*Major*	*Catastrophi*	
B1 TOTAL INFRASTRUCTURE COSTS						
Residential	<$10M	YES	.	.	.	
Commercial	<$10M	YES	.	.	.	
Community Infrastructure	<$10M	YES	.	.	.	
Dam repair or replacement cost	<$10M	YES	.	.	.	
Total Infrastructure cost severity level	**MINOR**					
B2 IMPACT ON DAM OWNER'S BUSINESS						
Importance of the system, need to replace the dam	Restrictions needed during dry periods	YES	.	.	.	
Effect on services provided by owner	Reduced services are possible with reasonable restrictions	.	YES	.	.	
Effect on continuning credibility	Exterme discontent	.	.	YES	.	
Community reaction and political implications	Some reaction but short lived	YES	.	.	.	
Impact on financial viability	Significant with considerable impact in the long term	.	YES	.	.	
Value of water in the storage	Can be absorbed in one financial year	YES	.	.	.	
Impact on dam owner' business severity level	**MAJOR**					
B3 HEALTH AND SOCIAL IMPACTS						
Human health	100 to 1,000 people affected	.	YES	.	.	
Loss of services to the community	<100 people affected	YES	.	.	.	
Cost of emergency management	<1,000 person days	YES	.	.	.	
Dislocation of people	100 to 1,000 person months	.	YES	.	.	
Dislocation of businesses	<20 business months	YES	.	.	.	
Employment affected	<100 jobs lost	YES	.	.	.	
Loss of heritage	Local facility	YES	.	.	.	
Loss of recreational facility	Local facility	YES	.	.	.	
Health and Social severity level	**MEDIUM**					
B4 ENVIRONMENTAL IMPACTS						
Area of impact	1 km2 to < 5 km2	.	YES	.	.	
Duration of impact	< 1 year	YES	.	.	.	
Stock and fauna	Discharge from dambreak would not contaminate water supplies used by stock and fauna.	YES	.	.	.	
Ecosystems	Discharge from dambreak is not expected to impact on ecosystems. Remediation possible.	YES	.	.	.	
Rare and endangered species	Species exist but minimal damage expected. Recovery within one year.	YES	.	.	.	
Environmental impacts severity level	**MEDIUM**					
Highest severity level	**MAJOR**					

Reasons for recommending a consequence category (refer ANCOLD Guidelines On The Consequence Categories For Dams October 2012) MUST include comments on the PAR (both permanent and itinerant), buildings, roads, other infrastructure and the natural environment downstream of the dam and the potential impacts arising from a dam break: ***(** Note** Provide photographs to support reasons for recommending consequence category)***

Population at Risk (PAR) ≥10 to <100	**CONSEQUENCE CATEGORY =**	**High B**

PAR includes all those persons who would be directly exposed to flood waters within the dam break affected zone if they took no action to evacuate

Note 1: With a PAR in excess of 100, it is unlikely damage will be minor, similarly with a PAR in excess of 1,000 it is unlikely damage will be classified as medium
Note 2: Change to 'High C' where there is a potential of one or more lives being lost

Completed By	*Amir Farazmand*
Date	*25-Jan-21*

11. Conclusions and Recommendations

Conclusions drawn throughout the report are summarised below along with recommendations for further actions needed.

11.1 Conclusions

1. The dam comprises a homogenous embankment without filter in the embankment and foundation. This type of the dam is generally susceptible to piping when no filter is used. However, a long history of the dam has not indicated any sign of piping in the in the embankment or its foundation.
2. The leakage in October 2020 was identified to be due a decommissioned pipe left in the embankment. This pipe is currently capped, and the operating water level is below the pipe collar at RL12mAHD.
3. The embankment material was found to consist of stiff to very stiff, medium to high plasticity clays. No excessively wet material was found in 2017 geotechnical investigation. Additional investigation of foundation material was carried out in 2020 with 4 piezometer installed to 5.5m depth. Stripping of topsoils from the beneath the embankment was also apparent.
4. The foundation materials consist of residual medium to high plasticity clays greater than 5.0 m depth. This is underlain by clayey sand/sandy clay below 5.0m depth. No wet material or sign of seepage was identified above 5.0m depth.
5. Groundwater was encountered in the foundation at 5m depth with long term level reaching to 3.3m and stabilising there.
6. All materials found in the investigation have been assessed as non-liquefiable.
7. The likelihood of an uncontrolled release from a piping failure and its estimated inundation area is modelled in a dam break scenario and reported in the AGTE20249-4 Rev 1 report.

11.2 Recommendations

1. Provision of a pipe spillway is recommended to ensure overfilling of the dam is controlled and to meet ANCOLD guidelines for the dam category. The pipe is recommended to be installed at 1m below the reservoir full service level. The spillway should be installed as soon as practicable to bring the dam in line with ANCOLD requirements.
2. While the initial operating level was at RL14 mAHD, the client has indicated to operate at a lower level to reduce the risk and operating cost of the dam. We propose a meeting to be held by SRW to discuss the future operation of the dam and any likely upgrade required and discussion of operating the reserboir at a lower level such as RL12 mAHD.
3. Installation of additional standpipe piezometers is recommended in the embankment.
4. Installation of full or partial filter on the embankment is recommended to strengthen the embankment further proportion to the risk associated with a “High B” dam category.
5. Inspections and monitoring of the dam should be completed in accordance with ANCOLD Guidelines on Dam Safety Management (2003) for a High B hazard dam.
6. These works should be added to client’s portfolio of risk mitigation works and completed in the appropriate order, however commencement of the work should not be left longer than 6 months.
7. Consider installation of filters and seepage collection around the sump pipe to intercept any seepage that may indicate of piping.

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Disclaimer

The findings and conclusions contained in this Report are made based on site conditions that existed at the time this work was conducted. The conclusions presented in this report are relevant to the conditions of the site and the state of legislation currently enacted as at the date of this report.

Findings and conclusions are made assuming that the soil, groundwater, geological and chemical conditions detailed within this report are accurate and remain applicable to the site at the time of writing. No other warranties are made or intended.

AGT has used a degree of skill and care ordinarily exercised by reputable members of our profession practicing in the same or similar locality.

does not make any representation or warranty that the conclusions in this report will be applicable in the future as there may be changes in the condition of the site, applicable legislation or other factors that would affect the conclusions contained in this report.

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Appendix A

Borehole Location and Logs

Figure A1 - Borehole Locations for Site Investigation in December 2017:

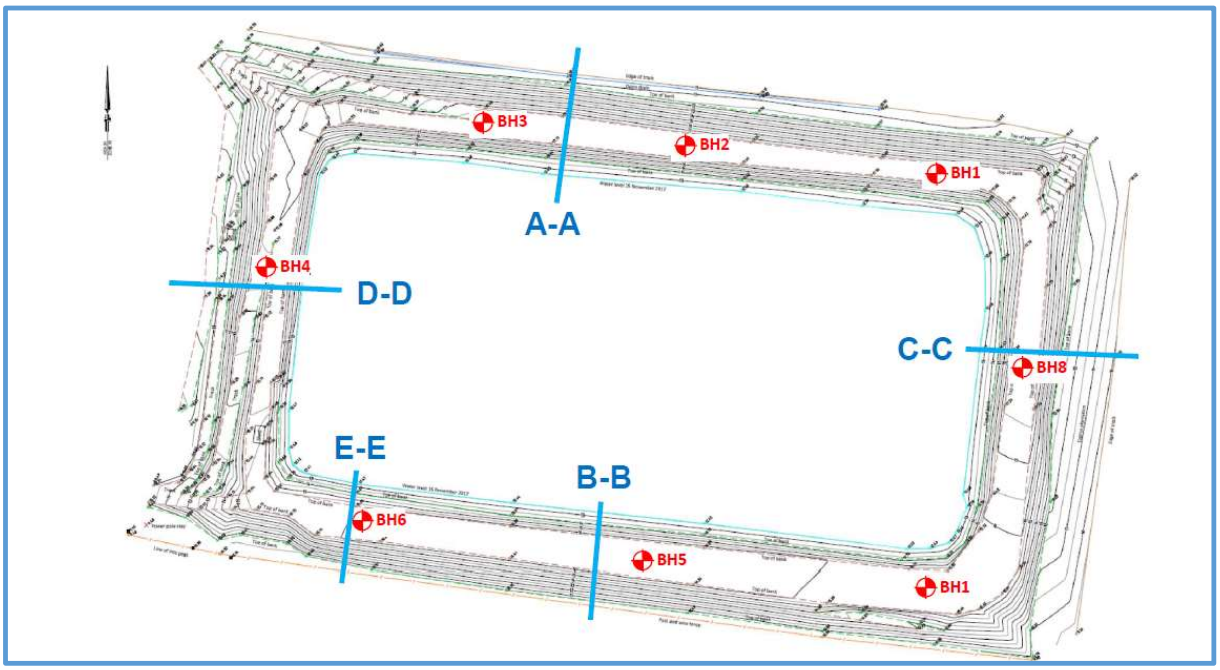

Figure A2 - Borehole Locations for Site Investigation done on 13th November 2020:

