Build something great™

BORAL®

Boral Resources (QLD) Pty Ltd
Level 6, 88 Musk Avenue
Kelvin Grove QLD 4059

www.boral.com.au

5 June 2019

Norfolk Island Regional Council
9 New Cascade Road
Norfolk Island
2899

Attention: Alistair Innes-Walker

Re: Norfolk Island Airport Repair and Resurfacing Project (SPT1718NIRC)
Cascade Cliff and Alternative Site Review

Dear Alistair,

Thank you for the opportunity to submit the reports to the Norfolk Island Regional Council for the full investigation in Cascade Cliff and Alternative Sites Review associated with the Norfolk Island Airport Repair and Resurfacing Project.

Having completed this process on numerous Boral locations across Australia and for other entities internationally, we have had our experienced Operational and Technical Group representatives review, analyse and report the information developed through this process. Boral understands the content intimately and has provided the technical content and operational guidance, appropriate for consideration prior to further practical development of important Norfolk Island infrastructure.

The information associated has been collated and is distributed through the two attached reports:

1. The ‘Investigation into Cascade Cliff & Review of Alternative Sites’ provides insight, analysis of the geology of the Cascade Cliff resource and other locations around Norfolk Island.

2. The ‘Mapping Resource Investigation’ provides analysis of the mineralogy of the resource at the Cascade Cliff.

We are committed to working collaboratively with NIRC in the upcoming Norfolk Island Airport Repair and Resurfacing Project to ensure this project is a success.

Please do not hesitate to contact me if you have any questions or wish to discuss in more detail.

Yours sincerely,

Chris Jeffery
Senior Project Manager
Boral Asphalt - Qld
M: +61 428 103 323
E: Christopher.Jeffery@boral.com.au

List of Attachments
1 - Investigation into Cascade Cliff & Review of Alternative Sites
2 - Mapping Resource Investigation

The attached documentation is intended to be used as a guide for general information purposes only and is not intended to constitute advice. The attached documentation must not be relied upon in any way by a party without that party first independently verifying the accuracy, quality and completeness of its contents, and any interpretations, deductions and conclusions made by or for the author. No liability, loss, damage or claim whatsoever will be accepted by the author, Boral Resources (Qld) Pty Ltd or its related bodies corporate (the Boral Group) arising out of or in connection with a party relying on the information contained or referenced in the attached documentation.

Investigation into Cascade Cliff & Review of Alternative Sites

Norfolk Island 2019

Prepared For: Norfolk Island Regional Council (NIRC)

Document Number: BORAL-NIRC-PLN-0001

Document Approval

Rev	Description	Prepared by	Reviewer	Approver	Date
1.0	Initial Issue	D Hackett	J Velez	C Jeffery	4 June 2019

Disclaimer

This disclaimer governs the use of this document. This is not a Joint Ore Reserves Committee (JORC) compliant resource / reserve statement. Use of terminology of including (but not limited to) “inferred”, “indicated”, “measured resource”, “probable,” and “proved” has been adopted to provide an indication only of geological confidence levels. No economic analysis (as indicated in the JORC 2012 guidelines) has been undertaken to determine the extraction constraint boundaries and depth for pit designs. This document outlines the data used along with the process of how the estimate was calculated only. Designs are based on property boundaries and adopted geotechnical guidelines applied as inferred from the previous extraction on site under the control of SMEC Holdings Ltd. All information contained herein is gathered from sources we believe to be reliable, however we cannot guarantee its accuracy. Appropriate care was taken in compiling the information herein however it is provided “as is” and Boral does not represent, warrant, undertake or guarantee the completeness and / or accuracy of the information. Interested parties should rely on their own enquiries. Under no circumstances should the contents of this document be relied on or used as an alternative to a comprehensive report in compliance with professional standards.

Executive Summary

From 24 - 28 March 2019, a review of the Cascade Cliff Quarry and alternative locations across Norfolk Island was undertaken by Boral Resources. The primary location for review is referred to as the Cascade Quarry. The quarry has not been operational for some years and had returned to a grass covered area. Remnant benching and old stockpiles remained on the site, however these stockpiles were not investigated as part of the site review.

Holes were drilled at three locations at Cascade Quarry and samples of chips and dust from the holes were collected. Additionally, rock samples (spall samples) were collected from the face of the basalt flow for testing.

The target area, a bench, is a small area projecting from the rest of the face of the cliff. The target area was selected by Norfolk Island Regional Council (NIRC) as a potential source of suitable materials for the Airport Overlay Project (AOP). The area was identified in tender documentation for the AOP. Boral had previous experience working with material from this source during the previous AOP in 2005. Testing has indicated the material in the target area fails to meet the standard for manufacturing asphalt in this airport application.

A range of tonnage estimates had been made prior to this review, however most were based upon observation, assumption and extrapolation. This report summarises the process of modelling the Cascade Quarry site using mining software, ground survey (drone) and modelling to more accurately estimate volumes within the site.

The resource estimate as at 10 May 2019 was:

Area	Resource (kt)			
	Inferred	Indicated	Measured	Total
Cascades Quarry target		13.5		
Total		**13.5**		

Note: This is not a Jorc[2012] compliant report.

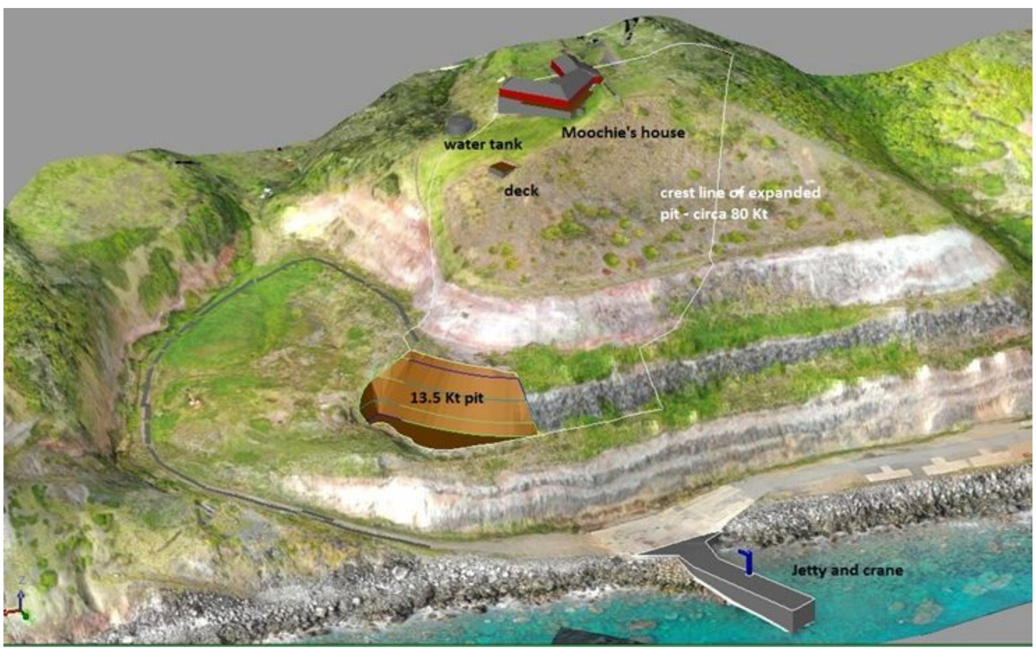
As at May 2019, there has not been advice confirming that the required approvals exist, therefore it is inappropriate to classify the resource reviewed as a “reserve” (according to JORC).

Boral has not completed an economic assessment at the possible project area, nor has any been provided for review.

In addition to testing the materials quality in target area, an estimate of time required to undertake a drill, blast, extraction and processing of this material was performed to gain a perception as to how this opportunity aligned to the AOP’s timeline (as defined in the tender documentation). Consideration was made of the plant and equipment required, their current availability on Norfolk Island, and other resources (including drill & blasting activity). Sourcing plant and equipment to complete the extraction of materials at the Cascade Quarry using industry standard equipment (used in Australia) was also taken into consideration. The intention of this exercise was to compare at a high level, the option of importing modern mobile crushing and screening equipment for the project versus using available equipment already on Norfolk Island.

It is our view that blasting of the basalt ledge would require off-island specialists to proficiently and safely break the rock. Other possible options identified included the use of expanding chemicals to break the rock. This process however, is typically applied to breaking individual rocks, the target area is formed of many small pieces of interlocked rock, rather then a small number of large lumps. The target area consists of a section of a large flow of basalt of more than 13kt and less than 20kt, which consists of many small pieces of rock. From the discussions with Council members, it is understood that the possible use of expanding chemicals (or grout) may have negated the need for blasting.

Discussions were held with a firm, Industry West Pty Ltd (based in Western Australia), which undertakes demolition and close proximity blasting to confirm the industry practices with this alternative materials. The discussion confirmed that the expanding grout is typically used for single rocks, granitic ground and concrete demolition. A rock mass of the type that flows at Norfolk Island consist of, are not amenable to expanding grout. Advice is that it may be technically possible despite an indicated excessive cost per tonne (approximately $4,000 / tonne). This process also requires small diameter holes (circa 45mm) to be drilled at about 1.0m deep and spaced at about 400mm. Therefore, this option is not recommended by Boral in this application.



Contents

1. Overview

1.1 Introduction

The contents of the report provides relevant information to the review and Boral's findings of the Cascade Quarry site. An overview of selected alternative quarry options on Norfolk Island has been included in this document..

Insufficient data was available at the three other sites, Puppies Point, Headstone Point and Cockpit, to determine the suitability for production of all quarry products.

It has not been determined whether the targeted basalt flow which extends across most of Norfolk Island, has rock of a suitable quality to manufacture all construction products, including the good quality asphalt aggregates. Preliminary tests have been performed on the samples collected at Cascades Quarry, as the area was identified by Norfolk Island Regional Council (NIRC). The results from the testing of the onsite samples indicates the material fail to satisfy the standard for asphalt aggregates as a single source. A visual inspection of the exposure indicates the rock quality is consistent throughout the flow.

As is often the case with selection of a quarry resource, compromises are required in the selection of the final location. Due to the small size of Norfolk Island (approximately 34Ha) and the level of development across the island (homes and commercial activities), identifying a site that does not excessively impact homes, businesses or an area of environmental value, is challenging.

Areas of lesser development (compared to other areas), such as Headstone Point may be a preferred option for further industrial development such as a quarry and supporting activities. Headstone Point is also the site of the Burning Pit and has been Norfolk Island's disposal site for some waste. Conversations with various individuals on the Norfolk Island and the NIRC highlighted that Headstone Point was a preferred location for both a quarry and alternative land backed wharf or pie. There was also support for the Puppies Point location, as was communicated to Boral staff by individuals on the island.

Norfolk Island is an extinct volcano (Mt Pitt) and the flow cone consisting of multiple flows and interlayered volcanic detritus ejected from the cone located approximately centrally on the island. The evidence is exposed around the perimeter of the island, in particular in the far eastern and far western cliffs leading down to the sea. Examples are present, at both north and south of Headstone Point (as seen from the memorial stone location) and are visible north of Cascade Pier (end of Cascade road) and south of Captain Cook Lookout at the end of Duncombe Bay Road.

Many reviewers have provided perspectives on the geology, and these are not revisited in this report.

The 2016 “Report on options for future supply of crushed rock on Norfolk Island”, adopted by NIRC on 21 December 2016 resolution 2016/143, along with the BCA report of 21 November 2018 were specifically used in this report and review. All other documents located on the Internet were read as background for this project.

Although Norfolk Island does not currently have an operating quarry, there is a demand for construction materials on the island.

