ARK ENERGY

PROPOSED WIND FARM
ST. PATRICKS PLAINS, CENTRAL HIGHLANDS TASMANIA

RECONNAISSANCE
ACID SULFATE SOILS REPORT

December 2022

Cover image

View north from near test pit ASS1 on the property *Wihareja*, 18 October 2022. The foreground vegetation obscures a soil profile about one metre deep developed on marshy ground, with an organic silt topsoil with mapped acid sulfate soil potential. The background with lower vegetation has thinner soils on ground less prone to marshy conditions, and no mapped acid sulfate soil potential.
Photo: Bill Cromer, 18 October 2022.

Refer to this report as

Cromer, W. C. (2022). *Reconnaissance acid sulfate soils report, proposed wind farm, St. Patricks Plains, central highlands Tasmania.* Unpublished report for Ark Energy by William C. Cromer Pty Ltd. 22 December 2022.

Use of this document

SUMMARY

A reconnaissance soil survey over part of the area proposed for the St Patricks Plains wind farm has supported published mapping which indicated some of the soils of the district have acid sulfate (ASS) potential.

Excavator test pits were dug at four locations which coincided with areas of potential ASS on ground also proposed to be disturbed for wind farm infrastructure. Fourteen soils were laboratory-tested. Five of them (mostly topsoils) returned net acidities (sulfur units) exceeding trigger values for ground disturbances up to 1000t, and all but three samples exceeded similar trigger values for larger ground disturbances.

The inference from this limited survey is that:

- ASS potential exists throughout the proposed wind farm footprint,
- dark-colored organic topsoils are ASS, but the effect may extend deeper through the soil profile,
- follow-up surveys are required to better understand the lateral and vertical distribution of the ASS soils, and
- based on the follow-up surveys, regulators may require an approved plan to management ASS soils.

1 INTRODUCTION

1.1 Background

Ark Energy (ARK) proposes a wind farm of approximately 46 towers at and in the vicinity of St. Patricks Plains in Tasmania's central highlands. The towers would be located on five agricultural properties which extend over approximately 90km^2 (Figure 1).

ERA Planning ERA) acts for ARK is facilitating the preparation of various environmental assessments required for the proposal by the Tasmanian Environment Protection Authority (EPA).

Parts of the footprint for the wind farm are mapped[1] as potentially subject to low-level[2] inland acid sulfate soils[3] (ASS; Figure 1). In discussions with ARK and ERA, EPA indicated that it would require ground truthing of the predictive ASS overlay over the area. Accordingly, ERA requested William C Cromer Pty Ltd (WCC) to conduct a reconnaissance soil survey of ASS potential for the proposal.

1.2 Methodology

1.2.1 Methodology and personnel

The methodology for this report included desk-top studies and field work by Bill Cromer (groundwater geologist and Principal of WCC). Mark Hocking (groundwater geologist and Principal of *Hydro Geo Environmental Consulting*, HGEC) assisted in the field.

The field work included geological reconnaissance, and the digging, logging, photography and sampling of four excavator test pits (labelled ASS1 – ASS4 in Figure 1).

Auslocations cleared each of the four test pit sites of underground services, and the 1.8t excavator supplied by *Glen Edwards Excavations* was operated by Seaton Waterfield.

1.2.2 Dates

Field work was conducted on 18 October 2022, in conjunction with hydrogeological studies including surface water and groundwater sampling, and aquifer pump testing[4].

[1] On www.thelist.tas.gov.au

[2] ASS overlay areas are attributed with a probability rating (high, low or extremely low) that indicate the potential to contain acid sulfate soil (ASS). The probability range for "Low" is 6 – 70%. Some locations have been field tested by others, and the test sites are also depicted on www.theist.tas.gov.au. However, there are no published test sites over the area proposed for the wind farm.

[3] ASS develop when sulphate-rich waters mix with soils or sediments which contain iron and organic matter. In oxygen-depleted water-logged soil or sediment, the sulphate is converted to sulphide by microbial decomposition of the organic matter. The sulphide combines with iron (or other metals) to form iron (or other metal) sulphides. The situation remains benign until the soil or sediment is disturbed and exposed to oxygen: iron sulphide is then oxidised and converted to sulphuric acid. The acid can mobilise other metals and move elsewhere in the environment. Deleterious effects include dissolution of soil, rock and concrete, corrosion of metal, or off-site soil contamination by heavy metals.