BOREHOLE LOG

BORE No: 01-2020

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Client:	The Dunes Torquay	Drilling Co:	AGT	Easting:	-38.3042
Project:	Torquay Dam	Driller:	AF	Northing:	144.34676
Job No:	AGTE20249	Rig Type:	GT10	Grid Ref:	
Location:	1075 Horseshoe Bend Rd, Torquay	Inclination:		Collar RL:	
Date Drilled:	13/11/20	Bearing:		Logged by: MF	Checked by: AF

Test Method: AS 1289.6.3.2-1997 & AS 1726-1993

Depth (m)	Drilling Method	Graphic Log	Group Symbol	MATERIAL DESCRIPTION Type, colour, particle size and shape, structure	Moisture	Consistency / Density	N-DCP Blows per 100mm	FIELD TESTS	Sampling / Runs	Water Levels	Depth (m)
0.00			SM	silty SAND trace gravel: brown orange	M	MD		PVC stand Pipe			0.00
			CH	silty CLAY: minor gravel, brown orange	M	F-St		Screen from 2.5m to 5.5m Sand 2mm as filter			
1.00											1.00
			CH	CLAY: brown orange red	M	St		grout from surface to 2.5m sand was measured to 1.35m(backfilled)			
2.00				grey brown orange below 2.0m							2.00
								Groundwater at completeion of drilling is 3m below from pipe collar at 9:30a.m.			
3.00								Groundwawter is 3.65m from collar pipe at 3:00pm			3.00
4.00				brown grey below 4.0m							4.00
5.00				wet from 5.0m to 6.0m	W						5.00
6.00				Borehole terminated at 6.0m							6.00
7.00											7.00
8.00											8.00
9.00											9.00
10.00											10.00

consistency:

VS	very soft
S	soft
F	firm
ST	stiff
VST	very stiff
H	hard

relative density:

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

moisture:

D	Dry
M	Moist
W	Wet
S	Saturated

water:

▼ water level

▼ level risen to

● water inflow

notes:

sampling / testing:

intact sample from core

Disturbed sample

T intact tube sample

B Bulk sample

Supp Su from Pocket Penetrometer

Suv Su from Field Vane Shear test

soil classification:
soil is classified in accordance with AS1726 unless otherwise noted

BOREHOLE LOG

BORE No: 02-2020

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Client:	The Dunes Torquay	Drilling Co:	AGT	Easting:	-38.30406
Project:	Torquay Dam	Driller:	AF	Northing:	144.34624
Job No:	AGTE20249	Rig Type:	GT10	Grid Ref:	
Location:	Torquay	Inclination:		Collar RL:	
Date Drilled:	13/11/20	Bearing:		Logged by: MF	Checked by: AF

Test Method: AS 1289.6.3.2-1997 & AS 1726-1993

Depth (m)	Drilling Method	Graphic Log	Group Symbol	MATERIAL DESCRIPTION Type, colour, particle size and shape, structure	Moisture	Consistency / Density	N-DCP Blows per 100mm	FIELD TESTS	Sampling / Runs	Water Levels	Depth (m)
0.00			CL	silty sandy CLAY: orange brown	M			Screen: 2.5m - 5.5m Sand: 2.5 - 5.5 Grout : 0 - 2.5m			0.00
1.00			CH	silty CLAY: brown orange	M						1.00
2.00				brown orange red below 2.3m trace sand below 2.5m							2.00
3.00				red below 2.8m							3.00
4.00											4.00
5.00			CL	sandy CLAY: brown red grey	M						5.00
6.00				Borehole terminated at 6.0m No groundwater encountered							6.00
7.00											7.00
8.00											8.00
9.00											9.00
10.00											10.00

consistency:

VS	very soft
S	soft
F	firm
ST	stiff
VST	very stiff
H	hard

relative density:

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

moisture:

D	Dry
M	Moist
W	Wet
S	Saturated

notes:

water: ▼ water level; ▼ level risen to; ● water inflow

sampling / testing: ■ intact sample from core; ● Disturbed sample; T intact tube sample; B Bulk sample; Supp Su from Pocket Penetrometer; Suv Su from Field Vane Shear test

soil classification:
soil is classified in accordance with AS1726 unless otherwise noted

BOREHOLE LOG

BORE No: 03-2020

Page: of 1

Client:	The Dunes Torquay	Drilling Co:	AGT	Easting:	-38.302578
Project:	Torquay Dam	Driller:	AF	Northing:	144.34813
Job No:	AGTE20249	Rig Type:	GT10	Grid Ref:	
Location:	Torquay	Inclination:		Collar RL:	
Date Drilled:	13/11/20	Bearing:		Logged by: MF	Checked by: AF

Test Method: AS 1289.6.3.2-1997 & AS 1726-1993

Depth (m)	Drilling Method	Graphic Log	Group Symbol	MATERIAL DESCRIPTION Type, colour, particle size and shape, structure	Moisture	Consistency / Density	N-DCP Blows per 100mm	FIELD TESTS	Sampling / Runs	Water Levels	Depth (m)
0.00			ML	sandy SILT: dark brown	M	F-St					0.00
			CL	silty CLAY trace sand: brown orange	M	St					
1.00											1.00
2.00			CL	sandy CLAY: brown grey	M	St					2.00
3.00											3.00
4.00			CH	CLAY trace sand: pale brown grey	M	St					4.00
5.00											5.00
6.00				Borehole terminated at 6.0m No groundwater encountered	M						6.00
7.00											7.00
8.00											8.00
9.00											9.00
10.00											10.00

consistency:

VS	very soft
S	soft
F	firm
ST	stiff
VST	very stiff
H	hard

relative density:

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

moisture:

D	Dry
M	Moist
W	Wet
S	Saturated

notes:

water: ▼ water level; ▼ level risen to; ● water inflow

sampling / testing: intact sample from core; ● Disturbed sample; T intact tube sample; B Bulk sample; Supp Su from Pocket Penetrometer; Suv Su from Field Vane Shear test

soil classification:
soil is classified in accordance with AS1726 unless otherwise noted

BOREHOLE LOG

BORE No: 04-2020

Page: of 1

Client:	The Dunes Torquay	Drilling Co:	AGT	Easting:	-38.30344
Project:	Torquay Dam	Driller:	AF	Northing:	144.35001
Job No:	AGTE20249	Rig Type:	GT10	Grid Ref:	
Location:	Torquay	Inclination:		Collar RL:	
Date Drilled:	13/11/20	Bearing:		Logged by: MF	Checked by: AF

Test Method: AS 1289.6.3.2-1997 & AS 1726-1993

Depth (m)	Drilling Method	Graphic Log	Group Symbol	MATERIAL DESCRIPTION Type, colour, particle size and shape, structure	Moisture	Consistency / Density	N-DCP Blows per 100mm	FIELD TESTS	Sampling / Runs	Water Levels	Depth (m)
0.00			SM	Silty SAND : Light brown	M	MD		Screen: 2.7m - 5.7m Sand: 0.3m - 5.7m Grout : 0 - 0.3m			0.00
			CH	CLAY : grey	M	F-St					
1.00								Groundwawter is 5.6m from collar pipe			1.00
2.00				red brown below 2.5m							2.00
3.00											3.00
4.00											4.00
5.00											5.00
					W						
6.00				Borehole terminated at 6.0m							6.00
7.00											7.00
8.00											8.00
9.00											9.00
10.00											10.00

consistency:

VS	very soft
S	soft
F	firm
ST	stiff
VST	very stiff
H	hard

relative density:

VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

moisture:

D	Dry
M	Moist
W	Wet
S	Saturated

notes:

water:

▼ water level

▼ level risen to

● water inflow

sampling / testing:

intact sample from core

T intact tube sample

Disturbed sample

B Bulk sample

Supp Su from Pocket Penetrometer

Suv Su from Field Vane Shear test

soil classification:
soil is classified in accordance with AS1726 unless otherwise noted