From the “Report on options for future supply of crushed rock on Norfolk Island”

> *“3. Anticipated need for rock on Norfolk Island into the future 3.1 Road base & concrete Over the most recent 20 year period the average amount of rock taken from Cascade Quarry has been about 7,000 tonnes per year, but this has more recently dropped to between 2,000 and 3,000 tonnes per year (see figures below).6 The amount of rock likely to be sold in the next few years is not expected to vary greatly from this range of figures.*
>
> *Figure 3.1: Materials taken from the quarry, 2008 to present (21 Dec 2016 date of report)*

Year	*Screened Rock (tonnes)*	*Hard fill (tonnes)*
2008	*3906.58*	*950.96*
2009	*1645.66*	*1517.64*
2010 (to 22 Oct 2010)	*1299.10*	*296.12*

“

It was raised with Boral during the Norfolk Island visit by numerous people, including some members of the NIRC, that developing a quarry is a desired / required activity that the island would benefit from. As such, other workers have reviewed many on-island options. Each of the opportunities would require compromises between community need and individual, community or company impact.

Information provided to Boral during the March site visit, indicated there is a community desire to establish an extraction site (quarry) on the western side of the Norfolk Island, at which a new landing place (of undefined configuration) may be established. The intent appears to be to improve access to freight and seaborne tourism, which is predicted to improve Norfolk Island’s economic performance. This concept has not been addressed as part of this report and is outside the scope of this review.

1.2 Location

The primary site identified to Boral is known as Cascade Quarry. It has clearly been the site of extraction and quarrying, as well as civil cliff face engineering. The face of the exposure is adjacent to the pier and pier access, has been the subject of a Face Stabilisation Project (FSP), which commenced on 24 May 1999 and had a planned final completion of 29 Dec 2000. In discussions with numerous people, it appears the bulk of the rock used in the last airport overlay (circa 2005) originated from Cascade Quarry. On further investigation and discussions, it appears that much of the cliff stone was extracted and stockpiled in the area, known as the Quarry, during the FSP managed by SMEC Australia Pty Ltd (SMEC). The information provided to Boral indicates the materials were not sorted, were stockpiled, and later screened as a source of construction materials for Norfolk Island. Materials were stockpiled in the quarry and at Lot 44a.

Currently there is limited room for stockpiling quarry materials for either raw feed or processed materials on Norfolk Island, but in particular at the Quarry.

Other locations inspected were visited, but not mapped, sampled, tested or modelled, during the Boral project (March 2019). Our view on other locations is included later in this report.

Figure 1: Norfolk Island primary targets for quarry locations

1.3 Cascade Quarry

Cascade quarry is located on the eastern shoreline of Norfolk Island, approximately halfway from southern to northern island extremities and is located adjacent to the Cascade pier.

A quarry has existed at this location since at least 1999 when SMEC was engaged to undertake a FSP. This project resulted in a sloping face (the current face) which is safe and stable and has an overall angle up the face of around 45 degrees. The project (as far as Boral has been able to determine), was to modify the cliff face (as it has been described elsewhere) to a safer landform. The materials sourced from the excavation were stored at Lot44a on Cascades road and also in the area known as the quarry.

These materials were later used as various construction materials up to the current date. This resource is virtually exhausted. Remaining materials inspected had the appearance of being predominantly the tuffaceous material with small lumps of basalt mixed through. This material is not considered economic or suitable for most uses due to the low yield expected from screening to recover the lumps.

During the FSP, a small shelf of the main basalt flow was retained at the southern end of the upper main bench. This area was identified to Boral by NIRC as the preferred extraction site for the airport overlay materials supply as it is partially exposed and seemed logical to extract.

Boral on discussions, the NIRC was engaged to undertake a geological and quarry modelling design of this site to estimate available materials, quality of material, and then forecast use of the material on conclusion of the testing.

Site Image

Oblique view of NIRC preferred target, illustrating completed extraction, modelled pit in the bench identified by NIRC as primary target for AOP.

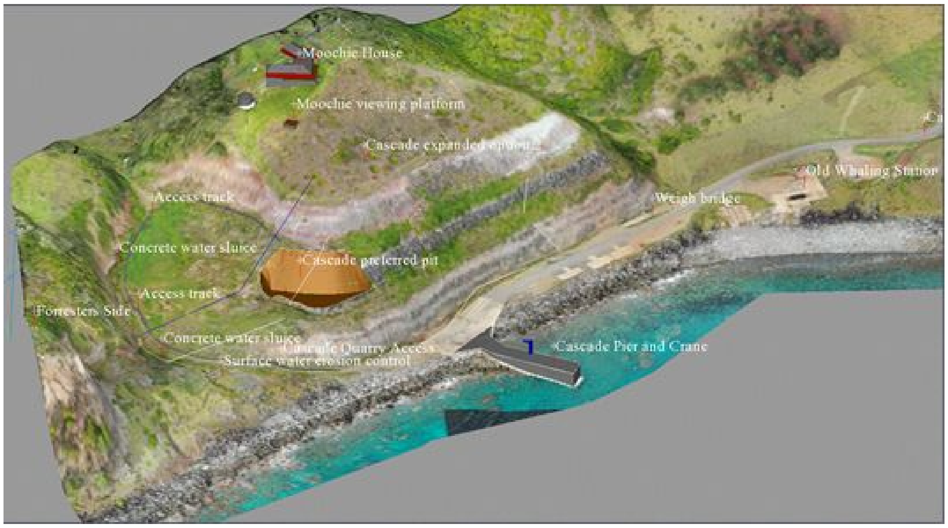


Figure 2 - Modelled Quarry

Data Collected and Used

The dataset collected was based on:

- Topography, sourced from a late 2018 drone flyover of the cascade area, captured and processed by Image Aviation.
- Rock quality:
  - A high level review of testing undertaken during previous airport overlay of products being laid on runway
  - Drill chips and spall samples collected in March 2019 by the Boral Geologist were tested in Australia.
- Drilling records from the on-island drilling of three test holes drilled into or through the target basalt flow in the area of land (thought to be) owned by NIRC and Commonwealth Govt. It is thought that no holes were drilled into land owned by John Moochie Christian, the third affected landowner. Best efforts were made to confirm the Youngs Road boundary, and due to the shape and size of the potential excavation, Youngs Road and Commonwealth land is thought to have been drilled.
- Land titles boundaries were sourced from documents provided by NIRC prior to and following on site activities.

- Observations of constructed fence lines, excavated portions, discussions with a local landowner, who pointed out some features of land ownership and comparison to plans available to the author of this report.
- Review of FSP to determine the landform designed by SMEC. The landform was copied for the purpose of the initial modelling undertaken.
    - This modelling is not a recommended final landform, but is intended to be in the "ball park" when one assumes SMEC undertook a far more detailed data acquisition exercise than Boral was able in a few days on site, supported by limited data gathering on the Internet.
    - This work should be considered a solid plan to further develop to create an operating plan in the future.
- Anecdotal data - Discussions with numerous island inhabitants who shared their previous experiences working with Boral during the previous overlay project and their knowledge of ownership, tonnage of rock, quality of rock as determined by them from other engineering works completed across the island, some of which had cursory examinations to consider how various concrete was performing with time and use.
- Discussions with both on-island crushing operators at various times including discussions on quality of products of crushing campaigns already completed.

Topography

The topography was deduced from drone flyover collected and processed by Image Aviation Pty Ltd in Nov / Dec 2018. Boral subsequently generated 1m contours over the surface created by the supplier.

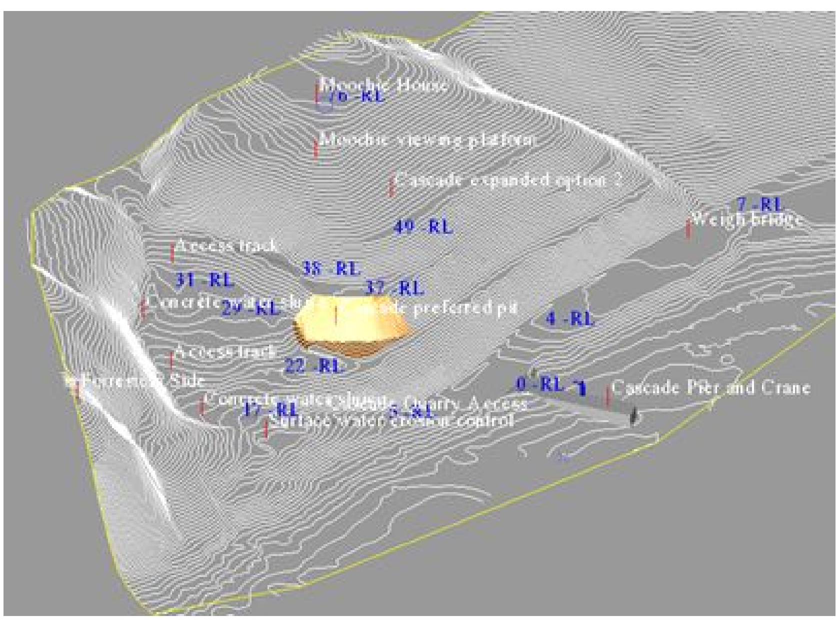


Figure 3 - Cascade topographical data used

Site Coordinate System

All data is in UTM system, position as metres of northing and easting.

Height Datum (above sea level, adopted from data set supplied). Actual datum point unknown.

Geological Modeling

Data collected was considered and with the use of geology and mine planning software, a model of the geology was generated. Subsequently an extraction model was also created.

The geology model was created digitally and was enhanced to include the following parameters:

- Topography
- Weathering (estimated, for rock soundness)
- Material types (only the target basalt was modelled as an individual unit)
    - The remainder of the rock pile was modelled as a single homogenised material type, as this was not of interest for the project.
- Ownership as determined from land boundaries (to aid in understanding possible impact on all landowners). The boundaries used and applied are approximate.
- Density of the target rock and "waste" rocks was estimated for the purpose of the project

The Mining Model

The mining model was created with the following parameters applied:

- Existing landform
- Indicated location of access road used inside quarry
- Estimated position of the bypass concrete open launder to divert surface water to the ocean discharge
- Cascade Pier, with crane
- John Moochie Christian's residence, water tank and viewing platform, all assumed from overlay aerial image
- FSP final face profiles, bench widths and face angles (assuming these would have to be created again at the end of any extraction in the quarry)
    - Information used in the design of final or back wall of excavation of identified area and an expanded larger extraction concept.
- Retained minimum 10m wide bench on the 37m (or 38m) bench, from which the test drilling was undertaken in March 2019
    - 10m was discussed during the NIRC extraordinary meeting on 29 March 2019 in chambers

- Boral initially assumed 7m while on the site, however modelling presented here uses a 10m wide retained bench at the nominal 37m bench, once having returned to Australia
- This reduced the extractable volume by approximately 5,500 tonnes

2. Geological Summary

Norfolk Island is a volcano cone on the Pacific Rim of fire. It is located on the submerged sea ridge which runs from New Zealand in the south, through to the Solomon Islands in the north.

2.1 Local Geology - Target Site

The cascade site is located on the remaining eastern edge of the cone (above sea level). Exposed at this location are a series of basalt flows and volcanic detritus, which has been expelled from the vent at Mt Pitt. Norfolk Island is the remnant of a larger volcanic cone.

2.2 Site Geology

The site consists of layered volcanic sequence of basalt flows and tuffaceous units interlayered. This sequence of flows is altered and weathered.

The fractured nature of the flow and many joint surfaces allow weathering within the rock mass as well as near surface.

This site has up to 80m of total depth of flow, the exposed cliff faces immediately north of the old whaling station are thicker.

Testing and review of the data indicates that the rock is a relatively porous basalt. This may pose changes to the actual end use application of the material to those desired.

