High-Grade Silica Sands in The Eastern Murray Basin NSW

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SUMMARY

Investigations in 1979 defined a sand resource at Wah Wah with three potential processing options to yield sand suitable for colourless glass making. In December 2016, further drilling was completed to infill some of the previously drilled area and extend into new areas.

From this drilling, coloured and white sand resources have been defined, overlain by a clay unit. The sand has generally been considered to have a fluvial origin, but recent work suggests that the white sands may have a beach origin.

White sand is defined by the 0.050% Fe_2O_3 contour and this resource coincides generally with higher yield, mostly underlying 6m to 8m of clay - the thinner overburden area.

Estimated resources are 15 million tonnes of white sand with 0.035% Fe_2O_3 and 0.20% Al_2O_3 at a yield of 58% for 8.7 million tonnes of sand suitable for colourless glass making. Sand not suited to glass making can be used for other products.

These resources are Indicated Resources for reporting under the JORC Code 2012. They are defined by drilling and testing, and found to be suited for glass and other uses.

From the investigations, a number of processing techniques can be employed with the final decision dependant on user requirements. However, the 2016 work demonstrated that an attrition-gravity process will be suitable for colourless glass sand, and cheaper than the other options considered in 1979.

Based on results, the sand appears to be suitable for other products, including filter media, various construction uses, and other applications depending on markets.

Compared to the resource defined in 1979 this deposit is now expected to be suited to:

- Selective extraction,
- Reduced focus on a single market,
- By-products to increase overall yield,
- Lower cost processing for the higher value products,
- Certainty that there is sufficient resource to meet longer term needs for a range of products.

Key words: Murray Basin, silica sand, glass sand, drilling, testing, resources.

INTRODUCTION

The sand resource is located at Wah Wah about 60km to the north-west of Griffith (see Figure 1). It includes an area previously investigated by the NSW Department of Mines (Gobert and Corkery, 1978) for glass making, with follow up work for the then NSW Department of Decentralisation. The writer was part of this investigation team; Lee and Stitt (1979) and Lee (1979). This earlier work comprised: auger drilling, followed by testing of the samples recovered.

The 1979 work defined a white sand bed beneath clay overburden. Follow-up aircore drilling in 2016 comprised step out holes with some in-filling between the 1979 auger holes. These 2016 holes defined extensions of the deposit and it is now apparent that the resource is significantly larger than previously known, which presents opportunities for future development of the sand. The project is now considered as a multi-sand commodity project, which will reduce the reliance on a single user customer with the inherent risks. Resulting from the recent investigations, it should be feasible to produce sand using lower cost beneficiation and still meet normal specifications used in Australia. Thus, the higher cost froth flotation and the grinding-gravity options previously considered can be discarded, in favour of lower cost attrition-gravity with the rejected sand fractions going into other products.

Because the two programs were undertaken 37 years apart there were inherent difficulties in conducting the 2016 work and interpreting the results. These will be addressed later.

Geological issues associated with the site are now better understood. The sands occurring at Wah Wah are located close to the eastern margin of the Murray Basin, a large intra-cratonic sedimentary basin of some 300,000km^2 extending over parts of New South Wales, Victoria, and South Australia, filled mostly with non-marine and marine Tertiary sediments. Before the 2016 drilling it was considered that these sands were all alluvial deposits forming part of the Calivil Formation as described by Whitehouse (2009), but now it is believed that the white sand unit could belong to the older marine shore line facies of the Parilla Sand.

GEOLOGICAL SETTING

Whitehouse (2009) page 6 describes the geological setting for the sands occurring in this eastern part of the Murray Basin as:
"Relatively coarse and poorly sorted fluvial sands and muddy overbank deposits of the Calivil Formation were deposited over the upper Renmark Group along the eastern side of the Murray Basin. The Calivil Formation onlaps the basin margin and grades upwards into the Shepparton and Coonambidgal formations – these are (mainly) Pliocene to Quaternary deposits forming the present Riverine Plain (Brown & Stephenson 1991: Page & Nanson 1996). Depositional settings for the Calivil Formation include valley fill adjacent to the basin margin, followed by alluvial fan to braidplain settings and, increasingly basinwards, fluvial to lacustrine environments dominated by channel, levee and floodplain deposits. The Calivil Formation, mostly poorly consolidated, consists of pale grey, poorly sorted medium- to coarse-grained quartz sand/sandstone and locally thick lenses of kaolin that assume commercial significance along the eastern margin of the Riverine Plain."

Until the 2016 drilling, it was believed that this white sand deposit belonged to the uppermost part of the Calivil Formation; however, now there is some suggestion that the white sand unit is part of the older beach deposited Parilla Sand unit. The white sands are better sorted than the alluvial sands and are like Parilla Sand observed by the writer elsewhere in the Basin. In the Wah Wah deposits, individual sand units are relatively well graded and fine upwards from coarser grained sands. The writer now interprets the sands as surf zone grading upwards to finer grained high beach or low dune sands. Thin white clay layers appear to fill shallow depressions in the back beach depositional areas. In some holes, the sequence appears to be stacked, while the whole unit is deposited onto an older white leached claystone/siltstone basement that appears to have been weathered and eroded to an irregular surface.