ENGINEERING LOG

BOREHOLE No
BH1

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***8.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.303919 **Longitude:** 144.347087

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing 75µm	% passing 0.425mm	% passing 2.36mm	% passing 19mm	% passing 37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Sandy CLAY: brown	M	VSt				450																			
	1				- grey mottled orange			SPT 2,3,3 N=6			450		19.1																		
	2				- orange-brown			SPT 3,5,7 N=12			450		18.7																		
	3							SPT 3,6,7 N=13			310		25.4	57			100		58	36	12.5									
	4							SPT 2,2,3 N=5			320																			
	5				- brown-grey						350		31.8																	
	6				- grey-brown			SPT 3,5,8 N=13			400		22.7 20.2	60			100		39	21	10									
	7	7.05		CI	- orange-brown Sandy CLAY: orange-brown	M	VSt	SPT 6,6,10 N=16			450		14.3																	
	8	8.5			**End of BH1 at 8.50m**			SPT 4,8,10 N=18			500		22.7																	
	9																													
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No
BH2

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***8.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.304105 **Longitude:** 144.34708

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing: 75µm	0.425mm	2.36mm	19mm	37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	1				FILL, Sandy Clay: orange-brown mottled grey	M	VSt				350																			
								SPT 4,3,3 N=6			500		23.7																	
	2				- yellow-brown, white			SPT 2,2,4 N=6			450		19																	
	3				- yellow-orange, red			SPT 3,4,4 N=8			480		23																	
	4				- orange-brown, trace gravel			SPT 2,4,5 N=9			350		31.2																	
	5							SPT 2,4,6 N=10			350		32																	
	6	6.1		CI	Sandy CLAY: orange-brown	M	VSt																							
		6.5			**End of BH2 at 6.50m**																									
	7																													
	8																													
	9																													
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH3

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***8.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.304129 **Longitude:** 144.349075

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing: 75µm	0.425mm	2.36mm	19mm	37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Sandy Clay: brown-orange						600																			
	1							SPT 4,3,3 N=6			600		20																	
	2				- yellow-orange, brown, grey			SPT 2,3,3 N=6			500		23.2																	
	3				- orange-brown			SPT 2,4,4 N=8			450		26.7																	
	4							SPT 2,3,5 N=8			520																			
	5				- thin sand layers			SPT 4,4,6 N=10			550		29.5																	
	6	6.1		CI	Sandy CLAY: orange-brown			SPT 7,12,14 N=26			600		27.9																	
		6.5			**End of BH3 at 6.50m**																									
	7																													
	8																													
	9																													
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH4

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***8.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.303599 **Longitude:** 144.349743

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing: 75µm	0.425mm	2.36mm	19mm	37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Sandy Clay: brown, grey, white, orange	M	VSt				550																			
	1							SPT 4,5,7 N=12			500		18.6																	
	2							SPT 6,11,11 N=22			450																			
	3							SPT 3,8,15 N=23			600		27.5	72			100		55	31	14									
	4										450		13.4																	
	5				- orange-brown, mottled red, grey			SPT 4,6,7 N=13			450		23.9																	
	6				- brown-orange, grey, some fine sand			SPT 3,5,4 N=9			600		27.4																	
	7				- orange-brown, mottled grey, red			SPT 2,3,3 N=6			250		32.3																	
	8	7.6		Cl	Sandy CLAY: orange-brown	M	VSt	SPT 5,11,14 N=25			500																			
	9	8.5			**End of BH4 at 8.50m**																									
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH5

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***9.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.302764 **Longitude:** 144.348326

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing 75µm	% passing 0.425mm	% passing 2.36mm	% passing 19mm	% passing 37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Sandy Clay: orange-brown	M	VSt																							
					- orange brown mottled grey						600																			
	1							SPT 3,5,6 N=11			450		20.6																	
	2				- bown orange mottled, red, grey			SPT 4,5,7 N=12			350		7																	
	3				- 50mm layer of sand, light grey-brown			SPT 3,6,7 N=13			600																			
	4							SPT 3,4,7 N=11			420		21.6																	
	5				- brown orange			SPT 2,3,6 N=9			420		29																	
	6							SPT 2,2,4 N=6			550			75			100		52	29	12.5									
	7										600		28.4																	
	8	7.5		Cl	Sandy CLAY: orange-brown mottled red, grey, trace fine gravel	M	VSt	SPT 7,11,16 N=27			600		20.7																	
	9	8.5			**End of BH5 at 8.50m**																									
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH6

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***9.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.302837 **Longitude:** 144.349305

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing 75µm	% passing 0.425mm	% passing 2.36mm	% passing 19mm	% passing 37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Silty Clay: orange-brown, grey	M	VSt				550																			
	1																													
	2										400																			
	3										500			65			100		51	32	14									
	4				- grey mottled orange-brown						500																			
	5				- orange-brown mottled grey						550																			
	6										450																			
	7	6.8		CI	Sandy CLAY: grey mottled orange	M	VSt				500																			
		7.5			**End of BH6 at 7.50m**																									
	8																													
	9																													
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH7

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***9.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.302619 **Longitude:** 144.347538

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing 75µm	% passing 0.425mm	% passing 2.36mm	% passing 19mm	% passing 37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	1				FILL, Silty Clay: orange-brown mottled grey	M	VSt				550																			
	2										400																			
	3	2.9			FILL, Clayey Sand: grey	M	MD																							
		3.1			FILL, Sandy Clay: brown-orange	M	VSt				300																			
	4				- red-brown						450																			
	5				- orange-brown mottled grey						600																			
	6																													
		6.5			FILL, Clayey Sand: grey	M	MD							32			100		31	19	7			10.7	1.904					
	7										450																			
	8	8		CI	Sandy CLAY: orange-brown mottled grey	M	VSt																							
	9	9			**End of BH7 at 9.00m**																									
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

ENGINEERING LOG

BOREHOLE No

BH8

PROJECT:	***1075 Horse Bend Road***	PROJECT NO:	***AGTE174663***
LOCATION:	***Torquay***	DATE OF BOREHOLE:	***9.11.2017***
CLIENT:	***The Dunes Torquay***	LOGGED BY:	***MN***

Chainage: **Direction:** **Offset** **Latitude:** -38.302918 **Longitude:** 144.346743

Method	Depth (m)	Depth of Unit	Graphic Log	Classification Symbol	Material Description	Moisture Condition	Consistency / Strength	Sample ID	Tests: DCP (per 100mm)	FIELD CBR	PP (kPa)	SV (kPa)	MC (%)	% passing 75µm	% passing 0.425mm	% passing 2.36mm	% passing 19mm	% passing 37.5mm	LL	PI	LS	CBR	SWELL	OMC	MDD	Additive	UCS	OMC - Add	MDD - Add	Water
Solid Auger	0				FILL, Silty Clay: brown-grey	M	VSt																							
	1				- orange-brown mottled grey, red			SPT 4,5,7 N=12			500		15.4																	
	2							SPT 4,6,9 N=15			600																			
	3				- orange-brown			SPT 4,6,9 N=15			550		23.3	58			100		50	32	14									
	4				- orange-brown mottled red, trace gravel			SPT 2,4,2 N=6			600		18																	
	5							SPT 2,4,4 N=8			300		26.1																	
	6				- orange brown mottled red, grey, trace gravel			SPT 4,6,7 N=13			400																			
	7	7.1		CI	Sandy CLAY: orange-brown	M	VSt	SPT 7,16,17 N=33			600		32.3																	
		7.5			**End of BH8 at 7.50m**																									
	8																													
	9																													
	10																													

This log should be read in conjunction with the Australian Geotechnical Testing Log Summary Sheet and the Site Plan

Appendix B

Detailed Piping Risk Assessment

Summary of the weighting factors for piping through the embankment mode of failure