It was observed that the full face had many flows within it, from strongly weathered (becoming clay) to relatively fresh, but also weathered. The fresher flow has less obvious weathering, however weathering does exist. During drilling of the target, observations of the operating drill (penetration rate, size of rock chips, type and tone of drilling noise) indicated the rock was of a higher quality than the testing confirmed. The small light drill rig was working toward its limit to drill the test holes and this resulted in an incorrect interpretation of this information.

2.3 Drilling Program

During the drilling of the basalt flow, the percussion sounds and rate of penetration hinted that the rock was of better quality than the laboratory testing has confirmed. On reflection, it may be due to the type of rig, its weight and the power it was able to apply to the drill bit in the holes drilled.

The dust generated and the ringing noise from the percussion are often indicators of hard fresh rock. However the laboratory testing does confirm the quality is less than that required for asphalt production.

2.4 Drill Hole Logs

The logs of the drill holes are below:

Hole ID: CasP2019-001		Log by: David Hackett	Drilled on 26 March 2019	
Rig: Ingersol Rand IR100, air track, 49mm diameter holes				
Depth interval (m)	Geology / Lithology	Comments	Colour	Hardness observation
0 - 1	Fill & soil			
1 - 2	Basalt	Weathered	Brown	Soft
2 - 2.4	Basalt	Dusty, small chips	Grey	Hard
2.4 - 3	Basalt	Fast penetration	Brown / Grey	Soft
3 – 4.5	Basalt	Basalt, fine dust, rate of penetration steady	Grey	Hard
4.5 – 4.7	Basalt	Fast penetration	Brown / Grey	Soft
4.7 – 4.9	Basalt	Slower	Greyer	Medium
4.9 – 5.3	Basalt	Faster penetration	Browner tint to dust	Medium
5.3 – 6.0	Basalt	Slow penetration (46 mins) Harder, grey, fine chips and dust	Grey	Hard

Hole ID: CasP2019-002		Log by: David Hackett	Drilled on 27 March 2019	
Rig: Ingersol Rand IR100, air track, 49mm diameter holes				
Depth interval (m)	Geology / Lithology	Comments	Colour	Hardness observation
0 – 1.4	Soil & Fill		Brown / Red	
1.4 – 1.6	Basalt	Possibly top of flow, fast penetration	Grey / Brown	Rapid / Soft
1.6 – 3.0	Basalt	Relatively harder, smaller chips. Consistent materials Consistent rate	Penetration at 4m /hr	Hard
3.0 - 5.0	Basalt	As above new rod		
5.0 – 5.6	Basalt	Softer, variable thin layers or weathered joints causing variable penetration rate	Grey with some brown zones	Variable soft / medium
5.6 – 6.0	Basalt	Harder again, grey. Variation less	Grey	Medium (57 mins rod 2)
6.0 - 9.0	Basalt	Grey, <100mm of soft sections, perhaps joints	Grey	Medium hard
9.0 – 12.0	Basalt	Grey chips	Grey	hard
12.0 – 12.9	Basalt	Small bands of soft material, joints probably, weathered basalt chips among hard chips	Grey / brown tint	medium
12.9 – 14.5	Basalt	Small chips, lots of dust, slow penetration rate, strong hammer noise ringing from rig	Grey	hard
14.5	Tuff	Broke though base of flow	Brown	Soft

Hole ID: CasP2019-003		Log by: David Hackett	Drilled on 28 March 2019	
Rig: Ingersol Rand IR100, air track, 49mm diameter holes				
Depth interval (m)	Geology / Lithology	Comments	Colour	Hardness observation
0 – 3.5	Fill & soil	Fill remaining on bench from previous stockpile		
3.5 - 6.0	Basalt	Coarse texture, chips and dust	Grey	Hard
6.0 – 9.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
9.0 – 12.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
12.0 – 15.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
0 – 3.5	Fill & soil	Fill remaining on bench from previous stockpile		
3.5 - 6.0	Basalt	Coarse texture, chips and dust	Grey	Hard
6.0 – 9.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
9.0 – 12.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
12.0 – 15.0	Basalt	Flat chips, significant dust, slow penetration	Grey / Dark grey	Hard
0 – 3.5	Fill & soil	Fill remaining on bench from previous stockpile		

2.5 Site Geological Rock Profile

Figure 4 - Cascade Cliff from Cascade Pier

2.6 XRD Analysis

A sample from the drilling at the site was processed and tested at Geochempet Services in Kipparing, Queensland. The sample selected for testing was the 6-9m interval of the second hole drilled. This hole passed through the base of the basalt flow at 14.5m and had about 1.0m of various fill materials from 0m-1.0m, therefore the basalt was in the order of 13.5m thick. The hole was located approximately 7m behind the face of the flow on the ocean side within the commonwealth lands.

XRD results are as follows and are expressed in weight %.

The result is consistent with a basalt rock group.

Primary Minerals

Mineral	Combined Holes 2 & 3	Hole 2: 6 - 9m interval
	Weight Percentage	
Plagioclase	58.3	50.6
Clinopyroxene	12.1	10.9
Olivine	8.0	10.5
Ilmenite	1.8	2.0
Hematite	1.5	1.4
Amorphous content	1.5	24.5

Comments

The interpretation is for this sample tested to be finely crushed basalt fragments. This aligns to the manner in which the sample was collected using the IR100 drill rig (airtrack machine) due to the relatively small size of this equipment, the material liberated from the drill holes was small as this drill was able to drill holes at a low penetration rate. The power of the air driven drifter (percussion force) was lower than an ideal more modern hydraulic drill rig would have available. This results in smaller chips and a greater percentage of dust being generated.

Taken directly from the Geochempet Report (pages 3 & 4)

> *"From XRD results, the -75 and -425 micron fractions appear to be essentially similar. The components regarded as essentially robust and benign components within the bagged fines sample amount to 81.6% and 75.5% respectively and are composed dominantly of plagioclase, clinopyroxene and olivine with minor amounts of ilmenite and hematite.*
>
> *There are traces of smectite clay present in the extracted powders from bagged fines samples. The amorphous content (18.4% and 24.5% respectively) is suspected to be iddingsite (a mineraloid mixture of smectite clay and secondary iron oxides) which cannot be identified by the XRD analysis. The lower iddingsite content in the -75 micron powder may be related to coarser size of iddingsite fragments.*
>
> *Thus, the -75 and -425 micron powdered fines are of similar composition and are considered to be mostly very finely crushed basalt rock fragments with some liberated mineral grains and iddingsite fragments."*

2.7 Spall Samples

Inspection of the spall samples was undertaken at Boral's Whinstanes Technical Services Laboratory, where it was noted that relative to other basalt sources that Boral processes, the samples were "light". They provided a dull response to being struck by and against a hard steel object. Inspection of the surfaces of the samples indicates there is an alteration or weathering layer on most samples to approximately 2.0mm into the material.

The samples were collected from the only locations accessible and assessed as safe enough on the ocean facing side of the cliff face. The samples were collected from an area of about 15 linear metres of face which could be reached while the geologist was standing on the ground. All best efforts were made to avoid joint fill materials and other surface coatings which were most likely deposited by precipitation surface flows from further up the face of the bench above.

The interpretation is that the rock does not meet the specification for airport resurfacing.

2.8 Resource Investigation

The program involved pre-work in the week before traveling to Norfolk Island. The short timeline was created by the negotiations on Boral forming a small team to address aspects of the AOP. An agenda for the week on the island and agreement from NIRC as to aspects of the trip was exchanged and addressed.

Arrangements were made quite quickly, preventing a long lead in and a more intensive a deeper review of data sets and previous work across the island on the topic of rock resources accessible on the island. Boral responded to a specific request from NIRC for the Cascade resource review and also a review of the remainder of the island resource via the Purchase Order supplied.

Cascade Site

As was proposed by Boral, a short drilling and exposure inspection at this site was completed. The only drilling equipment on island was contracted to drill the holes. As previously mentioned the equipment was small and while proved a reliable machine, it was not very powerful. Therefore, the rate of penetration was low and it took all of the available time to complete three holes for a total of 35.5m.

Other factors which impacted the program and were not understood prior to arrival to Norfolk Island include:

- Acceptable hours of work due to noise and dust generated during the program
- Objections from community members over the persistent and ongoing drilling activity on Day 2

- Day 3 drilling was curtailed with a later start and an early completion to do the best to allay community objections while managing to drill the area identified
- Once on-island and the site was inspected it became clear that the initial proposal included areas that were not to be excavated, therefore some drilling was culled from the program
- The holes were prioritised following site inspection and were drilling in order of priority
- Three holes were excluded from the program as they were located on the lower bench, which was not included in the target area
- The equipment used was under the circumstances was also only able to complete three holes of the original program. No other equipment existed on the island to undertake this program (to Boral's knowledge)

Information which was provided while on Norfolk Island further reduced the area to be considered due to requirements to retain a wider bench post extraction at 37 bench level, than had been estimated on the ground during the commencement of drilling. The retained bench (in the mining model) was increased from an estimated 7m to an indicated 10m as stated in the SMEC report associated with the Cliff Stabilisation Program report.

2.9 Program Summary

No previous investigations information was available in any format for this investigation.

This table provides a summary of the exploration and definition programs and activities completed at the site.

Program	Type	BHIDs	# Holes	Metres
2019	Percussion	P2019_001 to P2019_003	3	35.5

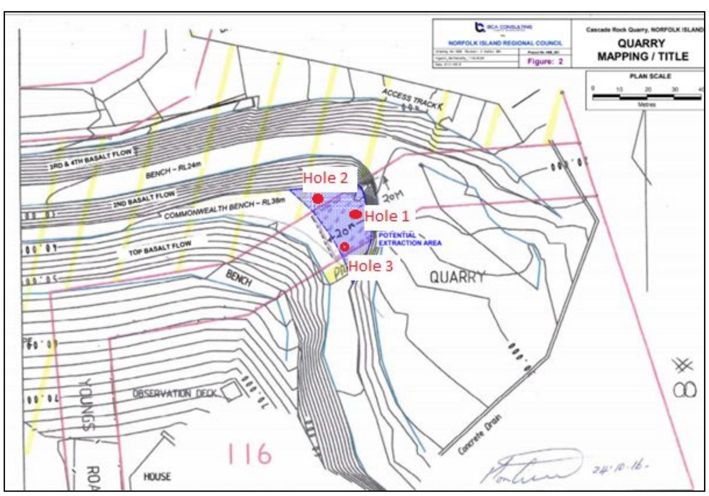


Figure 5 - Drill Hole Locations, March 2019

2.11 Geological Mapping

No field mapping of outcrops or quarry walls have been undertaken during the program, as the area was small and mapping did not add to the outcome.

2.12 Geological Structures

The rock mass is part of a deep layered volcanic sequence and contains numerous layers of basalt and interlayered tuffs. The target flow is blocky with block size range from sub 100mm to an estimated maximum size of 3m. The majority appear to be between 0.5m and 1.3m.

The rock mass is tightly packed and interlocked with some weak patterns in joint directions particularly in the vertical joints that may indicate early columns formation.

No geotechnical data was collected during this project.

The target layer is 14m to 15m thick at the target site. It shows reasonably consistent characteristics of colour surface breaks patterns, weathering and joint patterns.

2.13 Geophysics

No geophysics has been undertaken on this site.

2.14 Laboratory Testing

Samples were collected from rock spalls on the face where safe access was afforded. Drill cuttings and dust were collected as individual 3m samples, and also as large composite samples for each hole.

The samples (approximately 60kg) was dispatched to Australia and once passed customs, were processed at Boral's Eagle Farm NATA certified laboratory.