[4] Reported separately in Cromer, W. C. (2022). *Hydrogeological report for a proposed wind farm, St. Patricks Plains, central highlands Tasmania.* Unpublished report for Ark Energy by William C. Cromer Pty. Ltd. 21 December 2022.

1.2.3 Site selection

The number and locations of test pits were selected primarily by ERA and ARK, and were slightly modified after subsequent discussion with WCC.

Four locations (Figure 2) were chosen where ASS potential coincided with the proposed wind farm infrastructure.

The survey was accordingly reconnaissance in extent.

1.2.4 Sample collection and handling

Fourteen samples were collected: four from each of test pits ASS1 and ASS3, and three from each of test pits ASS2 and ASS4.

Each sample was from a discrete and recognisable soil horizon.

No field pH testing was done.

Samples were placed in plastic bags supplied and labelled by Australian Laboratory Services (ALS; Melbourne). Air was removed from each bag before sealing and placing it in a car freezer.

Samples were delivered to the courier *Tasfast* in Hobart the same afternoon for overnight despatch to ALS. *Tasfast* was instructed to keep the samples in a cool room until despatch.

1.2.5 Laboratory analytes

ERA indicated that samples should be tested using the chromium reducible sulphur technique[5], and for field pH [pH(F)] and for the pH after oxidation [pH(Fox)]. Accordingly, ASS suites EA033 and EA037 were requested of the laboratory. Suite EA033 also reports on Acid Base Accounting, and it is this approach which is largely considered in this report.

1.2.6 Reference documents

The field work including test pit logging was done in general accord with AS1726:2017 *Geotechnical site investigations*.

Sample handling and data interpretation were done in accord with *Tasmanian Acid Sulfate Soil Management* Guidelines (DPIPWE, undated).

Reference is also made to: Ahern C R, Stone, Y, and Blunden B (1998). *Acid Sulfate Soils Assessment Guidelines*. Published by the Acid Sulfate Soil Management Advisory Committee, Wollongbar, NSW, Australia.

[5] This technique is useful in assessing the contribution of organic sulphur to ASS potential.