Table 11.2

Factor	Selection	General Factors Influencing Likelihood of Failure				
		Much More Likely	More Likely	Neutral	Less Likely	Much Less Likely
Zoning		Refer to Table 11.1 for baseline annual probabilities of failure depending on Zoning Types				
Column		1	2	3	4	5
Embankment Filter WE (filt)	2		No embankment filter (for dams which usually have filters)	Other dam types	Embankment filter present - poor quality	Embankment filter present - well designed and constructed
Core Geology Origin WE(cgo)	1	Alluvial	Aeolian, Colluvial	Residual, Lacustrine, Marine, Volcanic		Glacial
Core Soil Type WE (cst) (Select one row only)	5	Dispersive clays	Clayey and silty sands (SC,SM)	Well graded and poorly graded gravels (GW,GP)	Clayey and silty gravels (GC,GM)	High plasticity clays
		Low plasticity silts (ML)		High plasticity silts	Low plasticity clays	
		Poorly and well graded sands (SP,SW)				
Compaction WE(cc)	2	No Formal compaction	Rolled, modest control	Puddle, Hydraulic fill		Rolled, good control
Conduits WE(con)	2	Conduit through the embankment - many poor details	Conduit through the embankment - some poor details	Conduit through embankment - typical USBR practice	Conduit through embankment - including downstream filters	No Conduit through the embankment
Foundation Treatment WE(ft)	3	Untreated vertical faces or overhangs in core foundation	Irregularities in foundation or abutment, Steep abutments		Careful slope modification by cutting, filling with concrete	
Observations of Seepage WE(obs)	5	Muddy leakage Sudden increase in leakage	Leakage gradually increasing, clear, Sinkholes, Seepage emerging on downstream slope	Leakage steady, clear or not observed	Minor leakage	Leakage measured none or very small
Monitoring and Surveillance WE(mon)	2	Inspections annually	Inspections Monthly	Irregular seepage observations, inspections weekly	Weekly - monthly seepage monitoring, weekly inspections	Daily monitoring of seepage, daily inspections

Multiplier = *1.296*

Summary of the weighting factors for piping through the embankment into foundation-accidents and failures

Table 11.4

Factor	Selection	General Factors Influencing Likelihood of Failure				
		Much More Likely	More Likely	Neutral	Less Likely	Much Less Likely
Zoning		Refer to Table 11.1 for baseline annual probabilities of failure depending on Zoning Types				
Column		1	2	3	4	5
Filters WF (filt)		Appears to be independent of presence/absence of embankment into foundation (use average value for all dams)				
Foundation cutoff trench WEF (cot)	3	Deep and narrow cutoff trench		Average cutoff trench width and depth	Shallow or no cutoff trench	
Foundation Type WEF(fnd)	2		Founding on or partly on rock foundations			Foundations on or partly on soil foundations
Erosion Control Measures of Core Foundation WEF(ecm)	5	No erosion control measures, open jointed bedrock or open work gravels	No erosion control measures, average foundation conditions	No erosion control measures, good foundation conditions	Erosion control measures present, poor foundations	Good erosion control measures present and good foundations
Grouting of Foundations	2		No grouting on rock foundations	Soil foundation only - not applicable	Rock foundations grouted	
Soil Geology Types (below cutoff) OR WF(sg)		Colluvial	Glacial		Residual	Alluvial, Aeolian, Lacustrine, Marine or Volcanic
Rock Geology Types (below cutoff) WF(sg) (Select one row only)		Sandstone interbedded with shale or limestone	Dolomite, Tuff, Quartzite	Agglomerate, Volcanic breccia	Sandstone, Conglomerate	Shale ,Siltstone, Mudstone, Claystone
	3	Limestone, gypsum	Rhyolite, Basalt, Marble	Granite, Andersite,Gabbro,Gneiss	Schist, Phyllite, Slate, Hornfels	
Core Geology Origin WE(cgo)	2	Alluvial	Aeolian, Colluvial	Residual, Lacustrine, Marine, Volcanic		Glacial
Core Soil Type WE (cst) (Select one row only)		Dispersive clays	Clayey and silty sands (SC,SM)	Well graded and poorly graded gravels (GW,GP)	Clayey and silty gravels (GC,GM)	High plasticity clays (CH)
	4	Low plasticity silts (ML)		Highly plasticity silts (MH)	Low Plasticity clays (CL)	
		Poorly and well graded sands (SP,SW)				
Core Compaction WEF (cst)		Appears to be independent of compaction - all compaction types				
Foundation Treatment WE(ft)	4	Untreated vertical faces or overhangs in core foundation	Irregularities in foundation or abutment, Steep abutments		Careful slope modification by cutting, filling with concrete	
Observations of Seepage WE(obs)	3	Muddy leakage, Sudden increases in leakage	increasing, clear, Sinkholes	Leakage steady, clear or not monitored	Minor leakage	Leakage measured none or very small
Monitoring and Surveillance WE(mon)	4	Inspections annually	Inspections monthly	Irregular seepage observations, inspections weekly	Weekly - monthly seepage monitoring, weekly inspections	Daily monitoring of seepage, daily inspections

Multiplier= *0.33696*

Summary of the weighting factors for piping through the foundation mode of failure

Table 11.3

Factor		Selection	General Factors Influencing Likelihood of Failure				
			Much More Likely	More Likely	Neutral	Less Likely	Much Less Likely
Zoning			Refer to Table 11.1 for baseline annual probabilities of failure depending on Zoning Types				
Column			1	2	3	4	5
Filters WF (filt)		2		No Foundation filter present when required	No foundation filter	Foundation Filter(s) Present	
Foundation Type (below cutoff) Wf (fnd)		1	Soil Foundation		Rock -clay infilled or open fractures and/or erodible rock substance		Rock - closed fractures and non-erodible substance
Cutoff Type (Soil foundation) (cts)	OR	2		Shallow or no cutoff trench	Partially penetrating sheetpile wall or poorly constructed slurry trench wall	Upstream blanket, Partially penetrating well constructed slurry trench wall	Partially penetrating deep cutoff trench
Cutoff Type (Rock foundation) (ctr)			Sheetpile wall Poorly constructed diaphragm wall	Well constructed diaphragm wall	Average cutoff trench	Well constructed cutoff trench	
Soil Geology Types (below cutoff) WF(sg)	OR	4	Dispersive soils or Volcanic Ash	Residual	Aeolian, Colluvial, Lacustrine, Marine	Alluvial	Glacial
Rock Geology Types (below cutoff) WF(sg)			Dolomite or Basalt	Tuff		Sandstone, Shale, Siltstone, Claystone, Mudstone, Hornfels	Conglomerate, Andesite, Gabbo, Schist Phyllite, or Slate
(Select one row only)			Limestone or Saline (gypsum)	Rhyolite, Marble or Quartzite		Agglomerate, Volc. Breccia	Granite, or Gneiss
Observations of Seepage WE(obs)	OR	3	Muddy leakage Sudden increase in leakage	Leakage gradually increasing, clear, Sinkholes, Sand boils	Leakage steady, clear, or not observed	Minor Leakage	Leakage measured none or very small
Observations of Pore Pressures WF (obp)			Sudden increase in pressure	Gradually increasing pressure in foundations	High pressure measured in foundation		Low pore pressures in foundation
Monitoring and Surveillance WE(mon)		4	Inspections annually	Inspections Monthly	Irregular seepage observations, inspections weekly	Weekly - monthly seepage monitoring, weekly inspections	Daily monitoring of seepage, daily inspections

Multiplier= *5.184*

Piping Failure of Torquay Dam

Dam Type: **Homogeneous Earthfill**

Type of Failure: **Embankment**

Average Probability of failure over the life of the dam
All Years of Operation = 2.07E-02

Average Annual Probabilities of Failure

First 5 Years of Operation = 2.70E-03

After 5 Years of Operation = 2.46E-04

Piping Characteristics	
Embankment Filter WE (filt)	*No embankment filter (for dams which usually have filters)*
Core Geology Origin WE(cgo)	*Alluvial*
Core Soil Type WE (cst)	*High plasticity clays*
Compaction WE(cc)	*Rolled, modest control*
Conduits WE(con)	*Conduit through the embankment - some poor details*
Foundation Treatment WE(ft)	*0*
Observations of Seepage WE(obs)	*Leakage measured none or very small*
Monitoring and Surveillance WE(mon)	*Inspections Monthly*

Associated Multiplier incorporated into above Failure Probabilities= **1.296**

Type of Failure: **Foundation**

Average Probability of failure over the life of the dam
All Years of Operation = 8.81E-03

Average Annual Probabilities of Failure

First 5 Years of Operation = 1.32E-03

After 5 Years of Operation = 9.85E-05

Piping Characteristics	
Filters WF (filt)	*No Foundation filter present when required*
Foundation Type (below cutoff) Wf (fnd)	*Soil Foundation*
Cutoff Type (Soil foundation) (cts)	*Shallow or no cutoff trench*
Soil Geology Types (below cutoff) WF(sg)	*Alluvial*
Observations of Seepage WE(obs)	*Leakage steady, clear, or not observed*
Monitoring and Surveillance WE(mon)	*Weekly - monthly seepage monitoring, weekly inspections*