2.15 Alternative Sites Reviewed

In addition to reading reports and undertaking a high level Internet search for data on the geology of Norfolk Island, a short list of sites were indicated to Boral as being considered acceptable to the NIRC and the community as an alternative to Cascade resource.

The list of sites is (those discussed):

1. Headstone Point
2. Puppys Point
3. Cockpit

These are in order of probability, as was indicated to Boral by NIRC during discussions in the Extraordinary Council Meeting. No specific rank nor any other detail was provided. The discussion was general, however it appeared Headstone Point was a preferred option based on the interest and details were shared. It was mentioned that BCA consulting had been engaged (as well as a diamond rig was being mobilised to the island) to undertake a resource investigation and it was assumed by the writer, a quarry plan for Headstone Point.

On review of the opportunities afforded by each site, the potential for resource, the access likely required to develop a modern and efficient quarry footprint (access, extraction, processing or stockpile before processing, possible product stockpile area and eventually a new weighbridge), was assessed and they appear here in the order of rank. However it is important to note that it is not possible to develop working quarry concepts without suitably detailed site topography, geological and geotechnical data. Economic and community impact (along with benefits) are required to complete any assessment. This has not been done in this project.

As was requested of Boral, a full site review was undertaken to consider the merits of each site and many other locations around the island in consideration of the operation of a modern quarry. Headstone Point was considered the best site (of this list) for an alternative quarry, due to the negligible development neighbouring it (biggest buffer to housing, least housing inside 350m from location, etc.).

Puppys Point was second choice due to the height of the steep terrain above Puppys Point. Other information on the island (community members) indicates that a proposal had been completed (perhaps a decade or so earlier, date unknown) to establish a quarry with a cliff face road running down the face to the south, accessing a manmade platform on the rock formation at about water level at this location. This proposal would impact the local house to the west (closest residence) and Anson’s Bay Road.

Topographical information has been used (indicative not accurate) which confirms that the cliffs are about 60m high on most of this coast with small local areas lower than this in height. To develop a road across this type of rock face and to have it “safe & stable” for years following, would likely require an engineering solution of either a sloping cut face (like the FSP at Cascade) or a supported face with some form of steel and concrete engineering structures to support, which are expensive to install and require replacement over time.

Others that were separately indicated as potential but less likely to be acceptable included:

1. Ansons Bay

    - Lower priority due to the tourism value of this bay, the proximity to houses effectively overlooking the bay

    - Is a location for surfing and generally aesthetically pleasing with a white sandy beach

    - A picturesque location with associated elevated tourism value

2. Ball Bay

    - An inspection of the outcrop in the faces of the valley (on Marshs Road) indicates much of the rock in this area is very soft, deeply weathered and unsuitable for construction material aggregates. To excavate at this location, would generate very large volumes of unwanted materials in excess of the volumes the island would use in a decade or more.

    - The bay is of significant interest to the community and tourism due to the concave shape and rounded boulders of basalt along the shoreline

    - It is also the site of the fuel import and storage facility, not a co-use that would be suited to a quarry extraction activity adjacent to it

3. Rocky Point

    - Is on the Rocky Point Reserve, the cliffs on the western aspect of the headland are an extension of those at Headstone Point and can be seen from Headstone Point.

    - There is no specific information provided to Boral regarding possible concepts, therefore it is assumed the west side of the Rocky Point would be the preferred location

    - This area was not inspected from the ground due to time frame restrictions

    - The challenges in accessing this location appear greater from a community perspective due to the risk of higher impacts on housing and the reserve

4. Pop Rock

    - This site was not located during the on-island investigation. It is described as a basalt outcrop requiring further investigation (BCA 21 Nov 2018)

    - A paddock of boulders which is currently exploited to a small scale to source materials for construction, may be an on-island useable resource option. This material requires hammering and breaking to lump size suited to the primary crushers on the island.

2.16 Expanding materials Rock Breaking (expanding grout)

This approach is outside Boral's normal operating scenarios. It is typically used for small scale (one or two 3 tonne boulders) type of project industrial or civil engineering work, such as excavations for foundations of buildings or in locations where the ground is too hard for excavator or dozer work and explosives can not be used.

A review of possible options indicated the following:

1. Expanding grout type materials
    - Typically used in boulder breaking
    - Best applied in massive and reasonably homogenous materials with little or no visible cracks, joint or other features
2. PCF – a gaseous but not high vibration type of explosive
    - This has little vibration or damage to nearby structures and uses expanding gas to open cracks in rock and "push" the rocks apart.
3. Hydraulic breaking using water as the medium with extremely high forces or shocks applied using a variety of mechanical devices.
    - This method can be noisy
    - Typically used in concrete or boulder breaking

Each of these methods requires the drilling of holes. The equipment will vary, however drilling into hard rock requires the use of noisy equipment in some format. There are custom made drilling equipment and robotic drilling / placing equipment on the market used by civil contractors, all of which introduce a range or performance and environmental issues.

Expanding Grout cost estimate example

This method typically requires short holes drilled at 400mm centres (spacing) and of 45mm diameter.

Estimation of holes required for one 'cut' assuming the holes can be 1.0m deep

Area = 370m^2

Hole spacing at 0.4m requires one hole per 0.16m^2 (0.4 x 0.4 = 0.16m^2)

Number of holes 370 / 0.16 = 2,300 holes per 1m lift and 14 lifts.

This will require a significant number of holes to be drilled. The other methods indicated also require significant of drilled holes to place the materials within the rock mass. The advice received is that this would also be an expensive exercise with in some contracts estimates as high as $900 / m^3 being quoted in basalt.

3. Estimates of Volume & Tonnage

3.1 Requested Site

An estimate of the volumes and tonnages of materials at the requested site location has been completed by applying the available data. The outcome or estimate will change as any of the variables are changed.

It is important to note that this estimate does not comply with JORC 2012. Best efforts were made to use the few days to estimate an indicative quantity of materials.

A further extrapolation of a hypothesised larger quarry has been made and is presented as one possible scenario for expansion. This quarry requires the removal of the residence above and assumes the FSP parameters will be repeated in the new excavation face.

This extrapolation is presented to indicate what tonnage may be extractable and also the impact an expansion would have on the locality a second expansion would be possible to remove the rest of the basalt flow closest to the council weighbridge.

Area	**Resource (kt)**			
	Inferred	Indicated	Measured	Total
Basalt flow		13.5		13.5
Total		**13.5**		**13.5**

The resource has been identified as indicated where the small bench is proud of the rest of the cliff.

Drill holes close to the extremities of the triangular footprint were drilled.

The face was inspected. The back limit of the zone estimated is the assumed position of the face retaining a 10m safety bench on the nominal 38rl bench.

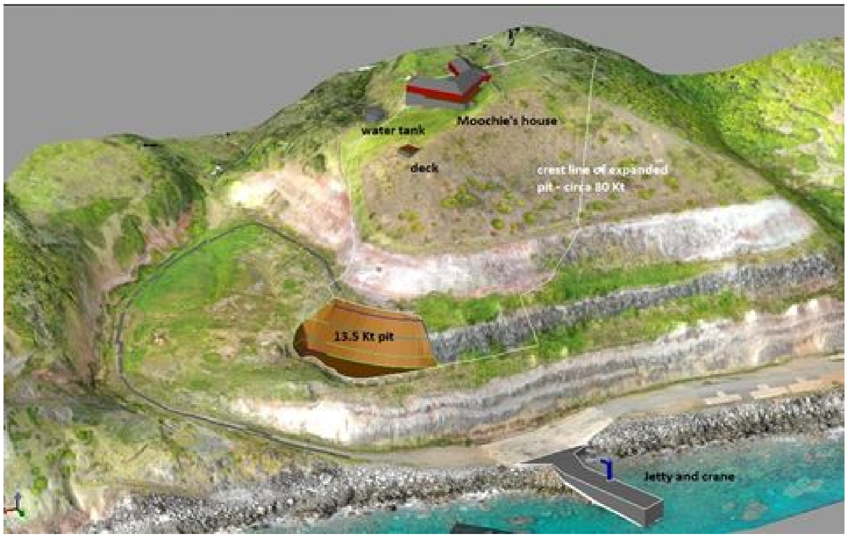


Figure 6 - Modelled Quarry

Procedure

Data was compiled and using Geovia Surpac mining software a geological model (surfaces) and Geological Block model were compiled. A quarry design was developed applying parameters taken from the topographic data (drone flight data) and then applied.

The result is a relatively small quarry shell design that potentially allows for approximately 13.5kt of extraction and develops / retains the FSP in this area as an extension of the rest of the face.

Pit Design

The design viewed from the east and from a modelled altitude of 60m ASL has this appearance.

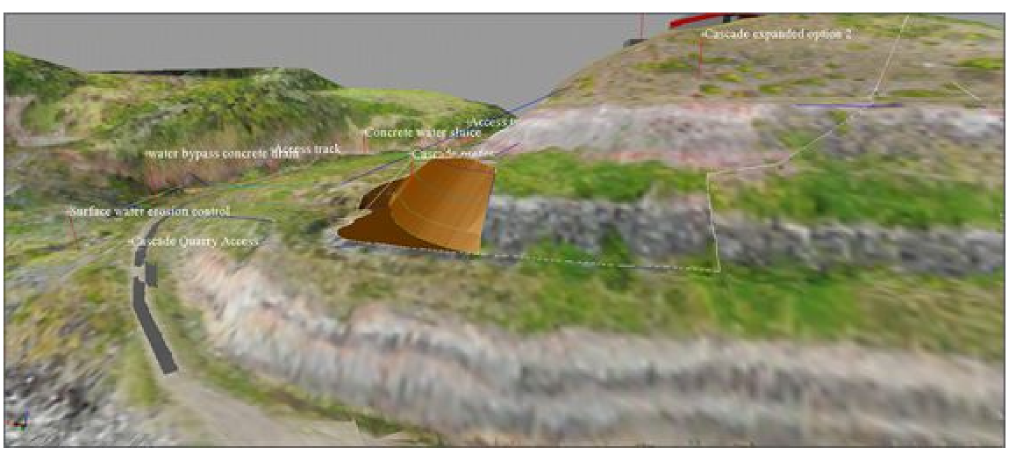


Figure 7 - Quarry viewed from the east

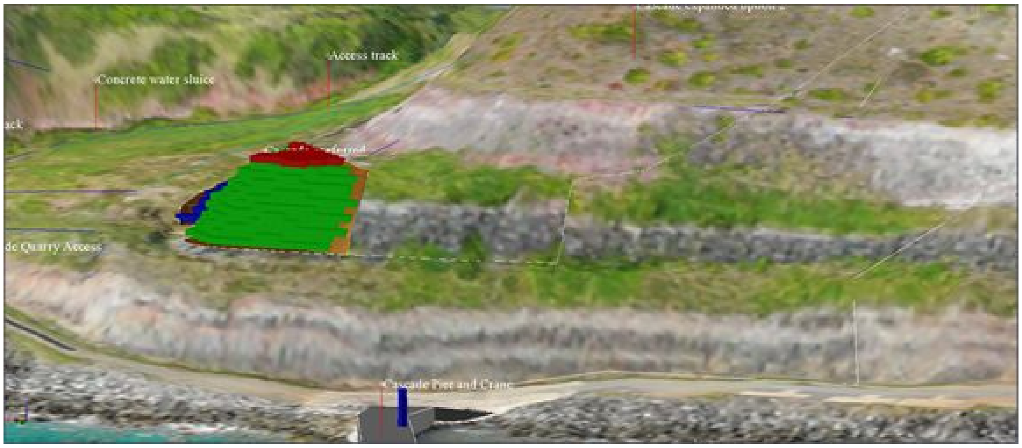


Figure 8 - Geological Model (Basalt flow shown in green)

Resource Summary

The resource for the defined excavation was estimate as at 30 April 2019 was:

Area	Resource (kt)			
	Inferred	Indicated	Measured	Total
Basalt flow		13.5		13.5
Total		**13.5**		**13.5**

This is based upon the review, geological modelling, quarry model and reporting of the combined dataset.