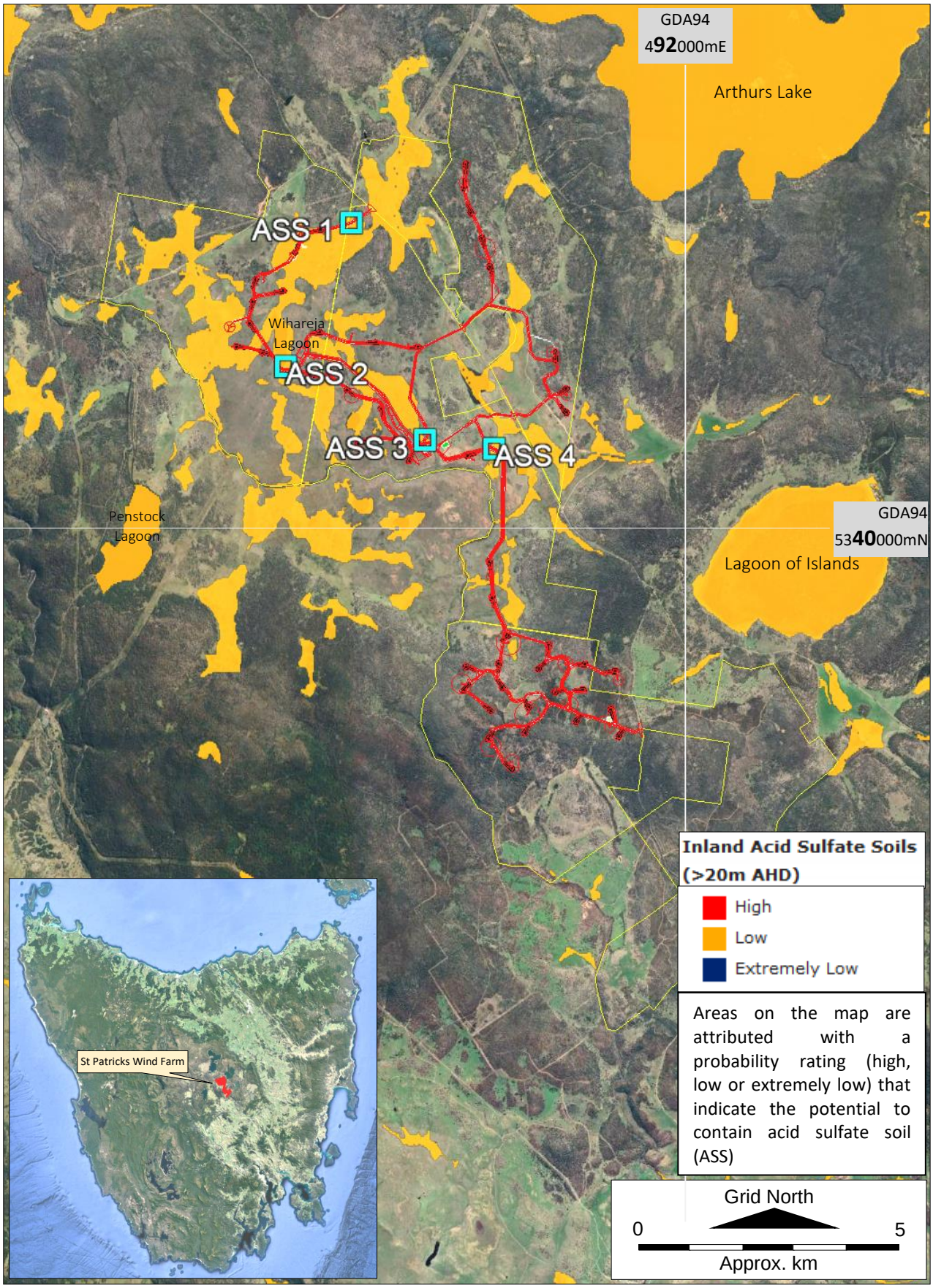


Figure 1. St Patricks wind farm infrastructure (red lines) on St Patricks Plains, and areas of potential inland ASS (orange). Yellow lines are property boundaries. Blue squares labelled ASS1 – ASS4 are test pit locations for ASS sampling. See detail in Figure 2. Source of base image: Google Earth; image date 28 October 2019; source for acid sulfate soil overlay www.thelist.tas.gov.au