Associated Multiplier incorporated into above Failure Probabilities= **5.184**

Type of Failure: **Embankment through Foundation**

Average Probability of failure over the life of the dam
All Years of Operation = 6.07E-05

Average Annual Probabilities of Failure or Accident

First 5 Years of Operation = 6.40E-06

After 5 Years of Operation = 1.35E-06

Piping Characteristics	
Foundation cutoff trench WEF (cot)	*Average cutoff trench width and depth*
Foundation Type WEF(fnd)	*Founding on or partly on rock foundations*
Erosion Control Measures of Core Foundation WEF(ecm)	*Good erosion control measures present and good foundations*
Grouting of Foundations	*No grouting on rock foundations*
Soil Geology Types (below cutoff) WF(sg)	*Granite, Andersite,Gabbro,Gneiss*
Core Geology Origin WE(cgo)	*Aeolian, Colluvial*
Core Soil Type WE (cst)	*Low Plasticity clays (CL)*
Foundation Treatment WE(ft)	*Careful slope modification by cutting, filling with concrete*
Observations of Seepage WE(obs)	*Leakage steady, clear or not monitored*
Monitoring and Surveillance WE(mon)	*Weekly - monthly seepage monitoring, weekly inspections*

Associated Multiplier incorporated into above Failure Probabilities= **0.33696**

NOTE: No dams of this design have failed, average probabilities are used

Appendix C

Laboratory Testing (2017 and 2020 Investigations)

Moisture Content Report

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	TG51066
Project:	1075 Horseshoe Bend Road Dam	Report:	1
Location:	Torquay	Test Date:	16-Nov-17

Test No:	51066-1	51066-2	51066-3	51066-4	51066-5	51066-6
Location:	BH 1	BH 1	BH 1	BH 1	BH 1	BH 1
Depth:	1m	2m	3m	6m	7m	8m
Moisture Content %	19.1	18.7	25.4	22.7	14.3	22.7
Material:						

Test No:	51066-7	51066-8	51066-9			
Location:	BH 4	BH 4	BH 3			
Depth:	1m	2m	3m			
Moisture Content %	20.0	23.2	26.7			
Material:						

Notes:

Test Method	AS1289.2.1.1	Sampling Method	As provided
Site Selection	N/A		

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation for compliance with ISO/IEC 17025 - Testing

The results of tests, calibrations and/or measurements included in this document, are traceable to Australian / national standards

NATA Accredited Laboratory No. 20245

Approved Signatory

Jon Lillecrapp

Date: 29-Nov-17

Moisture Content Report

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	TG51066
Project:	1075 Horseshoe Bend Road Dam	Report:	11
Location:	Torquay	Test Date:	03-Dec-17

Test No:	51066-25	51066-26	51066-27	51066-28	51066-29	51066-30
Location:	BH 2	BH 8	BH 5	BH 5	BH 8	BH 4
Depth:	4m	4m	2m	1m	**1**m	3m
Moisture Content %	31.2	**14.9**	**19.5**	20.6	15.4	27.5
Material:						

Test No:	51066-31	51066-32	51066-33	51066-34	51066-35	51066-36
Location:	BH 3	BH 4	BH 3	BH 5	BH 2	BH 3
Depth:	1m	5m	6m	4m	5m	5m
Moisture Content %	18.6	23.9	27.9	21.6	32.0	29.5
Material:						

Notes:

Test Method	AS1289.2.1.1	Sampling Method	As provided
Site Selection	N/A		

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation for compliance with ISO/IEC 17025 - Testing

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Approved Signatory

Jon Lillecrapp

NATA Accredited Laboratory No. 20245

Date: 05-Dec-17

Moisture Content Report

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	TG51066
Project:	1075 Horseshoe Bend Road Dam	Report:	12
Location:	Torquay	Test Date:	03-Dec-17

Test No:	51066-37	51066-38	51066-39	51066-40	51066-41	51066-42
Location:	BH 4	BH 5	BH 1	BH 5	BH 5	BH 3
Depth:	6m	8m	6m	5m	7m	2m
Moisture Content %	27.4	20.7	20.2	29.0	16.9	22.8
Material:						

Test No:	51066-43	51066-44	51066-45	51066-46	51066-47	
Location:	BH 2	BH 2	BH 2	BH 4	BH 8	
Depth:	1m	2m	3m	7m	5m	
Moisture Content %	23.7	19.0	23.0	32.3	26.1	
Material:						

Notes:

Test Method	AS1289.2.1.1	Sampling Method	As provided
Site Selection	N/A		

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation for compliance with ISO/IEC 17025 - Testing

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NATA Accredited Laboratory No. 20245

Approved Signatory

Jon Lillecrapp

Date: 05-Dec-17

Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-1
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH1 (3.0 - 4.0m)**

Australian Geotechnical Testing
Warrnambool Laboratory
2/1109 Raglan Parade Warrnambool Vic 3280
Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

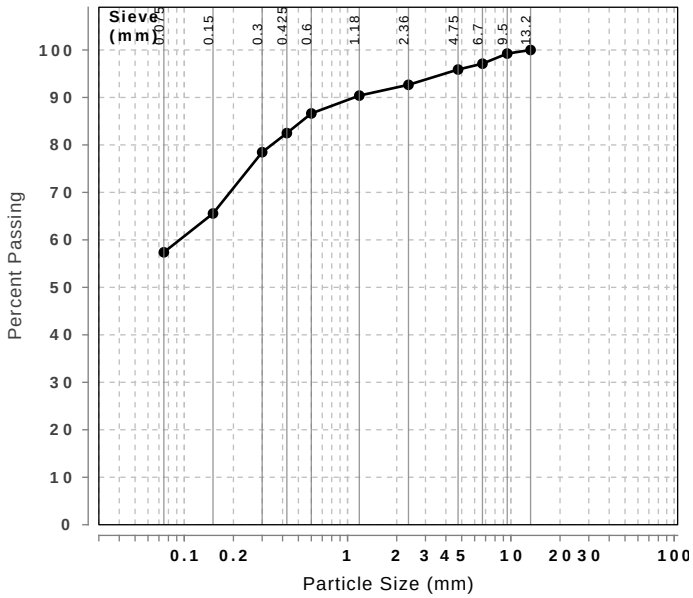
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	58		
Plastic Limit (%)	22		
Plasticity Index (%)	**36**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	Cracking		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**99**			1		
6.7 mm	**97**			2		
4.75 mm	**96**			1		
2.36 mm	**93**			3		
1.18 mm	**90**			2		
0.6 mm	**87**			4		
0.425 mm	**82**			4		
0.3 mm	**78**			4		
0.15 mm	**66**			13		
0.075 mm	**57**			8		

Particle Size Distribution



Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-2
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH1 (6.0 - 7.0m)**

Australian Geotechnical Testing
Warrnambool Laboratory
2/1109 Raglan Parade Warrnambool Vic 3280
Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

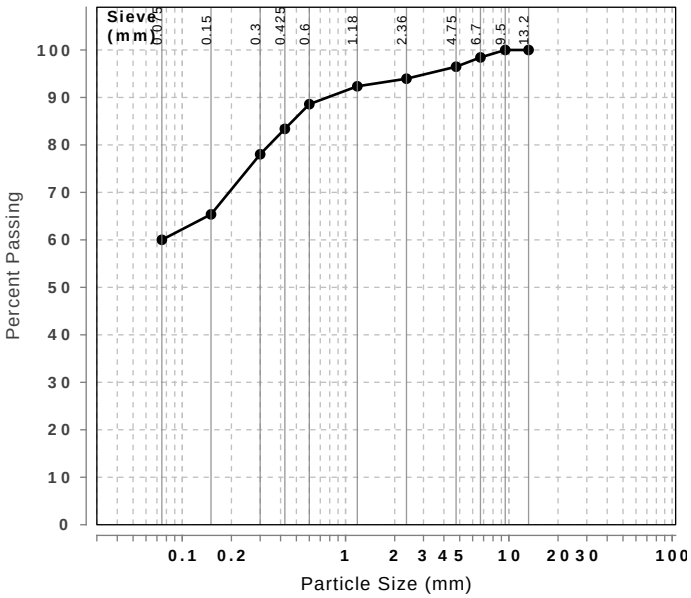
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	39		
Plastic Limit (%)	18		
Plasticity Index (%)	**21**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	10.0		
Cracking Crumbling Curling	None		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**100**			0		
6.7 mm	**98**			2		
4.75 mm	**96**			2		
2.36 mm	**94**			3		
1.18 mm	**92**			2		
0.6 mm	**89**			4		
0.425 mm	**83**			5		
0.3 mm	**78**			5		
0.15 mm	**65**			13		
0.075 mm	**60**			5		