Post deposition, the white sand especially has undergone changes resulting from the movement of groundwater within the sand beds. Feldspars have broken down to white clay minerals and then the clays have migrated through the unit forming a matrix to the sand. Calcite has been deposited as cement to the sand and this is particularly observed at about the level of the water table in some holes; where drying of the sand during periods of falling water table has caused the calcite to precipitate and cement the quartz grains.

INVESTIGATIONS CONDUCTED

Drilling was completed as two programs in 1979 and 2016. Table 1 presents the details for these drilling programs and Figure 2 shows the hole collar locations.

TABLE 1. DETAILS OF DRILLING PROGRAMS

	1979 DRILLING	2016 DRILLING	TOTAL
Type	Gemco 210B, 100mm dia spiral auger, 1.5m long rods. Drilled dead stick, sampled every 1.5m.	Mantis 300, NQ rods & bit (76mm dia) aircore, 3.0m long rods. Drilled continuous, sampled every 1.0m.	
Maximum hole depth	21.36m	36.0m	
Holes	35	26	61
Metres	589.3	599.6	1188.9

For both programs, the upper clay unit was drilled and discarded. In 1979 dead stick auger drilling required the rods to be removed from the hole to recover each sample. When the leading auger rod was removed the contaminating outer material was scraped off and discarded, then the clean 1.5m interval of sand nearest to the central column was removed and bagged as the sample. In 2016 the 1.0m sand samples were returned to the surface through the inner tube of the rods and thus were clean and free of any contamination from the sides of the hole. Sand was separated from the drilling air stream in a cyclone and the sample dropped into a plastic bag placed beneath the cyclone outlet. Upon hitting the sand, drilling progressed until the hole was terminated in either; basement material, wet running sands (which filled the drill string at a rod change and could not be removed with the air), or due to some other impediment to advancing the hole. In both programs all samples were logged on site for lithology.

Testing in 1979 of composited 1.5m samples included: froth flotation, heavy liquid (gravity) separation, grinding (to increase yield of suitably sized finer sand) and magnetic separation. All testing was aimed at removing iron bearing minerals and obtaining a suitable size grading.

In 2016, drill hole 1.0m samples were composited into intervals representing about 5m, or stratigraphic sections of similar sand. Composites were then tested by ALS in Perth using a process of sizing, light attrition, wash decantation, and heavy liquid separation. This process was similar to the process used in 1979 described as the "attrition-gravity" treatment which represents a lower cost processing option than using froth flotation. In more detail, the 2016 "attrition-gravity" test procedure comprised:

1. Soak a 1.2kg sample for approximately 12 hours in water.
2. Light attrition at approximately 600-800rpm for 5 minutes.
3. Wet screen at 0.710mm. Dry and weigh oversize. Retain undersize. (The 1979 testing screened at 0.600mm.)
4. Hand agitate the <0.710mm fraction, decant fines cutting at 0.075mm, use additional water as necessary to wash until clear.
5. Dry and weigh <0.710 to >0.075mm fraction.

6. Split two x 100g sub-samples from <0.710 to >0.075mm fraction.
7. Dry sieve analysis on one of the 100g sand splits.
8. Static heavy liquid separation on the other 100g sand split at 2.9kg/m^3, retain sinks and floats.
9. Analyse float fraction by XRF for Fe_2O_3, Al_2O_3, CaO, MgO, K_2O, Cr_2O_3, TiO_2; with ICP for more precise Fe_2O_3.

RESOURCE ESTIMATION

Resources at Wah Wah have been estimated for a single sand domain within the site. The total resource area boundary is shown on Figure 3 as a solid black line.

A model of the sand resources was constructed accounting for:

Boundaries: The total resource area boundary is 50m beyond drill holes and is a series of straight line segments forming a polygon, Figure 3. This boundary includes both white and coloured sand and is referred to as the 'All Sand' boundary. The 'White Sand' boundary is the 0.050% Fe_2O_3 contour shown on Figure 4.

Batters: Have been assumed as vertical.

Bottom: For estimation, the bottom of the sand intersected in each hole.

Construction: A pit shell was created. The upper surface is the natural surface, the bottom is the base of drilled sand.

Lithology: The deposit is divided into three lithological units comprising: 'Clay', 'Sand', and 'Basement'; from the surface, down. Based on quality the sand unit is subdivided into 'Coloured' and 'White' as determined by lithological logging and testing of samples.

Depth: Based on drilling, lithology, and test results.

Overburden: Overburden comprises clay extending from the surface down to the top of the sand bed.

Interburden: Within the 'All Sand' boundary there are thin clay lenses interbedded in some places within the sand unit. These clay units have been included into the sand unit estimates, being too thin for selective rejection in extraction.

In situ density: An in situ density of 1.6t.m^3 has been used.

Block: The resource has been treated as a single block with both a Bottom surface and an Upper (natural) surface, and has been divided into: Overburden. All Sand (coloured and white). White Sand only.