The constraint applied of the retained upper bench being 10m has caused approximately 5,500 tonnes of material estimated to be accessible being removed from the final numbers used in this report.

A number of the variable used could be changed to adjust to the quoted tonnes, however without a materially impacting change (such as significantly excavating the complete wall), a major change to tonnage excavated is unlikely.

This resource tonnage can be categorised as a JORC equivalent to JORC confidence of 'Indicated'.

Boral is not making a statement in this report that it is JORC compliant and does not warrant the values here quoted as such.

Any decision to operate this quarry resource should not rely on this report alone, it may only be considered as a concept review.

It is strongly recommended that further work is required to test the concepts discussed and to develop a commercially acceptable confidence in geology risk, geotechnical risk as well as mining process risk.

In any process, all steps should be taken to address the concerns of all regulators and the community.

3.2 Expanded Concept at Cascade Quarry

At the council meeting, it was agreed that an estimation of the expanded quarry would be provided for reference.

It is important to note that Boral is not recommending this option as being viable. Boral has compiled this concept to assist with the understanding of alternatives to the NIRC target area. It is intended to allow a discussion which clarifies what has been considered and to raise the issues associated with such an expansion.

The issues this highlighted include:

- Repeat FSP face profiles
- Assume only a narrow extraction of the basalt is made and it is a longer strip along the face
- All materials above are of no value and are mixed on extraction
- Only limited extraction of basalt is required over the next 20 years (ignoring possible airport overlays)
- It may be possible to make a second expansion along the face to release an additional circa 40kt of basalt and perhaps ~150kt of additional mixed materials (this has not been modelled nor included in the totals)

This expanded concept has little technical input, but follows the general principles determined from the review of the FSP, and the rest of the drilling / testing done on the target area.

The expanded concept (note this is a concept, not a completed or fully appraised model):

Location	Geology	Inferred Resource (kt)	
Commonwealth Buffer	Basalt	43.5	
	Undifferentiated Tuff & Basalt (weak)		20.3
Youngs Road	Basalt	12.6	
	Undifferentiated Tuff & Basalt (weak)		78
	Quarry Fill (previously quarried and placed)		0.2
Moochies Land	Basalt	0	
	Undifferentiated Tuff & Basalt (weak)		109
	Quarry Fill (previously quarried and placed)		.02
All tonnage listed is inferred only		56	207
		Basalt	Other material

The expanded concept, referred to in the table above is based upon an extrapolation of the geology, assumptions about geological units and a significant lack of data in areas beyond the NIRC target area reported earlier in this report.

To achieve these additional tonnages, it is necessary to remove the house above the quarry, the deck and the water tank shown. This is as a result of application of the FSP face slope angles to retain the established face stability.

Other solutions may exist, but have not been considered for this report.

The expanded quarry model showing the target quarry for comparison of scale, is shown in Figure 9.

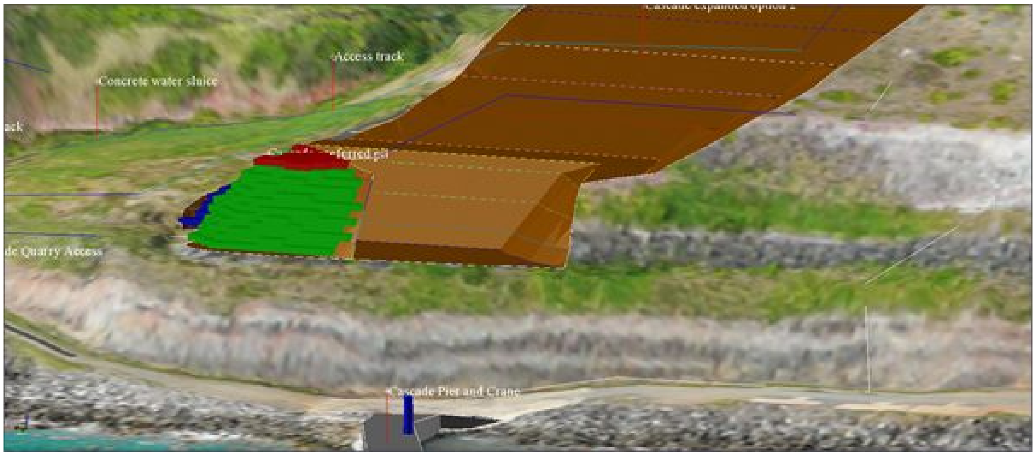


Figure 9 - Expanded Quarry Concept, shown with Target tonnage as reference

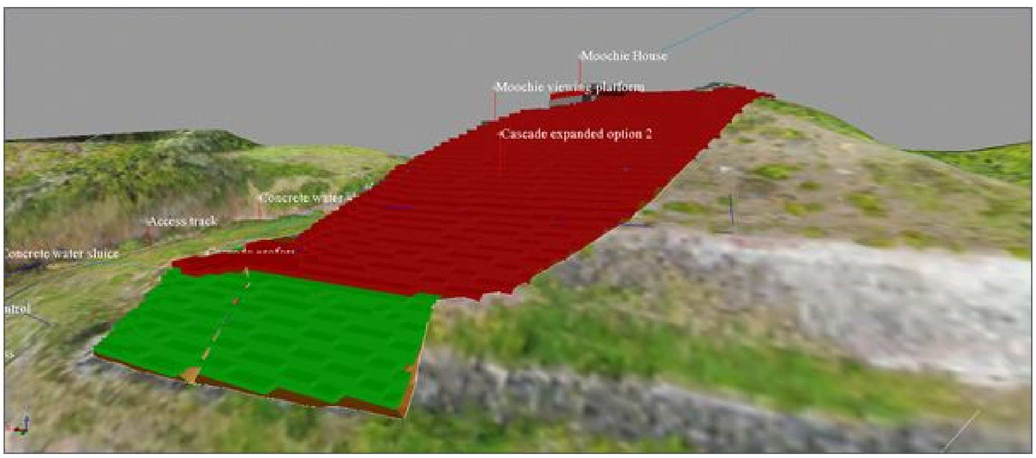


Figure 10 - Expanded Quarry Concept, showing Modelled Geology

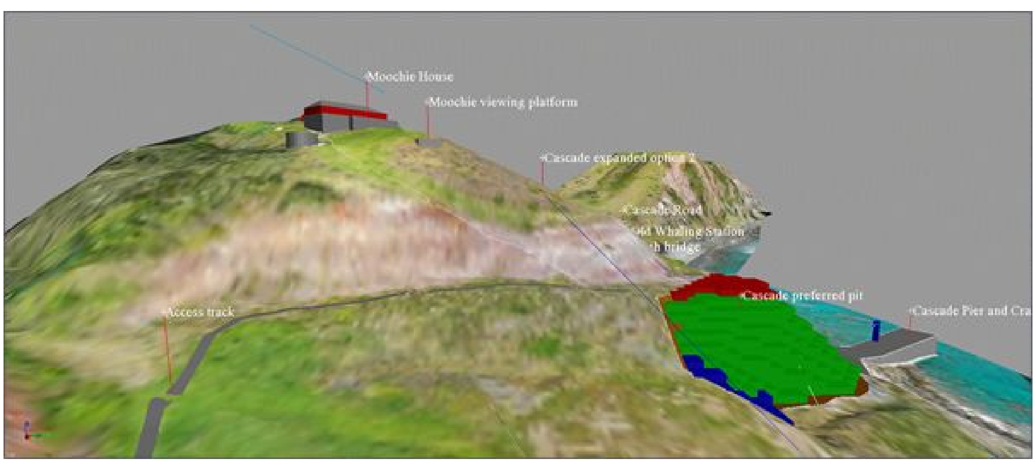


Figure 11 - View to north showing Moochie House, Deck, and Water Tank - above Target

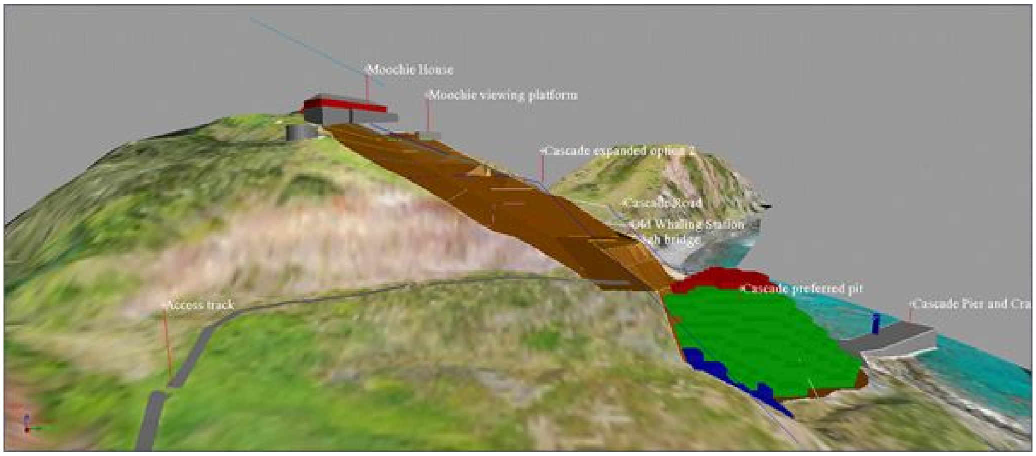


Figure 12 - View from north with modelled pit removed. Showing FSP repeat compromises house

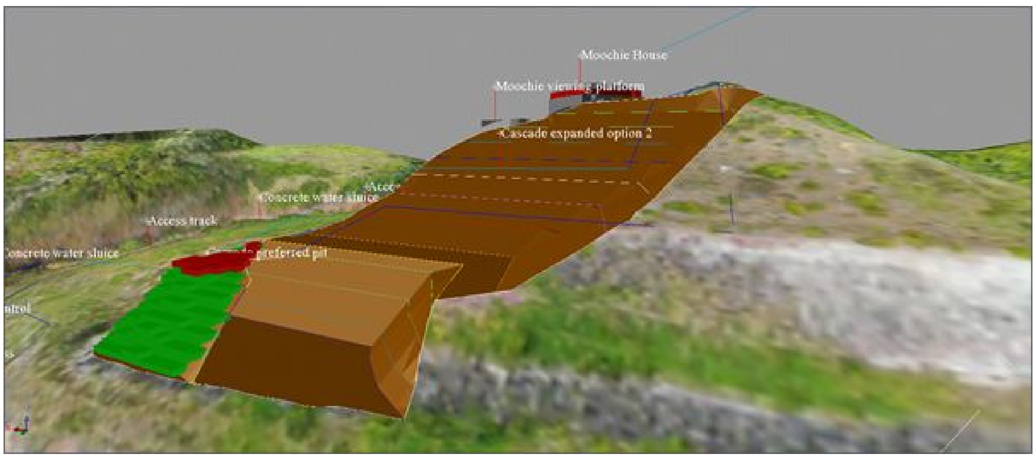


Figure 13 - Expanded Concept with view of Geology Model displayed (Green is Basalt flow, Red is undifferentiated materials)