Particle Size Distribution



Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-3
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH4 (3.0 - 4.0m)**

Australian Geotechnical Testing
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Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

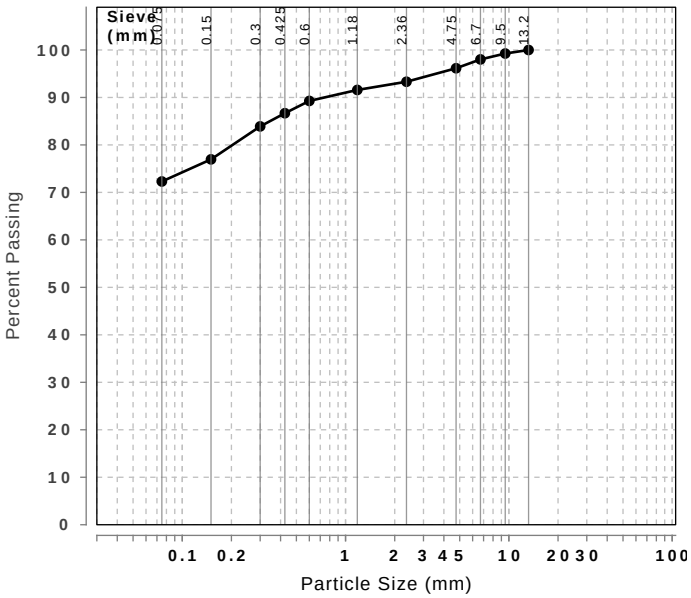
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	55		
Plastic Limit (%)	24		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.0		
Cracking Crumbling Curling	None		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**99**			1		
6.7 mm	**98**			1		
4.75 mm	**96**			2		
2.36 mm	**93**			3		
1.18 mm	**92**			2		
0.6 mm	**89**			2		
0.425 mm	**87**			3		
0.3 mm	**84**			3		
0.15 mm	**77**			7		
0.075 mm	**72**			5		

Particle Size Distribution



Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-4
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH5 (6.0 - 7.0m)**

Australian Geotechnical Testing
Warrnambool Laboratory
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Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

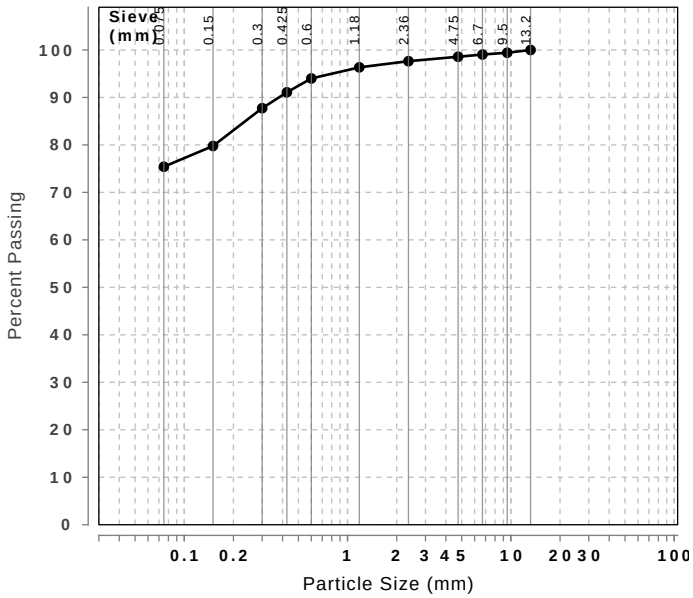
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	52		
Plastic Limit (%)	23		
Plasticity Index (%)	**29**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	Cracking		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**99**			1		
6.7 mm	**99**			0		
4.75 mm	**99**			0		
2.36 mm	**98**			1		
1.18 mm	**96**			1		
0.6 mm	**94**			2		
0.425 mm	**91**			3		
0.3 mm	**88**			3		
0.15 mm	**80**			8		
0.075 mm	**75**			4		

Particle Size Distribution



Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-5
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH6 (2.5 - 6.0m)**

Australian Geotechnical Testing
Warrnambool Laboratory
2/1109 Raglan Parade Warrnambool Vic 3280
Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

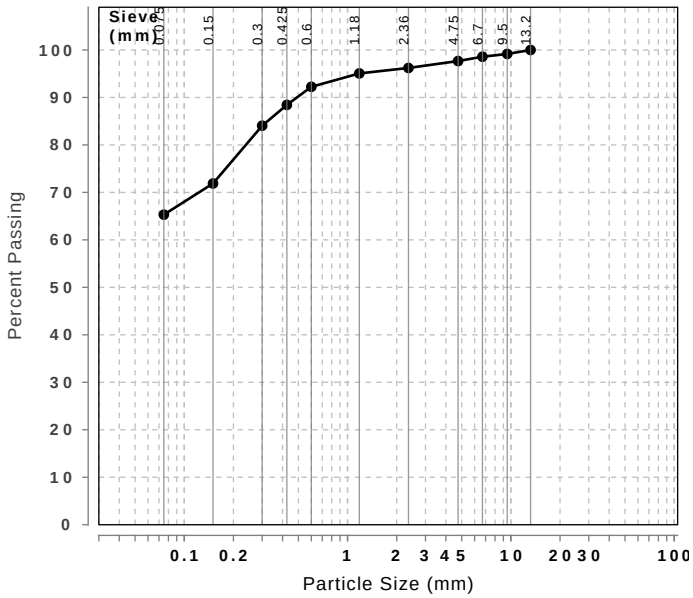
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	51		
Plastic Limit (%)	19		
Plasticity Index (%)	**32**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.0		
Cracking Crumbling Curling	Cracking		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**100**			0		
9.5 mm	**99**			1		
6.7 mm	**99**			1		
4.75 mm	**98**			1		
2.36 mm	**96**			1		
1.18 mm	**95**			1		
0.6 mm	**92**			3		
0.425 mm	**88**			4		
0.3 mm	**84**			4		
0.15 mm	**72**			12		
0.075 mm	**65**			7		

Particle Size Distribution



Material Test Report

Report Number: **AGT11654-1**
Issue Number: 1
Date Issued: 17/11/2017
Client: The Dunes Torquay (AGTE)

Contact: Matt Noonan
Project Number: AGT11654
Project Name: 1075 Horseshoes Bend Road Dam
Project Location: The Dunes Torquay
Work Request: 106
Sample Number: 11654-6
Date Sampled: 13/11/2017
Sampling Method: AS1289 1.2.1 6.5.4 - Machine excavated pit or trench
Sample Location: **BH8 (2.5 - 4.0m)**

Australian Geotechnical Testing
Warrnambool Laboratory
2/1109 Raglan Parade Warrnambool Vic 3280
Phone: (03) 5023 2870
Email: danielt@ausgeotest.com.au
Accredited for compliance with ISO/IEC 17025 - Testing

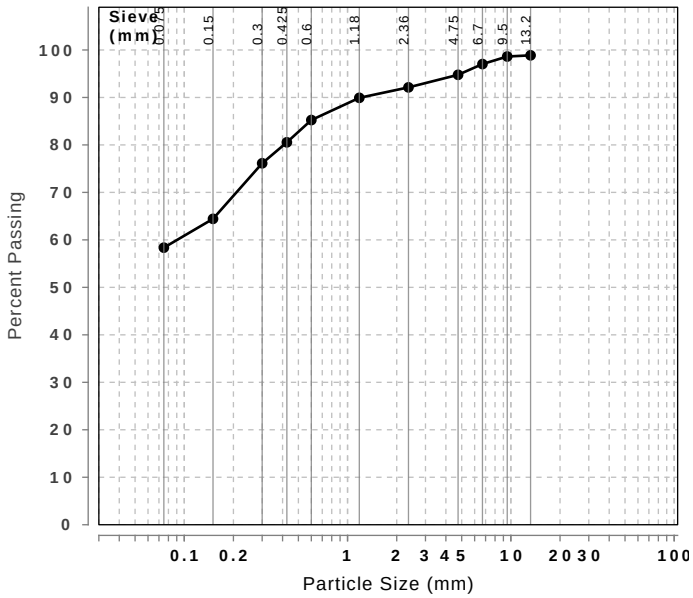
Approved Signatory: Daniel Talbot
Senior Geotechnician
NATA Accredited Laboratory Number: 20246