Modelling: A model was created as follows:

- A digital elevation model (DEM) surface was created for the natural surface.
- Using drill hole intersections, a bottom of clay DEM was created (this is also the top of sand).
- A third DEM, was created for the bottom of the sand unit.
- All DEMs were clipped to the appropriate boundary, i.e. 'All Sand' or 'White Sand'.
- For the 'All Sand' boundary, the bottom of the clay DEM was subtracted from the surface DEM and both the overburden clay area and volume were calculated.
- For the 'All Sand' boundary, the bottom of sand DEM was subtracted from the bottom of clay DEM and both the area and volume were calculated.
- For the 'White Sand', the same process was adopted using the clipped DEMs for the 'White Sand' boundary and both area and volume were calculated for the overburden and the 'White Sand'.

Table 2 is a summary of the resources within the Wah Wah deposit sub-divided into the categories of 'All Sand' (including the coloured sands not suitable for producing white glass sand), and 'White Sand' (for glass making).

TABLE 2: RESOURCES SUMMARY

	ALL SAND	WHITE SAND				
	In Situ	In Situ	%Yield	Product	%Fe_2O_3	%Al_2O_3
Area (m^2)	1,242,000	669,000				
Overburden clay (m^3)	11,000,000	6,360,000				
Sand Volume (m^3)	14,900,000	8,840,000				
Sand Quantity (t)	25,000,000	15,000,000	58	8,700,000	0.035	0.20

The coloured sand quantity is determined by subtraction of the 'White Sand' from the 'All Sand' and is:
25,000,000 – 15,000,000 = 10,000,000 tonnes.

The resources shown in Table 2 are considered as Indicated Resources for reporting purposes under the JORC Code 2012. They have been defined by drilling and testing and found to be suited for glass making and other uses. The chemical properties from each program are summarised in Table 3, the white sand resource quality is summarised in Table 4, while the particle size grading of washed sand is presented in Figure 5, and the <0.600 to >0.075mm 'product' sand is presented in Figure 6.

DEPOSIT PROPERTIES and RESOURCES

The properties of the deposit are considered based on the whole ('All Sand'), and then the more valuable 'White Sand' is examined as a separate sub-set.

Figure 3 shows drill hole locations with overburden thickness contours. The colours range from red thickest overburden (deepest top of sand), to blue for the thinnest overburden (shallowest top of sand). This figure also shows the 'All Sand' resource boundary which extends 50m beyond the drill holes; it includes both the coloured and white sand. For simplicity, it assumes a nil sand thickness in calculating the resource estimates for holes which terminated at shallow depths in clay, but which may have potential for sand at greater depth. Figure 7 shows the 'All Sand' area and quantities.

Figure 4 plots the Fe_2O_3 content of the attrition-gravity product sand. In creating this plot all the untested coloured sand was assigned Fe_2O_3 = 0.3% to create a real plot where the high iron coloured sands fall outside of the area of low iron white sand. On this figure the 0.050% Fe_2O_3 contour, created using minimum curvature, has been used as the boundary defining the white sand resource. Sand within this contour therefore has Fe_2O_3 ≤0.050% after treatment by the attrition-gravity laboratory process (except for hole WW06-16 = 0.053% Fe_2O_3 which is surrounded by lower iron sand).

Figure 8 plots the white sand thickness, contours are at 2m intervals and range from 0m (dark blue) to greater than 20m (red). The bulls-eyes around the 2016 holes WW20-16, WW04-16, WW08-16, and WW09-16 are the result of having been drilled to a greater depth than the nearby 1979 holes W2R17, W2R14, W2R03, W2R05, and W2R27; and indicate that the full resource depth has not been defined by these 1979 holes.

Figures 4 and 9 show the extent of the white sand resource based on the combined 1979 and 2016 drilling and testing results. The white sand has been shown to be suitable for glass making after appropriate treatment. The boundary to this white sand part of the deposit is defined by the 0.050% Fe_2O_3 contour shown in Figure 4.

Figure 10 is a typical cross section through the deposit with the trace of this section shown on Figure 2. It shows the overburden, white sand, and basement where it has been intersected by drilling. The boundaries to the estimated resource are also shown, and the %Fe_2O_3 from the white sand attrition-gravity test results are included as blue coloured numerals. Some of these blue Fe_2O_3 results are shown as "0", because these intervals have been tested by methods other than the attrition-gravity process which show that the interval is suitable to be considered as 'white' sand, but there is no actual data for this interval using the attrition-gravity test procedure. Coloured sand is shown on each side of the white sand.

Table 3 summarises the results from testing of white sand samples in both 1979 and 2016 by similar testing methods. It presents comparative data for the two sets of results obtained from testing of the white sand intervals from each of the drilling campaigns.

TABLE 3: SUMMARY COMPARISON 1979 WITH 2016 WHITE SAND TEST SAMPLE INTERVALS RESULTS

Hole ID	%>0.600 mm	%<0.600 – >0.075mm	%<0.075 mm	%Al_2O_3	XRF %Fe_2O_3	ICP %Fe_2O_3
1979 Results						
No Samples	21	21	21	15	15	
Minimum	6.2	15.1	5.7	0.1	0.025	
Maximum	67.1	85.8	24.5	0.3	0.046	
Mean	31.9	54.2	13.9	0.2	0.036	
2016 Results	%>0.710mm					
No Samples	49	49	49	49	49	49
Minimum	0.9	20.5	3.3	0.07	0.01	0.010
Maximum	68.7	91.4	61.4	0.31	0.05	0.076
Mean	27.0	62.6	10.5	0.14	0.02	0.034

In Table 3 the most important data are the mean results (highlighted) for each of the properties from the 1979 and 2016 programmes, with the mean Fe_2O_3 results; 0.036% for 1979 and 0.034% for 2016. For practical purposes, these two sets of Fe_2O_3 results are the same and are within the normal range of error for analyses of low iron sands. Therefore, the results from both drilling campaigns can be used with confidence in preparing estimates of resources and establishing quality parameters for the white sand. (The 0.076% Fe_2O_3 by ICP is an anomalous sample result, from hole WW09-16 with a total white sand intersection averaging 0.043% Fe_2O_3.)