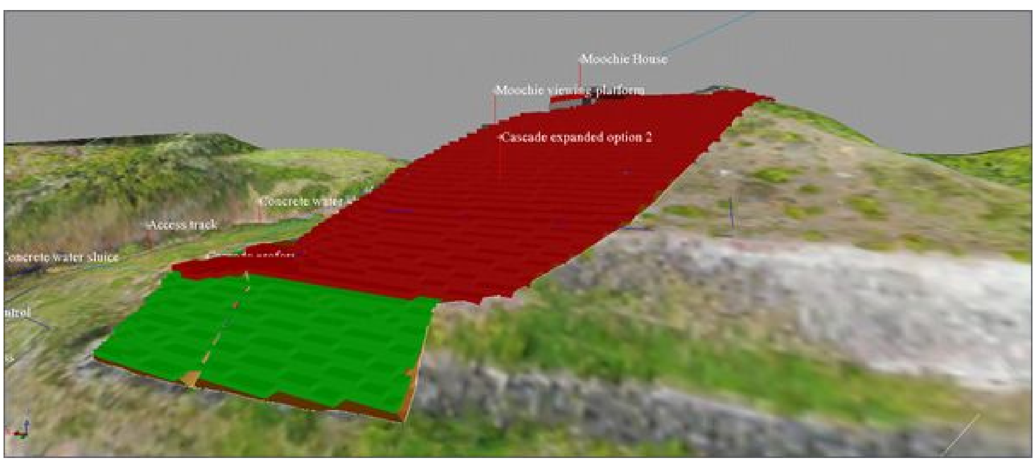


Figure 14 - Model filled with Excavation Image

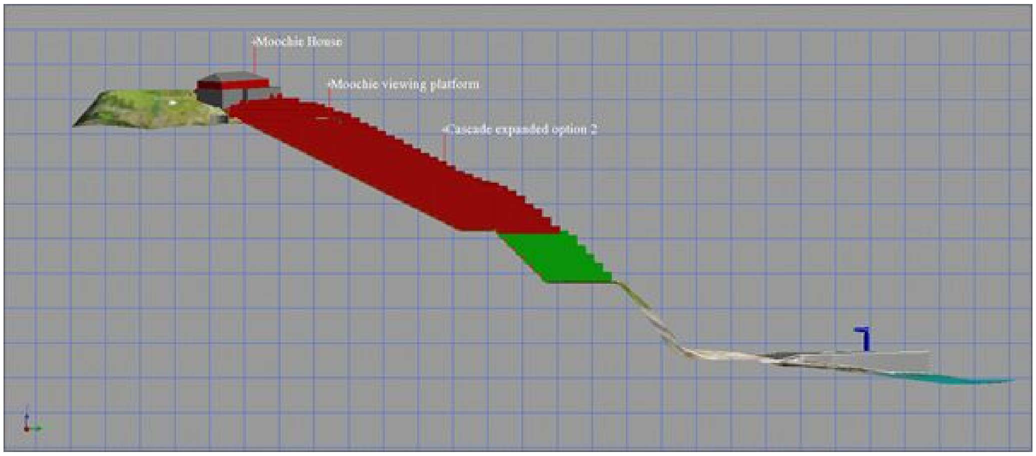


Figure 15 - Sectional View from south to north, indicating how excavation would compromise the House

Procedure

The previous model was expanded using assumptions regarding consistency of geology and dimensions of flow.

Then a new quarry concept was created and the two compared for tonnage reported above.

4. Risks

4.1 NIRC Target

The following preliminary risks have been identified:

Category	Risk (There is a risk that…)	Rating	Mitigation Options
Basalt	Fails to meet specification required for the Airport Overlay	Moderate	• Replace with alternative source • Blend with better material delivering a compliant blend
Extraction	There is inadequate time to apply for and receive approvals	High	• Apply as soon as possible • Identify an alternative resource, which has approvals • Delay overlay project using materials
Approvals	There is a lapse to the operations approval	Low	• Seek renewal prior to expiry date
Geology	Rock quality may vary impacting product compliance. (rock is a naturally variable material	Moderate	• Have a larger volume of material available which allows selection of compliant material • Plan for excess raw feed so the lower quality material can be used for lower specification products
Geology	Useable volume is lower than projected. Geotechnical or other access issue reduces volume of planned extraction.	Moderate	• Have a larger resource available • Blend alternative material • Reduce planned end use • Change planned end use
Operational	Hours of daily operation required may conflict with community expectations	High	• Plan for reduced hours • Operate efficiently to minimize total duration of operation • Engage community and compensate members for the inconvenience
Operational	Area at Quarry is inadequate for all activities	Moderate	• Identify alternative off site location for stockpiling
Environment	Waste emplacement could slump	Moderate	• Determine impacts on safe storage (water, drainage, compaction, material properties) • Determine engineering design • Construct to design profile and placement guidelines
Weather	There is an uncontrolled release of storm water during a weather event	Moderate	• Maintain water management system
Weather	Weather slows or halts safe operation in quarry	Low	• Commence operating early to provide buffer allowing for processing halts
Management	There is a breakdown in communication between groups that may lead to variations	Moderate	• Ensure all people involved maintain the open and clear communication on changes seeking approval for variances • Set clear documented goals • Have an operating plan which details what actions, when they will occur, who is responsible to deliver

4.2 Expanded Quarry Concept

The following risks have been identified to illustrate issue with this type of concept and work that would be required to test this concept prior to any engagement in developing such a concept. This list will need review and expansion prior to any further work on this concept.

The following preliminary risks have been identified:

Category	Risk (There is a risk that…)	Rating	Mitigation Options
Basalt	Geology model is inaccurate	High	• Undertake a full resource investigation program • Diamond drill through the target zone to collect samples for testing. • Ensure drill holes also provide confidence in further expansions to such a concept.
Extraction	There is adequate room to operate this expanded quarry	High	• Undertake an operating plan of the site with attention to various material volumes, machine selection. • Consider stock piles of discrete materials not one pile of all materials • Consider onsite processing or off site processing
Approvals	Approvals are difficult to achieve	Moderate	• Seek renewal prior to expiry date • Develop a strong and suitably detailed project outline to address all issues facing the application
Geotechnical	The area may need to be extracted to manage localised, but important weaknesses in the rock mass to retain stability	Moderate	• Include a suitably detailed geotechnical data collection and interpretation • Ensure a face is maintained that addresses risk to operations and the community below at the pier

Boral Risk Assessment Matrix is attached in Appendix 1.

5. Remaining Issues

Boral has not undertaken a full economic review of this site as some aspects are unknown.

As was discussed with Council, it is thought that the delivery date for the quarry is problematic for the delivery of the airport overlay (regardless of volumes at the quarry) due to the time it would take to drill, fire, load and haul then process the rock on Norfolk Island using the infrastructure available. The delivery date for the AOP is a major constraint on the success of establishing Cascade Quarry.

Testing has indicated the rock does not meet the applicable Australian standard for asphalt aggregates.

Delivery of materials (including plant and equipment) is on a timeline that is dictating actions. It has been estimated elsewhere and discussed at the Council meeting, that the timelines for operating the quarry in rapid and efficient manner is a challenge. Boral would have to mobilise a hydraulic drill rig and explosives experts to Norfolk Island in time to undertake quarrying.

Boral has considered using the available on-island crushing equipment. In response to a question from the NIRC regarding mobilising an off-island crushing train to the island, the processes required to mobilise a crushing train to the island is hampered by the lack of approvals for the quarry.

6. Possible Alternative Use for Cascade Quarry

Discussions on the island included the possibility that the Cascade site could be retained and operated over a longer time frame to supply construction materials to the local demand, and not target the AOP.

Using Cascade as a quarry for ongoing construction activities on the island would provide the benefit of:

- Support the on island industry in the period following AOP and prior to a new quarry resource being established
- Provide an opportunity to finalise the quarry rehabilitation at Cascade

7. Recommendations

The quarry is not considered a source of materials for the AOP due to:

- Not meeting quality specifications
- The quarry has no approvals
- Tonnage available would at best be blended in with high quality of stone sourced from off island (considering the CASA timelines)
    - Assuming a quarry can be recommenced, operated and material prepared in time for blending and testing of products for the airport overlay
- Prospects of approvals appear poor at end April 2019
- Lack of suitable equipment on the island to operate the quarry at a commercial production rate to meet AOP consumption demands (when delayed approvals considered)
- Lack of commercial blasting resources on the island to enable mitigation of the risks surrounding drill and blast at the quarry
- Resource could be used to support and maintain the on-island construction industry until a replacement or expansion is achieved

List of Appendices

1. Boral’s Risk Assess Matrix

List of References

No.	Document	Source
1	Administration of Norfolk Island Vs SMEC Australia Pty Ltd [2004] NFSC	https://jade.io/article/331207
2	THE ADMINISTRATION OF NORFOLK ISLAND REPORT ON OPTIONS FOR FUTURE SUPPLY OF CRUSHED ROCK ON NORFOLK ISLAND Author: Alan McNeil, Acting Manager Land Use & Environment October 2010 Adopted by Norfolk Island Regional Council 21 December 2016, Resolution 2016/143	http://www.norfolkisland.gov.nf/sites/default/files/Future%20Supply%20of%20Rock%20Alan%20McNeil%202010%20Adopted%20Dec%202016.pdf
3	Cascade Quarry Development Options & Alternative Quarry Rock Options BCA Consulting - Earth Resources Basi Notoli 21st November 2018 BCA Project Ref: N09_001	NIRC April 2019

Appendix 1: Risk Assessment Matrix

A "4 x 4" risk assessment matrix is to be used to assess the risks identified through Boral's Managing Risk framework. All risk factors are to be applied on a residual basis, post the impact of **CURRENT** control and mitigation strategies in operation within the site, business unit (BU) or division.

Consequence/Impact				Rating	Risk Factor			
Operational/Reputational	**Financial**	**Health & Safety**	**Environment**					
Severe impacts to production or supply with long term operational consequences and material remediation costs. Widespread industrial action. National brand exposure with long term reputational damage. Risk of regulatory prosecution of Company Officers.	>20% EBIT loss	Risk of fatality or life-shortening effects and permanent significant disability.	Permanent or long term destruction of habitat through contamination of the natural environment.	Severe (4)	4	8	12	16
Significant impact on production or supply with medium term operational consequences and material remediation costs. Targeted industrial action. National brand exposure with medium term reputational damage. Risk of formal regulatory intervention at multiple sites.	10-20% EBIT loss	Risk of significant life impacting illness or minor permanent disabling injury.	Extensive and measurable medium term environmental impacts.	Major (3)	3	6	9	12
Material loss, delay, or interruption to production or supply with medium term operational consequences and limited remediation costs. Regional brand exposure with short term reputational damage. Risk of formal regulatory intervention at a single site.	5-10% EBIT loss	Illness requiring high level medical treatment or injury leading to lost time.	Localised and measurable medium term environmental impacts.	Moderate (2)	2	4	6	8
Some loss, delay, or interruption to production or supply with short term operational consequences and minor remediation costs. Regional brand exposure with limited reputational damage. Risk of punitive regulatory actions is unlikely.	1-5% EBIT loss	Mild illness or injury requiring low level external professional medical assistance.	Localised and measurable short term environmental impacts.	Minor (1)	1	2	3	4
					Unlikely (1)	Possible (2)	Likely (3)	Almost Certain (4)
					The risk is possible or has occurred in the industry albeit infrequently.	The risk is possible in the medium term (next 3-5years) or has occurred in the last 5 years .	The risk has eventuated within Boral in the past or is expected in the short term (next 3 years).	The risk is expected to occur at least once annually.
					Likelihood / Frequency			

Rating	Action Required
Extreme	Risk mitigation strategies to be implemented immediately. Frequent reporting of the status of the strategies to be provided to the Group/Divisional Executive.
High	Additional control measures to be implemented in the short term to reduce the residual risk. Regular reporting of the progress of the strategies should be provided to regional or BU management.
Medium	Management are responsible for ensuring that adequate safeguards are in place and operating. Control measures to be implemented in the medium term to further mitigate the risk.
Low	Risks to be managed through routine procedures.