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	50		
Plastic Limit (%)	18		
Plasticity Index (%)	**32**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.0		
Cracking Crumbling Curling	None		

Particle Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**99**			1		
9.5 mm	**99**			0		
6.7 mm	**97**			2		
4.75 mm	**95**			2		
2.36 mm	**92**			3		
1.18 mm	**90**			2		
0.6 mm	**85**			5		
0.425 mm	**81**			5		
0.3 mm	**76**			4		
0.15 mm	**64**			12		
0.075 mm	**58**			6		

Particle Size Distribution



Particle Size Distribution and Atterberg Limits Report

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job Number:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	10
Location:	Torquay	Test Date:	24-Nov-17
Material:	Clayey SAND		
Sample Number:	51066-17	Sample Location:	BH 7 6.6-8.0

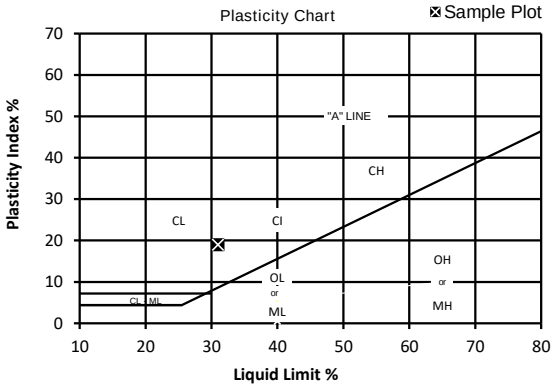
Sample Source:	N/A	Client Test Req. No.:	N/A
Product Designation:	N/A	Lot Identification:	N/A
Product Specification:	N/A	*Sampling Method:*	0

Atterberg Limits

SAMPLE HISTORY:
Test Methods:

Liquid Limit:	AS1289.3.1.2	Linear Shrinkage:	AS1289.3.4.1
Plasticity Index:	AS1289.3.3.1	Moisture Content:	AS1289.2.1.1
Plastic Limit:	AS1289.3.2.1	Moisture Content %	12.5
Weighted PI:	RC326.01		

Plasticity Index Results		*Limits*
LIQUID LIMIT:	31	
PLASTIC LIMIT:	12	
PLASTICITY INDEX:	19	
LINEAR SHRINKAGE:	7.0	
WPI (% passing 0.425mm x PI):	1464	
0.075mm X 0.425mm SIEVE:	2464	
L.S. X 0.425mm SIEVE:	540	
Linear Shrinkage Remarks:		

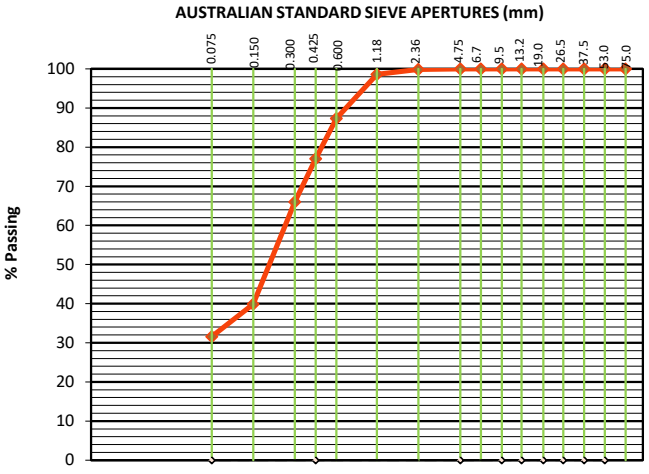


Particle Size Distribution

SAMPLE HISTORY: Oven Dried (105-110 deg C), -19.0mm Washed
Test Method: AS1289.3.6.1

Grading Envelope

SIEVE SIZE (mm)	*Lower Limits*	% PASSING (by mass)	*Upper Limits*
75.0		100	
53.0		100	
37.5		100	
26.5		100	
19.0		100	
13.2		100	
9.5		100	
6.70		100	
4.75		100	
2.36		100	
1.18		99	
0.600		87	
0.425		77	
0.300		66	
0.150		40	
0.075		32	



NOTES:

Accreditation for compliance with ISO/IEC 17025 - Testing
The results of tests, calibrations and/or measurements included in this document, are traceable to Australian / national standards

NATA Accredited Laboratory No. 20245

Approved Signatory

Marcus Green - Manager

Date: 29-Nov-17

Permeability Report
Constant Head Permeability

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquuay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report No:	9
Location:	Torquay	Date of Test:	19-Nov-17

Test Number:	51066-17
Material Description:	Clayey SAND
Sample Location:	BH 7 - 6.6-8.0m

Compaction Details	AS1289.5.1.1
Maximum Dry Density t/m^3	1.904
Optimum Moisture Content %	10.7
Compactive Effort	Standard
Oversize material retained on 19.0mm sieve %	0
Dry Density Ratio Required %	98
Moisture Ratio Required %	100
Achieved Dry Density t/m3	1.904
Achieved Density Ratio %	100
Achieved Moisture Content %	10.7
Achieved Moisture Ratio %	100
Percolation Details	
Surcharge Pressure kPa	3228.8
Permeant Used	Water

Coefficient of Permeability m/sec -5E-06

Notes:

note: 1.0E-13 = 1 x 10 $^{-13}$

Test Methods: AS1289 1.2.1, 2.1.1, 5.1.1, AS1289.6.7.1

Sampling Method: N/A
Sampling Date: 13-Nov-17

Accreditation for compliance with ISO/IEC 17025
The results of tests, calibrations and/or measurements included in this document, are traceable to Australian / national standards

NATA Accredited Laboratory No. 20245

Approved Signatory

Marcus Green - Manager

Date: 29-Nov-17

TRIAXIAL PERMEABILITY TEST

AS 1289.6.7.3

47 National Avenue, Pakenham VIC 3810
ph 03 5943 0980 www.terrafirmalabs.com.au

job No	9999
report No	9999-4
issue date	27-Nov-2017

Client:	Australian Geotechnical Testing	**date tested**	17/11/17 - 24/11/17
Address:	21 Garden Boulevard, Dingley Village, 3803		
Project:	1075 Horseshoe Bend Rd Dam	**tested by**	PP
Location:	Torquay	**checked**	SB

IDENTIFICATION	(AGT51066-16) BH8 - 3.0m	
SAMPLE DESCRIPTION	Silty CLAY	
PERMEANT USED	Deaired water	
CONFINING PRESSURE kPa	600	
HEAD PRESSURE kPa	590	
BOTTOM PRESSURE kPa	570	
MEAN PRESSURE kPa	20	
SPECIMEN HEIGHT	6.90	cm
SPECIMEN DIAMETER	6.30	cm
LENGTH TO HEIGHT RATIO	110	
DENSITY RATIO	N/A	
MOISTURE RATIO	N/A	
PERCENTAGE OVERSIZE (19.0 mm sieve)	N/A	
MOISTURE INITIAL	23.3	
MOISTURE FINAL	27.8	
PERMEABILITY M/SEC	**1×10^{-10}**	

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LABORATORY ACCREDITATION No **15357**

Approved Signature

S Benbow

TRIAXIAL PERMEABILITY TEST

AS 1289.6.7.3

47 National Avenue, Pakenham VIC 3810
ph 03 5943 0980 www.terrafirmalabs.com.au

job No	9999
report No	9999-3
issue date	27-Nov-2017

Client:	Australian Geotechnical Testing	**date tested**	17/11/17 - 24/11/17
Address:	21 Garden Boulevard, Dingley Village, 3803		
Project:	1075 Horseshoe Bend Rd Dam	**tested by**	PP
Location:	Torquay	**checked**	SB

IDENTIFICATION	(AGT51066-15) BH5 - 7.0m	
SAMPLE DESCRIPTION	Silty CLAY	
PERMEANT USED	Deaired water	
CONFINING PRESSURE kPa	600	
HEAD PRESSURE kPa	590	
BOTTOM PRESSURE kPa	570	
MEAN PRESSURE kPa	20	
SPECIMEN HEIGHT	6.83	cm
SPECIMEN DIAMETER	6.30	cm
LENGTH TO HEIGHT RATIO	108	
DENSITY RATIO	N/A	
MOISTURE RATIO	N/A	
PERCENTAGE OVERSIZE (19.0 mm sieve)	N/A	
MOISTURE INITIAL	28.4	
MOISTURE FINAL	32.9	
PERMEABILITY M/SEC	**3×10^{-10}**	