Table 4 combines the 1979 and 2016 data sets and provides a summary of the white sand quality within the total resource shown on Figure 9.

TABLE 4: WHITE SAND WITHIN RESOURCE AREA – SUMMARY OF QUALITY

	%>600	%<600 >75um	% <75um	%Al_2O_3	%CaO	%Cr_2O_3	XRF/ICP %Fe_2O_3	%K_2O	%MgO	%TiO_2
No Holes	37	37	37	31	18	16	31	16	16	16
Min	6.2	15.1	3.5	0.07	0.01	0.002	0.024	0.006	0.034	0.023
Max	67.1	85.8	40.1	0.31	0.68	0.004	0.053	0.016	0.053	0.061
Mean	29.1	58.1	12.8	0.20	0.2	0.002	0.035	0.011	0.044	0.034

Note: *Fe_2O_3 = XRF for 1979 data. Fe_2O_3 = ICP for 2016 data*

In preparing Table 4, the results for %>0.600mm from the 2016 testing were calculated by adding both the washing %>0.710mm and the %>0.0600mm from the product sand size grading. This was necessary to allow direct comparison with the 1979 results, where the initial wash screening used a 0.600mm sieve.

Table 4 includes data for 37 drill holes with white sand Fe_2O_3 less than 0.050%. Importantly, the Fe_2O_3 content averages 0.035% and compares favourably with the average Fe_2O_3 for each set of drill holes shown in Table 3, above. Falling within the 0.050% boundary and included into the resource, there is one drill hole (WW06-16) with average Fe_2O_3 of 0.053% surrounded by holes with Fe_2O_3 <0.050%.

The minimum and maximum values presented in Table 4 show the extent of chemical variation within drill hole intersections throughout the deposit. These variations can be used to advantage while extracting the sand by selecting those parts most suited to the target product and by blending to achieve a consistent product; in particular, the lower Fe_2O_3 and finer grained white sands should be targeted if glass making sand is to be produced, while the higher Fe_2O_3 and coarser sands should be utilised for products such as filter sands.

Figure 5 presents the size grading maximum and minimum values graphically for the 2016 washed <0.710mm sand. It shows a wide spread between the minimum and the maximum with the mean as the green line.

The data used to prepare Figure 5 has been re-calculated to remove all of the >0.600mm and <0.075mm fractions. It was then plotted as Figure 6 to determine how close this sand grading is to typical glass sand, the red line. It is apparent that the green line representing the mean is now approaching the typical glass grading, but still has too much sand retained on the 0.500mm and 0.425mm sieves, and too much fine sand on the 0.150mm and 0.100mm sieves. These size grading deficiencies can be corrected during processing by using appropriate sizing and classification equipment such as; an upward current hydraulic classifier (possibly in conjunction with screening) to reduce the coarse fraction, and suitable cyclone classifiers for reducing the fine fraction. Product yields will be lower, but the sand fractions removed should be suitable (probably with some blending) to make other products.

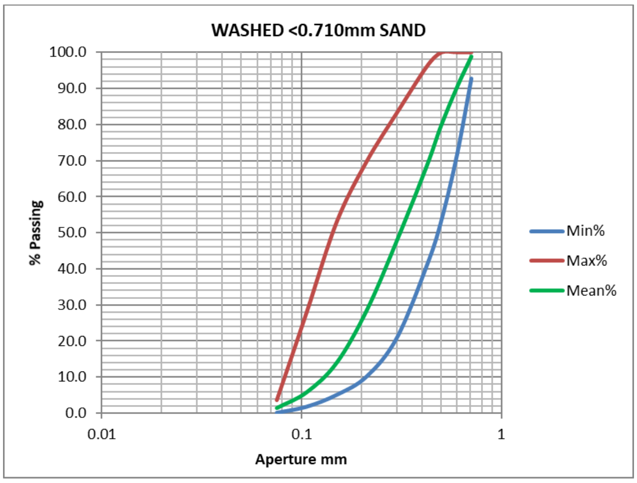

FIGURE 5: Size grading %Passing plot for the washed <0.710mm white sand.