Mapping Resource Investigation

Norfolk Island 2019

Prepared For: Norfolk Island Regional Council (NIRC)

Document Number: BORAL-NIRC-PLN-0002

Document Approval

Rev	Description	Prepared by	Reviewer	Approver	Date
1.0	Initial Issue	J Velez	D Hackett	C Jeffery	4 June 2019

Disclaimer

The attached documentation is intended to be used as a guide for general information purposes only and is not intended to constitute advice. The attached documentation must not be relied upon in any way by a party without that party first independently verifying the accuracy, quality and completeness of its contents, and any interpretations, deductions and conclusions made by or for the author. No liability, loss, damage or claim whatsoever will be accepted by the author, Boral Resources (Qld) Pty Ltd or its related bodies corporate (the Boral Group) arising out of or in connection with a party relying on the information contained or referenced in the attached documentation.

Contents

1. Introduction

Norfolk Island resource has been tested and analysed as a potential raw material constituent to manufacture high quality aggregate products for the overlay of Norfolk Island Airport. The resource is an Olivine Basalt from medium to high degree of weathering located at an existing source on Norfolk Island at what was the Cascade Quarry at Cascade. The intent of this report is to fully investigate by technical analysis the quality of the resource and the material performance in the manufacture of aggregates for incorporation into an asphalt mix design suitable for the Norfolk Island Airport Repair and Rehabilitation Contract.

Due to the fact that aggregates (coarse and fines) comprise about 60-75% of the total volume of an asphalt mix design, it is vital to characterize the aggregates and their surface chemistries in order to determine the influence of the coarse and fine aggregates material properties on the final performance of the asphalt and concrete, and in this instance the performance of a premium asphalt. Additional fine aggregates often contain small coatings that may, or may not be, deleterious and bound strongly (or weakly) to the grain surface (surface coating). Due to the small size of these undesirable elements and their large surface area and chemistry, it's then important to determine their reactive capacity and potential detrimental effects in the asphalt matrix.

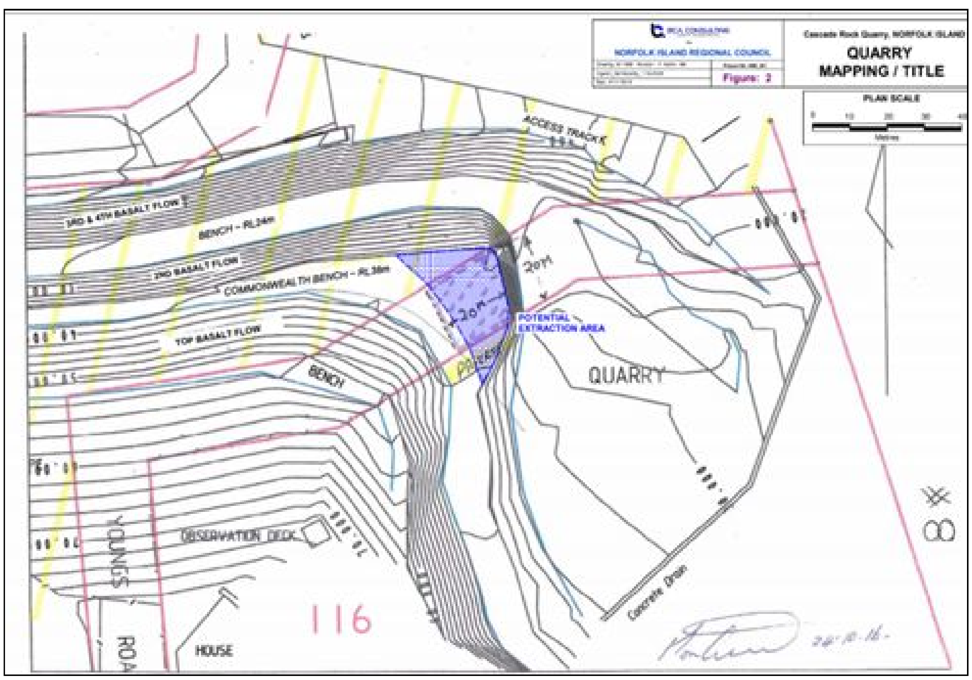


Figure 1 - Norfolk Island Map Resource - Potential Extraction Area, March 2019

Figure 2 - Norfolk Island Map Resource - Potential Extraction Area marked in Red, March 2019

This investigation and factual interpretation of reports reveals that the drilled holes investigated on the resource are of marginal use and it cannot be used as the only and main source to produce asphalt aggregates and concrete aggregates of high quality for the overlay works at the Norfolk Airport.

2. Sample Data

A physical, chemical, optical and mechanical analysis of the coarse component, fines and micro-fines of three specific hole locations and associated samples. The sequence of analysis involves:

1. Detailing the resource geology
2. Determine the quality of the resource and
3. A determination for the resources potential to be incorporated into a premium asphalt

The three locations are identified as Hole 1, Hole 2, Hole 3 as shown on Figure 1 and 2. These locations were identified by Boral's Geologist as the best representation from visual inspection this resource and would offer adequate sample information sufficient for analysis.

It was further identified by Boral's Geologist onsite that the targeted test depth would be 15m depth and at this depth, would offer the most suitable outcomes for the samples collected, as it would encapsulate the observed available resource depth. From the results in the Table, the achieved depth of each borehole has been shown with depths up to 12 -14m before drilling operations were stopped.

Hole Number	Depth of Hole (m)
Cascade Hole 1	6
Cascade Hole 2	14.5
Cascade Hole 3	15

Table 1 - Norfolk Island Drilling Holes and Depth

The samples of the drilling operations were prepared on Norfolk Island by Boral within 24hrs of being sampled from the resource. The samples were labeled and sealed in storage bags for air freight transport from Norfolk Island to Boral's Laboratory in Brisbane Australia.

The larger samples of the resource (300g plus) were also prepared for shipping by being placed directly into separate plastic lined heavy duty bags suitable for the transportation of such materials.

Hole 1 was drilled up to 6m depth only, as from a visual inspection whilst drilling, it was determined that below 6m the rock was marginal, and highly weathered.

3. Analysis

3.1 Mineralogy Analysis

The methods used to characterise the material were X-ray diffraction test, X-ray SEM test, scanning electron microscopic test, and optical petrography analysis.

The phase identification for the samples under X-ray diffraction test were analysed using JADE (V2010, Materials Data Inc.), and TOPAS (V5, Bruker) for quantitative phase analysis using the Rietveld method. The petrographic analysis for the samples, in relation to use as aggregates, was conducted under ASTM C295 standard guide for Petrographic Assessment of Aggregates.

Table 2 shows the elements from the optical and X-ray testing of samples at different boreholes within the resource.

Results		-75um Sieve Size Combined Hole 2 & 3	-425um Sieve Size Hole 2 6 – 9 m Depth	Full depth Hole 2 - fines	Full depth Combined Hole 1, 2 & 3
X-ray Results	Clinopyroxene	12.1%	10.9%		
	Plagioclase (Andesine)	58.3%	50.6%		
	Olivine	8.0%	10.5%		
	Ilmenite	1.8%	2.0%		
	Hematite	1.5%	1.4%		
	Unidentified / Amorphous/ Altered (smectite clays/iron oxides) Secondary content	18.4%	24.5%		
Optical Results	Pyroxene			17%	23%
	Plagioclase (Andesine)			40.%	49%
	Opaque oxides (magnetite / ilmenite)			3.0%	6%
	Iddingsite (secondary mineral content)			17%	14%
	Smectite clays (secondary mineral content)			11%	3%
	Porosity (vesicles)			4%	3%
	Pyroxene			17%	23%

Table 2 - Mineralogy Composition by Optical and X-ray Test Methods

3.2 X-ray and Optical Results

The combination of various minerals within the boreholes is evidenced by high amorphous (unidentified) content in comparison to essentially unweathered basalt sources (generally 3 – 12%). The amorphous content was of 18.4% and 24.5% from X-ray diffraction test, that account for almost 25% of the rock that have not got defined crystallisation of minerals which in most cases, tends to be secondary, deleterious components within the rock. The amorphous content is highly deduced to be Iddingsites because of the high iron content and, high aluminium content as shown on Table 3. Minerals that are undesirable for a premium aggregate (mixture of smectite clay and secondary iron oxides) at those high levels as further in this study reflected on tests, such as the methylene blue value.

The primary elements identified for X-ray and optical methods are slightly different (as the combination of 3 minerals within the rock on the X-ray made the identification difficult which caused misidentification of minerals due to the high alteration on the rock geology. In addition, the secondary mineral content (fine & deleterious components) and altered minerals are at slightly higher levels on the X-ray test.

It is then acceptable to state that from the X-ray and optical analysis of the mineralogy that these borehole samples represent Olivine basalt porphyritic texture of finely vesicular basic volcanic style with large variation.

3.3 Electro-Scanning Microscopy (SEM) Analysis

This test was used here to characterise the surface composition of the micro-fines elements on the samples.

For this test, a sub-sample of the resource was placed on a conductive carbon tab, mounted on an aluminium stub. Then the sample was coated with a ~10nm conductive layer of gold. The analysis were carried out at 20kV using JEOL JSM 7001 Field Emission SEM equipped with an Oxford Instruments X-Max detector for energy dispersive spectroscopy analysis.

The picture below shows the element composition analysis for certain spectrums (specific imaging location).

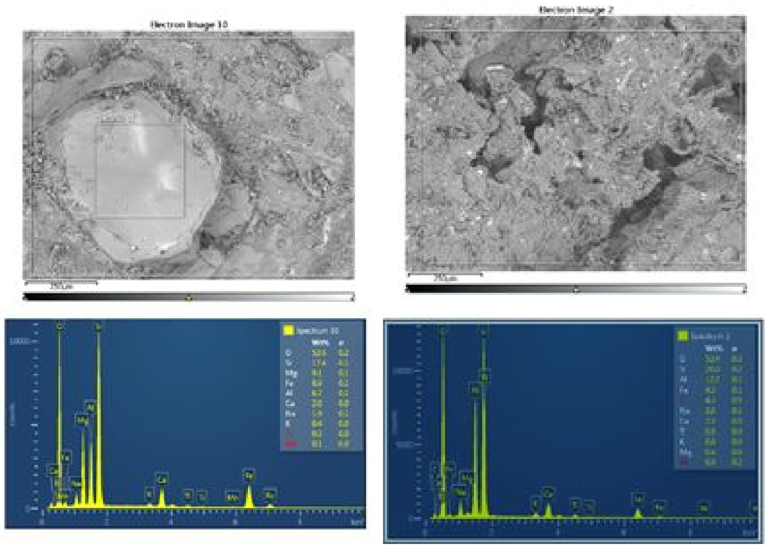


Figure 3 - Norfolk Island Map Resource - Hole 2, 6-9m SEM analysis, May 2019

3.4 SEM Results

The data from Hole 2 at a depth of 6 – 9m has been analysed and, in conjunction with X-ray and petrography results, the large alteration of the rock from the inddingsite (mix of smectite clays and iron oxides) is represented in this sampled data by the presence of iron oxides by the increase in the oxide content and the subsequent reduction in the silica content. From composition analysis on the SEM reports it is seen by having higher Fe(Iron) Oxides levels and relatively low (Si Silicon) levels.

Additionally, typically due to the alteration of the rock into smectite clays the Aluminium content is also high. It is possible that the high Aluminium content is also being influenced from the feldspar component of the resource.

Under the laboratory analysis reports section, it also confirms the analysis from the petrography, X-ray and SEM reports, The reported high methylene blue value is a consequence of the elevated and undesirable expansive elements such as Al+, Fe2+ on the rock.