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TRIAXIAL PERMEABILITY TEST

AS 1289.6.7.3

47 National Avenue, Pakenham VIC 3810
ph 03 5943 0980 www.terrafirmalabs.com.au

job No	9999
report No	9999-2
issue date	27-Nov-2017

Client:	Australian Geotechnical Testing	**date tested**	17/11/17 - 24/11/17
Address:	21 Garden Boulevard, Dingley Village, 3803		
Project:	1075 Horseshoe Bend Rd Dam	**tested by**	PP
Location:	Torquay	**checked**	SB

IDENTIFICATION	(AGT51066-14) BH4 - 4.0m	
SAMPLE DESCRIPTION	Silty CLAY	
PERMEANT USED	Deaired water	
CONFINING PRESSURE kPa	600	
HEAD PRESSURE kPa	590	
BOTTOM PRESSURE kPa	570	
MEAN PRESSURE kPa	20	
SPECIMEN HEIGHT	6.57	cm
SPECIMEN DIAMETER	6.28	cm
LENGTH TO HEIGHT RATIO	105	
DENSITY RATIO	N/A	
MOISTURE RATIO	N/A	
PERCENTAGE OVERSIZE (19.0 mm sieve)	N/A	
MOISTURE INITIAL	13.4	
MOISTURE FINAL	26.9	
PERMEABILITY M/SEC	**4×10^{-11}**	

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LABORATORY ACCREDITATION No **15357**

Approved Signature

S Benbow

TRIAXIAL PERMEABILITY TEST

AS 1289.6.7.3

47 National Avenue, Pakenham VIC 3810
ph 03 5943 0980 www.terrafirmalabs.com.au

job No	9999
report No	9999-1
issue date	27-Nov-2017

Client:	Australian Geotechnical Testing	**date tested**	17/11/17 - 24/11/17
Address:	21 Garden Boulevard, Dingley Village, 3803		
Project:	1075 Horseshoe Bend Rd Dam	**tested by**	PP
Location:	Torquay	**checked**	SB

IDENTIFICATION	(AGT51066-13) BH1 - 5.0m	
SAMPLE DESCRIPTION	Silty CLAY	
PERMEANT USED	Deaired water	
CONFINING PRESSURE kPa	600	
HEAD PRESSURE kPa	590	
BOTTOM PRESSURE kPa	570	
MEAN PRESSURE kPa	20	
SPECIMEN HEIGHT	6.99	cm
SPECIMEN DIAMETER	6.28	cm
LENGTH TO HEIGHT RATIO	111	
DENSITY RATIO	N/A	
MOISTURE RATIO	N/A	
PERCENTAGE OVERSIZE (19.0 mm sieve)		
MOISTURE INITIAL	31.8	
MOISTURE FINAL	33.2	
PERMEABILITY M/SEC	**2×10^{-10}**	

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LABORATORY ACCREDITATION No **15357**

S Benbow
Approved Signature

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	4
Location:	Torquay		

Sample Number:	51066-19	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 1 - 4.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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NATA Accredited Laboratory No. 20245

Approved Signatory

Marcus Green - Manager

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	3
Location:	Torquay		

Sample Number:	51066-17	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 7 - 6.5-8.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water Water Temperature: 23 °C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

NATA Accredited Laboratory No. 20245

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	2
Location:	Torquay		

Sample Number:	51066-11	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 5 - 3.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
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ph 1300 026 583

info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	8
Location:	Torquay		

Sample Number:	51066-24	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 3 - 3.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
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info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	7
Location:	Torquay		

Sample Number:	51066-23	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 2 - 6.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
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Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	6
Location:	Torquay		

Sample Number:	51066-22	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 8 - 2.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
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PO Box 221 Hallam, VIC 3803
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info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	5
Location:	Torquay		

Sample Number:	51066-21	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	SH
Date Sampled:	9/Nov/17	Date Tested:	1-Dec-17

Sample Location: BH 5 - 6.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 23 °C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Marcus Green - Manager

NATA Accredited Laboratory No. 20245

Date: 04-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
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Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	13
Location:	Torquay		

Sample Number:	51066-10	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	MG
Date Sampled:	9/Nov/17	Date Tested:	5-Dec-17

Sample Location: BH 4 - 2.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 24 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 05-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
PO Box 221 Hallam, VIC 3803
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info@ausgeotest.com.au

Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	15
Location:	Torquay		

Sample Number:	51066-20	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	MG
Date Sampled:	9/Nov/17	Date Tested:	5-Dec-17

Sample Location: BH 4 - 3.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 24 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 05-Dec-17

Emerson Class Report
AS1289.3.8.1

Australian Geotechnical Testing
21 Garden Boulevard
Dingley Village VIC 3172
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Client:	The Dunes Torquay	Job No:	AGT51066
Project:	1075 Horseshoe Bend Road Dam	Report:	14
Location:	Torquay		

Sample Number:	51066-12	Sampled By:	MN
Sampling Method:	AS 1289.1.2.1.6.4(b)	Tested By:	MG
Date Sampled:	9/Nov/17	Date Tested:	5-Dec-17

Sample Location: BH 8 - 6.0m

Material Description: Clayey SAND

Emerson Class Number 4

Water Used: Distilled Water

Water Temperature: 24 ^{o}C

Notes:

2% solution of barium chloride showed that gypsum is present.

Test Method: AS1289.3.8.1

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Approved Signatory

Marcus Green - Manager

Date: 05-Dec-17

Material Test Report

Report Number: **P20405-1**
Issue Number: 1
Date Issued: 27/11/2020
Client: Australian Geotechnical Testing
2/1109 Raglan Parade, Warnambool Victoria 3280
Project Number: P20405
Project Name: Torquay Dam
Project Location: Torquay
Work Request: 4902
Sample Number: P20-4902A
Date Sampled: 20/11/2020
Dates Tested: 24/11/2020 - 27/11/2020
Sampling Method: Sampled by Client
The results apply to the sample as received
Sample Location: **BH1, Depth: 4.5m**
Material: CLAY

terra firma laboratories

Pakenham Laboratory
47 National Avenue Pakenham VIC 3810
Phone: (03) 9769 5799
Email: jsomaratne@terrafirmalabs.com.au

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NATA WORLD RECOGNISED ACCREDITATION

Approved Signatory: Janaka Somaratne
Lab Manager
NATA Accredited Laboratory Number: 15357

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Dispersion	Moderate Dispersion		
Soil Description	CLAY		
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		

Material Test Report

Report Number: **P20405-1**
Issue Number: 1
Date Issued: 27/11/2020
Client: Australian Geotechnical Testing
2/1109 Raglan Parade, Warnambool Victoria 3280
Project Number: P20405
Project Name: Torquay Dam
Project Location: Torquay
Work Request: 4902
Sample Number: P20-4902B
Date Sampled: 20/11/2020
Dates Tested: 24/11/2020 - 27/11/2020
Sampling Method: Sampled by Client
The results apply to the sample as received
Sample Location: **BH3, Depth: 2.5m**
Material: CLAY

terra firma laboratories

Pakenham Laboratory
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Approved Signatory: Janaka Somaratne
Lab Manager
NATA Accredited Laboratory Number: 15357

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Dispersion	Slight Dispersion		
Soil Description	CLAY		
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		

Material Test Report

Report Number: **P20405-1**
Issue Number: 1
Date Issued: 27/11/2020
Client: Australian Geotechnical Testing
2/1109 Raglan Parade, Warnambool Victoria 3280
Project Number: P20405
Project Name: Torquay Dam
Project Location: Torquay
Work Request: 4902
Sample Number: P20-4902C
Date Sampled: 20/11/2020
Dates Tested: 24/11/2020 - 27/11/2020
Sampling Method: Sampled by Client
The results apply to the sample as received
Sample Location: **BH4, Depth: 4.4m**
Material: CLAY

terra firma laboratories

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Phone: (03) 9769 5799
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Approved Signatory: Janaka Somaratne
Lab Manager
NATA Accredited Laboratory Number: 15357

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Dispersion	Moderate Dispersion		
Soil Description	CLAY		
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		