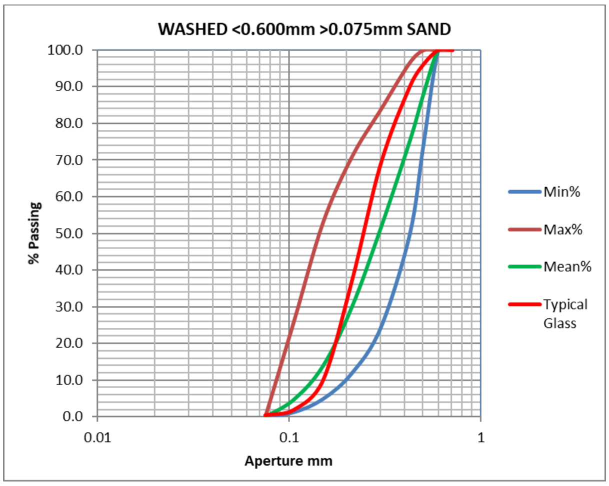

FIGURE 6: Size grading %Passing plot for the washed <0.710mm white sand with both the >0.600mm and <0.075mm fractions removed. This mean grading is closer to typical glass sand, plotted as the red line.

The data from both the 1979 and 2016 drilling was combined and some features become apparent due to differences in the information. The most obvious is the shorter 1979 drill holes, which reduce the overall average thickness of the sand shown in Figures 8. This results in 'bulls-eye' contours around some of the shallow holes and indicates that the full depth of the resource is not represented by these 1979 holes, i.e. the resource represented in the area surrounding these holes is somewhat less than is the likely total resource.

DISCUSSION

The drilling campaigns used different drilling methods, spiral auger (1979) and aircore (2016). A significant difference is the ability to drill deeper using aircore. A result from the 2016 drilling is a better definition of the basement underlying parts of the deposit. However, there are other 2016 drill holes which have still failed to reach the basement (usually below the water table) where the hydrostatic head has forced running sand through the bit and into the drill string when the air pressure was reduced at a rod change. Considering that most of the 2016 holes which failed to reach basement had drilled to 30m (or deeper), and that a significantly increased resource has been defined, compared to that based on the 1979 drilling, the holes not reaching basement appear to have only a small impact on the total resource. It may be that the deepest sands in this deposit cannot be extracted due to the hydraulic properties of the sand causing a low angle of repose along the extraction boundaries.

During this investigation, the issue of comparing the 1979 sample test results against the 2016 results always had the possibility of showing a distinct mismatch, with one or other of the sample sets being vastly different (biased), or there being significant random differences. The reasons could be due to the different drilling methods, recovery of the samples from the drill, different laboratories, and the slight differences in the test methods used. In the final analysis, there appears to be good comparison with generally similar results from the two data sets for product chemistry shown in Table 3, with mean Fe_2O_3 results of respectively 0.036% and 0.034% for the 1979 and 2016 programmes. There is an indication that the 2016 samples, after a slightly less rigorous laboratory treatment, have yielded a very slightly lower Fe_2O_3 in the sand product. This may be due to the aircore drilling producing a clean sample off the face of the hole which was delivered to the surface and then directly into the sample bag through the inner tube of the drill rod; while the 1979 auger sampling method required drilling in an open hole and then the rods were withdrawn from the hole for sample recovery by pulling them up through the overlying materials including the brown clay overburden. While during the auger drilling, care was taken to clean off any outer contamination before sampling only the sand closest to the auger central column, there is always the possibility that contamination removal was not 100% effective, thus causing some slight contamination of the samples.

The total deposit is referred to as ‘All Sands’ and it includes both the white and coloured sands of all qualities. It has volume of 14.9 million m^3 at an overburden ratio of 0.74:1.0 which equates to $0.44m^3$:1.0 tonne of raw sand. Most of the coloured sand has not been subjected to any testing, but samples from the 2016 drilling are available for testing to be undertaken if required.

White sand occurs throughout the central part of the drilled area. On Figure 4 the white sand boundary is defined by the 0.050% Fe_2O_3 contour. The white sand boundary happens to coincide with the lowest fines content and most of the higher yield sands, but it does include some of the coarser (higher >0.600mm content) sands. For the most part, the white sand has 6m to 8m of overburden which is generally the thinner parts of overburden. The ‘White Sand’ resource amounts to 8.84 million m^3 and is beneath 6.36 million m^3 of overburden at a ratio of 0.72:1.0, or $0.42m^3$:1.0 tonne of raw sand.

From the investigations conducted it has been demonstrated that a suitable glass making sand can be produced from the Wah Wah white sand resource using at least three processing techniques. The final decision to select a processing method suited to product chemical requirements will to a large extent depend on the glass type to be made and the quality of the other raw materials used in the glass batch. If coloured glass (amber and green) is to be produced then simpler processing, at lower cost, will suffice. If white (colourless) glass is to be produced then more rigorous control on both the extraction and processing will be needed. Particle size grading will utilise the same treatment irrespective of the chemical quality sought.

Based on the 2016 work, a process of washing, screening, attrition, gravity separation, and classification (referred to as ‘attrition-gravity’) appears to be suitable, and much less costly than the other options considered in 1979. Part of the reason for considering the attrition-gravity process now, is the significantly increased resource quantity resulting from the 2016 drilling, which together with the chemical quality (Fe_2O_3) suited to white glass, allows this process option to be considered more seriously.

Overall the Wah Wah resource is now expected to be suited to:

- Selectively siting of extraction areas; to work sand having in situ characteristics more closely matching the product requirements,
- A reduced focus on yield for a single market,
- Use of by-products to supply other markets, and hence increase overall yield of saleable sands,
- Use of lower cost treatment options for the higher value products,

There is an increased certainty that a sufficient resource is available to meet long term requirements for a range of products. As a result of the 2016 drilling, the resource is now considered to be the basis for a multi-sand commodity project.