Components												
Spectrum Label	C	O	Na	Mg	Al	Si	K	Ca	Ti	Fe	W	Total
Spectrum 1	3.71	50.64	2.95	0.73	11.61	20.69	0.76	3.26	0.71	4.93	0	100
Spectrum 2	4.26	52.42	2.62	0.39	12.22	20.01	0.62	2.54	0.64	4.27	0	100
Spectrum 3		51.51	3.35	0.82	11.89	22.25	0.79	3.68	0.68	5.03	0	100
Spectrum 4	4.55	48.74	3.12	0.79	10.76	20.71	0.87	3.84	0.85	5.76	0	100
Spectrum 5	5.89	48.3	2.66	2.16	9.55	19.48	0.84	3.32	0.64	7.17		100
Spectrum 6	4.82	51.11	3.23	0.8	10.58	20.3	0.79	3.73	0.57	4.05		100
Spectrum 7	5.12	45.67	2.93	1.14	11.35	19.96	0.9	4.67	0.9	7.36	0	100
Spectrum 8	5.39	45.66	2.87	1.32	11.57	20.42	0.88	4.41	0.76	6.74		100
Spectrum 9	6.49	54.57	3.24	2.3	8.42	16.86		0.66	3.54	0.44		3.47
Spectrum 10		52.6	1.93	9.1	6.71	17.36		0.36	2.63	0.28	0.13	8.9
Spectrum 11		51.61		18.43	2.45	16.87		0.16	0.6			9.9
Spectrum 12		54.15	3.3	1.7	9.77	19.5		0.96	4.94	0.85		4.69
Spectrum 13	7.16	55.24	2.6	0.57	10.19	16.14		0.64	2.5	0.48	0.18	4.3
Spectrum 14	7.43	55.08	2.26	0.72	9.97	15.49		0.5	2.01	0.58	0.19	5.76
Spectrum 15	8.01	55.79	2.36	0.63	10.05	15.54		0.56	2	0.55	0.3	4.08
Spectrum 16		55.51	3.29	1.7	9.92	19.75	0.25	0.76	3.62	0.65	0.14	4.41
Spectrum 17	7.6	55.73	2.59	0.95	9.63	16.12		0.57	2.43	0.5	0.12	3.73
Spectrum 18		58.7	2.81	0.81	11.52	18.89		0.67	2.32	0.54	0.15	3.59
Spectrum 19	9.4	49.52	2.33	1.67	8.23	14.54		0.55	2.48	0.75		10.51

Table 3 - SEM result Hole 2; 6-9m - Potential Extraction Area; May 2019

3.5 Laboratory Result Analysis

The following tests were conducted under Australian standards for testing aggregates (coarse and fines):

- Particle density and water absorption (AS1141.5/6.1)
- Sodium sulphate soundness (AS1141.24)
- Clay & fine silt (AS1141.33)
- PH (AS1289.4.3.1)
- Material finer than 75um (AS1141.11), wet-dry variation (AS1141.22) , degradation factor (AS1141.25.1/.3) and sulphate/chloride test (AS1012.20.1)

The samples were received undamaged at Boral's Testing Services Laboratory at Whinstanes, QLD 4007 and, they were secured within its original conditioning for transport.

At Boral's Technical Testing facility the testing process involves the replication of typical crushing process to assess the practical manufacturing properties of the resource and the resultant outcomes achieved through this process.

The jaw crusher used is a forward-move with jaw opening of 100-30mm size.

Figure 4 - Boral Whinstanes - Jaw Crusher

3.6 Methylene Blue Test (MBV) Grace Method

The Methylene Blue Test or (MBV test) was conducted as per in-house test "Grace method - accelerated methylene blue test". Previous research indicates that the MBV-Grace method is a more accurate test to determine the quantity of deleterious clays/components in aggregates than the test method established under the Australian Standard AS1141.66 which is the titration method. Previous studies (Boral QLD technical R&D studies and University of Texas studies "treatments in cays for aggregates") have shown that correlations between the titration method and Grace method are very strong (it is not the intention of this study to prove such correlations).

Methylene blue testing was carried out at NATA certified Boral Whinstanes Laboratory. The MBV tests were carried out for each of the three boreholes at different depths. The test method (Grace method) requires a sample size of 20g passing the 0.425mm sieve however, due to the high deleterious content the use of 20g as a sample size, didn't provide an accurate result. By reducing the sample size from 20g to 10g (practice commonly use on high altered sources), a measurable result was achieved.

The data obtained from the MBV testing has been summarised in Table 4.

Hole / Sample	Depth	10g sample MVB
Hole 1	0-6m	6.32
Hole 2	0-3m	5.66
Hole 2	3-6m	4.94
Hole 2	6-9m	3.06
Hole 2	9-12m	5.81
Hole 2	12-14.5m	5.43
Hole 3	3-6m	6.68
Hole 3	12-15m	5.23

Table 4 - MBV Results, May 2019

3.7 MBV Results

The MBV results have shown highly elevated results (MBV of 4+ are considered to be high from existing data).

Hole 2 6-9m showed the lowest reactivity from a cation exchange capacity view point (MBV). When this result is correlated with the other testing data, it indicates that a MBV values of 3+ for this resource are deemed to be a material with large alteration.

The lab results for MBV clearly shows that throughout the whole depth-bench, there is a lot of alteration and the material presents medium to low durability characteristics.

3.8 Sodium Sulphate Soundness Test (AS1141.24)

Sodium sulphate soundness test was used to identify the durability of the fines component on the material and results are intended to provide an estimate of the resistance of the material to natural weathering action. Tests were conducted under Australian Standards – test method AS1141.24

Due to insufficient sample quantity to perform the test on multiple samples this test was only performed on one rock sample that represent the three boreholes.

3.9 Sodium Sulphate Soundness Results

The assessment of the durability of the resource by this testing has also evidenced that the vesicles (porosity) as well as the alteration of the rock into iddingsites (smectite clays / iron oxides) has made the material weak in constitution.

Sodium Sulphate Soundness result = 11.3% Fine component (maximum limit 6%)
Sodium Sulphate Soundness result = 3.5% Coarse rock spall sample (coarse component)

While current concrete and asphalt Australian specifications (AS2758.1) states a maximum limit of 6%, current performance of Boral Queensland basalt rock types are in the order of 0.6 – 1.9% generally.

3.10 Particle Density / Water Absorption Test (AS1141.5/6.1)

The Particle Density / Water Absorption Test is used to determine the penetration of liquids into permeable voids in the fine grains structure with a resulting increase in particle weight. Tests were conducted under Australian Standards – test method AS1141.5.1/AS1141.6.1.

3.11 Particle Density / Water Absorption Results

The results are shown in the table below:

Hole / Sample	Depth	APD (apparent Particle Density)	SSD (density at saturated surface condition)	WA (Water Absorption)
Hole 1	0-6m			
Hole 2	0-3m			
Hole 2	3-6m	2.88t/m3	2.66t/m3	4.50%
Hole 2	6-9m			
Hole 2	9-12m	2.85t/m3	2.53t/m3	7.40%
Hole 2	12-14.5m	2.83t/m3	2.50t/m3	7.80%
Hole 3	3-6m	2.89t/m3	2.65t/m3	5.00%
Hole 3	12-15m	2.79t/m3	2.56t/m3	5.20%
Combined Hole 2	All depth	2.82t/m3	2.54t/m3	6.3%
Combined Hole 3	All depth	2.86t/m3	2.66t/m3	4.0%

Table 5 - Particle Density / Water Absorption, May 2019

It is concluded that the sampled material has extremely high water absorption and for a basalt is also a light basalt rock (water absorption limits for asphalt aggregates is 2.0% - 2.5% and normal densities for a basalt basic igneous ranging from 2.90-2.98 t/ m3 (APD) and water absorptions between 0.3% - 2.8%.

3.11 Clay & Fine Silt Test and PH test (AS1141.33 / AS1289.4.3.4)

A slightly alkaline source rock is normal and is expected for basic basalt rocks.

Elevated clay and fine silts on samples independently of the depth. Borehole 1 from 0 – 6 m has C7FS of 38% while borehole 2 at 9 – 12 m has C&FS of 24%. There is not C&FS limits under Australian standard, however Boral Quarries QLD, through local experience, adopts a limit no higher than 18%.

The analysis for clay & fine silt reveals that for the 3 values reported, the resource might have in general a very-high clay & fine silts value. The clay and fine silt is an indicative test method only and it is a high probability that some high values are influenced by the presence of the iron oxides, and silt like particles on the material.

3.12 Wet-dry Variation AS1141.22, Degradation Factor AS1141.25.1/.3, Liquid Limit (AS1289.3.9.2)

Wet-dry variation test is one of the most reliable methods to determine the strength and durability properties of an aggregate as the rock is submitted to normal loads under dry and wet conditions and the effect of those two conditions drives the determination of the wet-dry variation. The test was performed under AS1141.22 test method.

Chemical testing was performed under AS1012.20 to determine levels of sulphate and chloride as it was necessary to understand those since the exposed rock is in close proximity to open salt water. Degradation factor is another important test to determine durability of aggregates and the test was conducted under AS1141.25.1. coarse and AS1141.23 fine component.

	Wet-dry variation/ wet strength	CHLSUL	Degradation Factor
Rock Samples	51% / 99kN/W	0.031 / 0.010	81

	Liquid Limit	Degradation Factor
Hole 2 fines	26	56
Hole 3 fines	25	72

Table 7 - Other Property Results, May 2019

3.13 Wet-dry Variation, Degradation Factor, Liquid Limit Results

The wet-dry variation result on the resource sample is marginal and indicates that under wet saturated conditions the rock performs poorly. The wet-dry variation limit under current Australian specifications is 25% and minimum wet strength of 150 kN. Neither of those two limits were met by the completed testing.

Sulphate and chloride testing doesn't show any high values and the reported figures are well within the tolerable and acceptable ranges.

Degradation factor results under AS1141.25.3 fines of 56 & 72 and 81 on the coarse were odd results. The results obtained were reasonably high which typically indicates a good performance for durability. This result does not align with all petrography tests and the other laboratory tests performed on these samples. It can only be concluded from observation of the data that degradation factors for fine component under AS1141.25, tend to provide 20% higher values than the coarse component. The high values of the fine samples are also in contradiction with the high liquid limits obtained on the sample. Generally, Basalt sources have liquid limits from 15.5 - 22.5% for aggregates. Liquid limits in excess of the upper limit are an indication of the larger capacity for the fines to absorb water and impact the performance of the aggregate.

4. Conclusions

Cascade boreholes 1, 2, 3 representing the potential extracted area to crush and manufacture aggregate suitable for incorporation into a premium asphalt mix design to overlay of the current airport were found to be unsuitable for this application.

The primary concerns found with the resource are the high level of alteration on the rock, those alterations manifested as smectite clays and opaque oxides has made the rock weak in terms of strength and durability properties for medium to high premium aggregate performance.

The high level of alteration on the rock presented by the high levels of amorphous content, high percentage of soft/weak and deleterious secondary mineral components, and the low performing laboratory results indicates the low physical and mechanical characteristics of the material. It is envisaged should this rock is crushed onsite and utilised under Australian standard guidelines to manufacture aggregates for asphalt and concrete, it would not be conforming to those. Laboratory reports conducted on the samples didn't meet current Australian standard guidelines for aggregates overall to be used in asphalt and concrete.

High water absorptions, low density values, high methylene blue values, elevated clay and fine silt values, high percentage of secondary mineral components, high degree of variation/weathering are intrinsic properties of the rock that can be improved somewhat with the crushing process but, in any manner could potentially dictate the usability of the rock as asphalt and concrete aggregate from the extraction zone studied.