ACKNOWLEDGEMENT

This paper has been prepared and presented with the consent of Mr Paul Josling and Mr Grant Dowling proprietors of LG Civil Pty Ltd from Griffith NSW. LG Civil hold title to the project area and have funded the 2016 investigations which form the subject of much of this presentation.

REFERENCES

JORC, 2012, Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves. Joint Ore Reserves Committee. 2012.

Gobert, V. and Corkery, R.., 1978. Glassmaking Sand in The Griffith Area - Preliminary Investigations. Geological Survey of New South Wales Department of Mines. Geological Survey Report No GS1978/294. October 1978.

Lee, G.F. and Stitt, P.H., 1979. Glass Sand Potential of the Wah Wah Sand Deposit Near Griffith, NSW. Final report, prepared for the NSW Department of Decentralisation, by Peter H Stitt & Associates Pty Ltd. Report Number 6/79. October 1979.

Lee, G.F., 1979, Preliminary Processing Costs for Treating Potential Glass Making Sands in the Griffith Area, NSW. Peter H Stitt & Associates Pty Ltd. Technical Note Number 1/79. January 1979.

Whitehouse, J., 2009, Mineral Systems of the Murray Basin, New South Wales. Quarterly Notes of Geological Survey of New South Wales; No. 132.

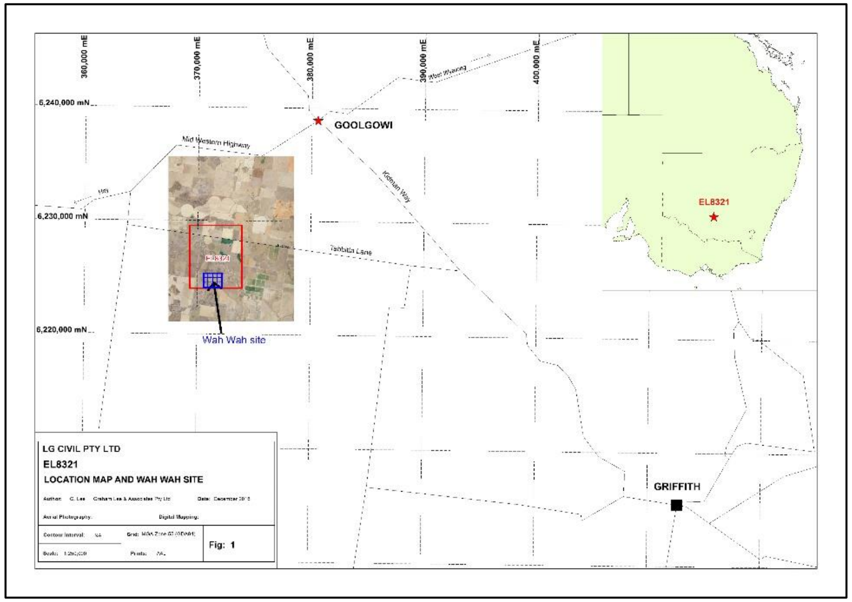

FIGURE 1: Location of the Wah Wah sand deposit.

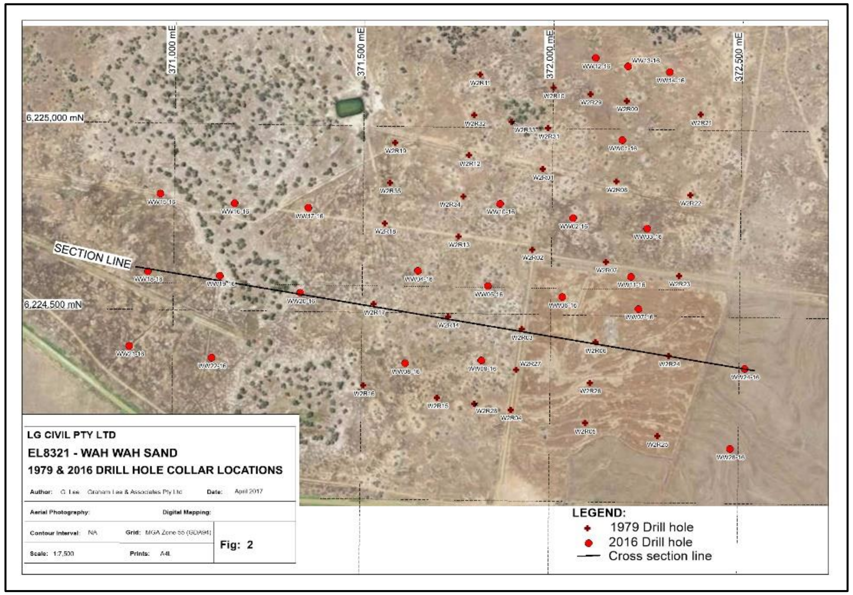

FIGURE 2: 1979 and 2016 drill hole collar locations with cross section line.

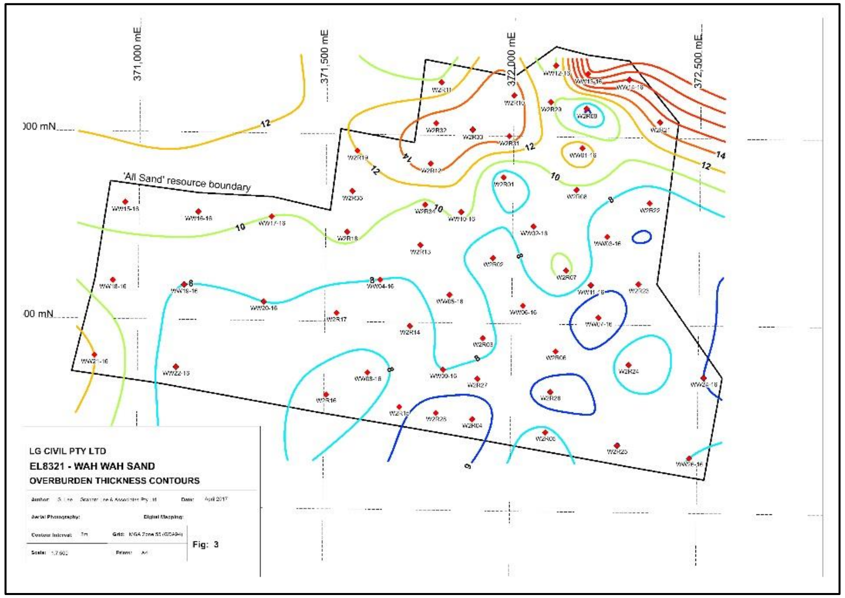

FIGURE 3. Overburden thickness contours and boundary to sand resource estimates.

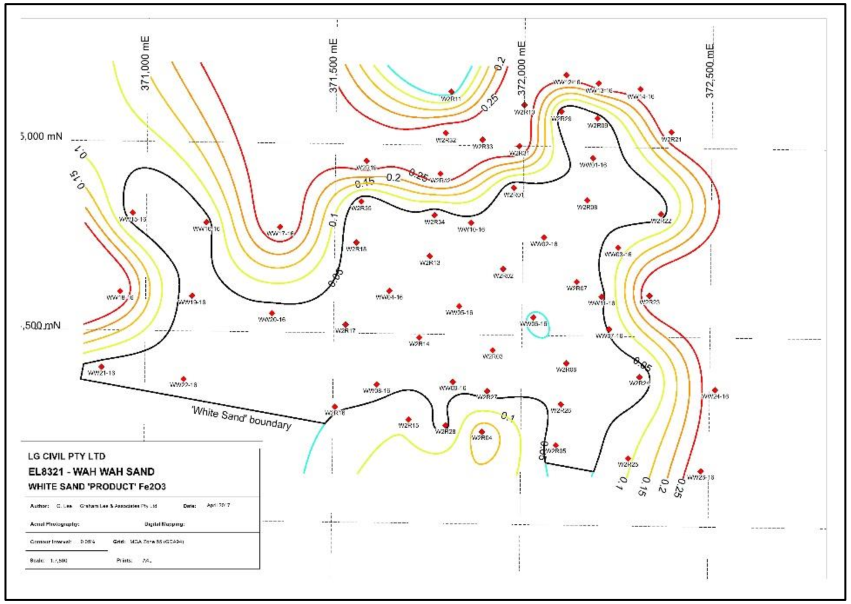

FIGURE 4. White Sand drill hole interval 'product' Fe_2O_3 contours.

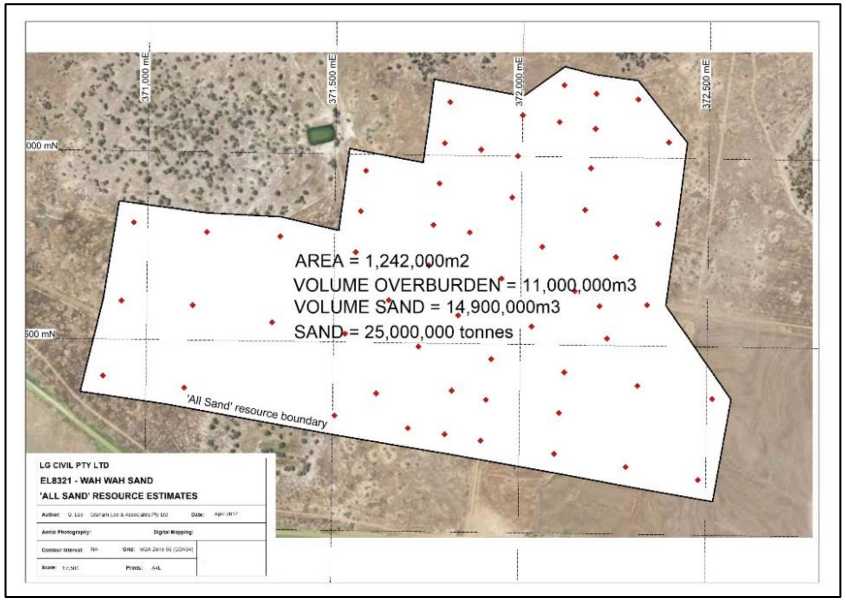

FIGURE 7: Resource estimates within the 'All' Sand resource boundary.

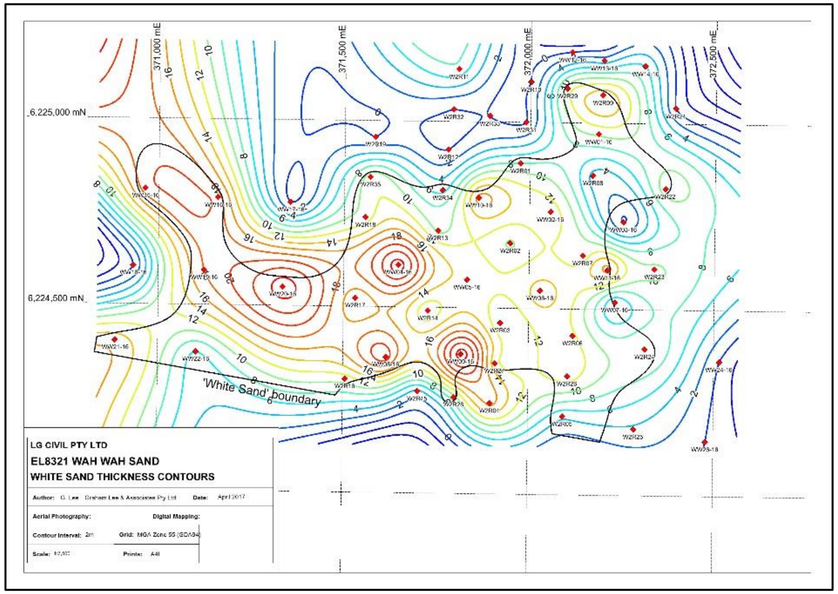

FIGURE 8. White sand thickness contours.

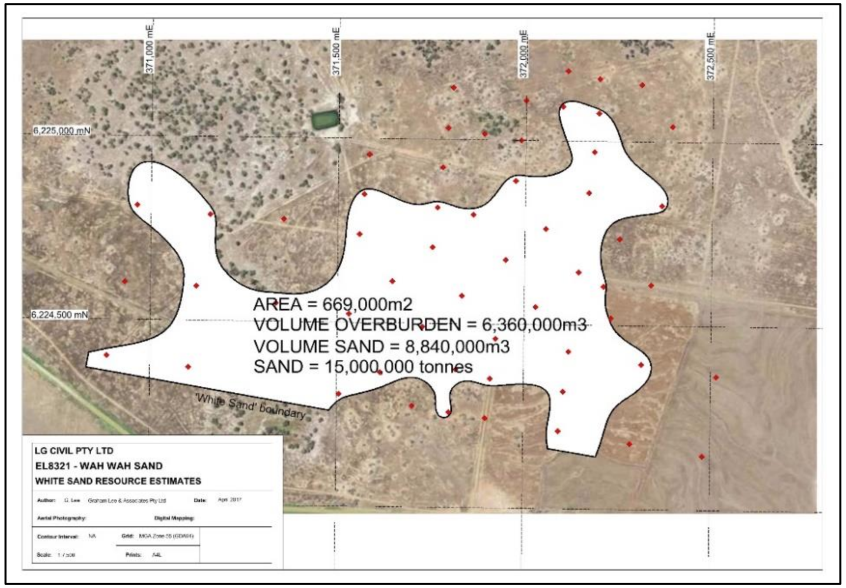

FIGURE 9. Resource estimates for sand within the 'White Sand' boundary.

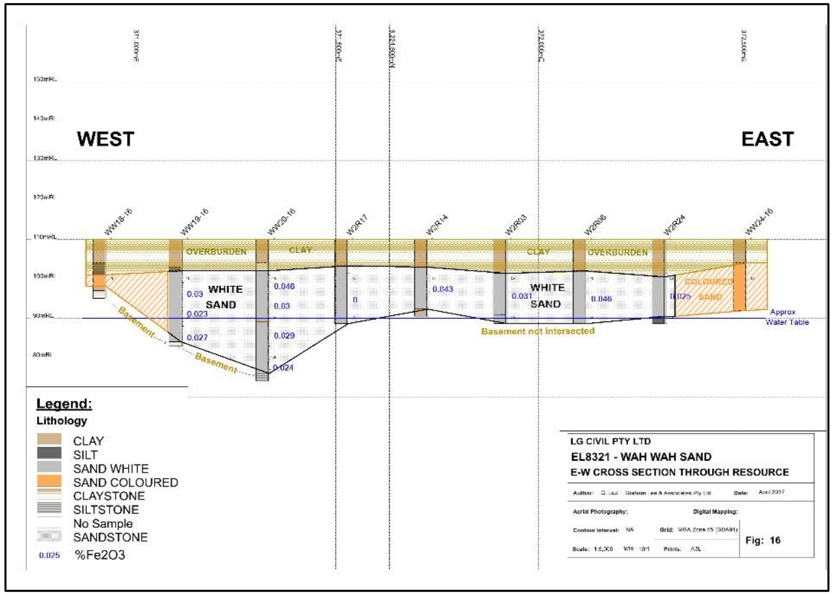

FIGURE 10: East-West cross section through white sand resource.