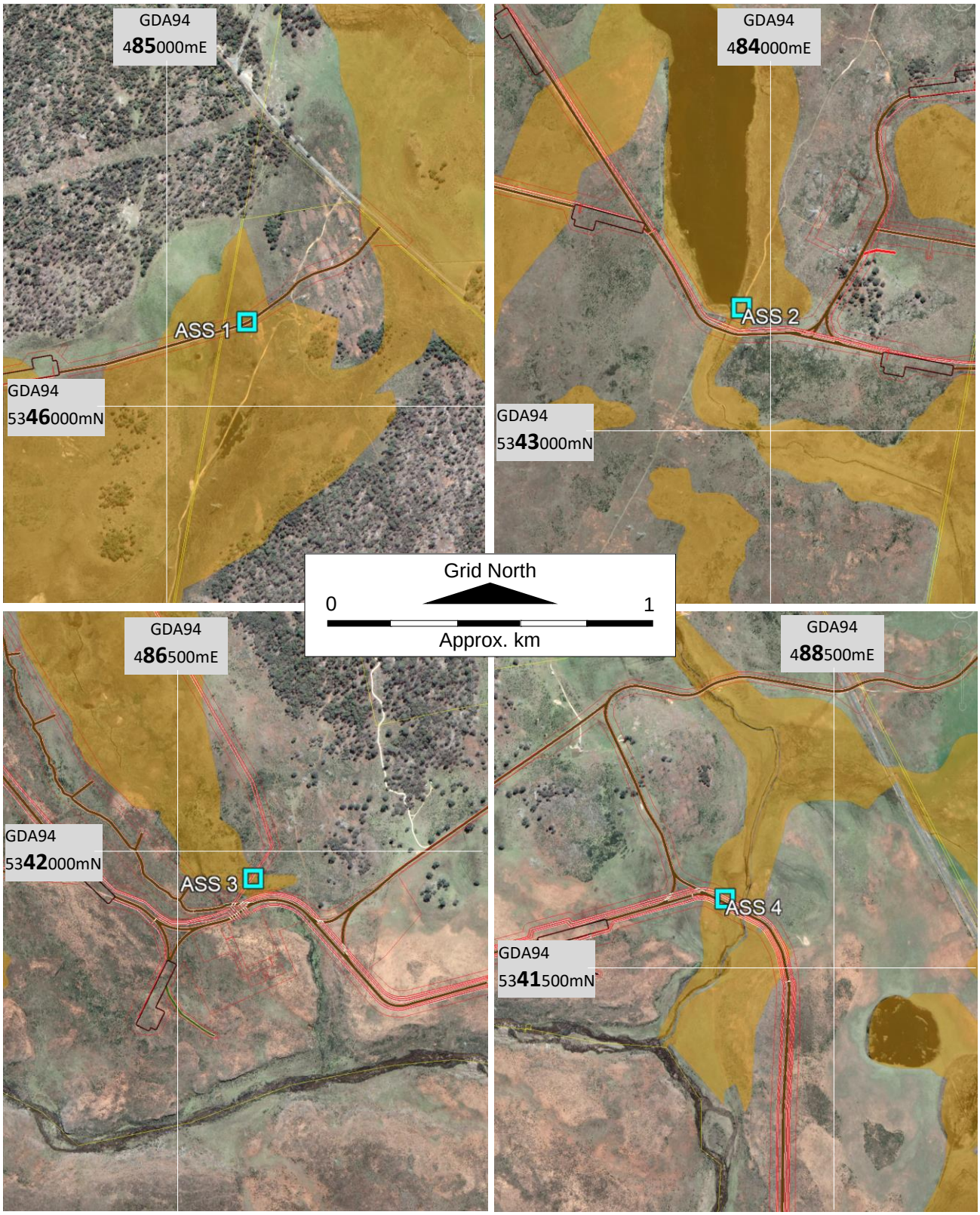


Figure 2. Test pits ASS1 – ASS4 (labelled blue squares) are each located in areas of potential inland ASS (orange). Red lines = St Patricks wind farm infrastructure. Yellow lines = property boundaries. Source of base image: Google Earth; image date 28 October 2019; source for acid sulfate soil overlay www.thelist.tas.gov.au

2 RESULTS

2.1 Topography and surface drainage

2.1.1 Topography

St Patrick Plains and the general area of the proposed wind farm is of subdued relief (850 – 900m ASL), with more elevated land (Sheepyard, Norths and Shepherds Hills, and Diamond Tier) rising some 50m or so along the eastern side. To the west, the valley of the Ouse River cuts through the plateau to depths of 100m or so.

In a west-to-east direction the plateau is essentially flat, but in a north-to-south direction it falls about 100m in altitude over a distance of 15km (ie 1:150, or 0.4^0).

2.1.2 Surface drainage

2.1.2.1 Hierarchy of drainage systems

As with all surface drainage systems, the hierarchy of drainage areas in the district is:

- major river catchments
- river and creek subcatchments, and
- creek sub-subcatchments ("CFEV River section subcatchments" on www.thelist.tas.gov.au),

2.1.2.2 Major river catchment

The proposed wind farm is wholly contained within the 1,500km^2 Ouse Catchment, within which is the deeply incised Ouse River flowing south along the western side of St Patricks Plains.

2.1.2.3 River and creek subcatchments

The proposed wind farm is wholly contained within the 212km^2 Upper Shannon Subcatchment, and the Shannon River flows south along its western side. Major creeks in the subcatchment draining to the Shannon River include Ripple Creek and its tributary Noels Creek to the east, and Wihareja Creek to the west.

2.1.2.4 Creek sub-subcatchments

Within the Upper Shannon Subcatchment, smaller defined sub-subcatchments, often only a few hectares in size, include individual minor and mostly intermittent watercourses and wetlands, marshes and lagoons: these generate potential ASS conditions.

2.2 Published geology and soils

2.2.1 Regional geological setting

The geology of the district is characterised by Jurassic-age dolerite, which as sills and associated dykes has intruded flat-lying or gently-dipping Permian-age and Triassic-age sedimentary rocks. Together with contemporaneous and later faulting, the rocks have been lifted almost a kilometre vertically above surrounding terrains to form Tasmania's central highlands.

2.2.2 Geology of the St Patrick Plains area

The geology of the St Patrick Plains and adjacent areas is dominated by Jurassic-age dolerite.

Small areas of Permian-age sedimentary rocks occur to the south on the property *Christian Marshes*.

Fairly extensive areas of volcanic rocks (basalt) occur over St Patricks Plains. The volcanics are probably relatively thin, although more than twenty deeper volcanic eruptive centres are inferred to be present[6].

Superficial deposits of unconsolidated Quaternary-age alluvium occupy many of the drainage lines in the district. Soils developed on the alluvium have generated potential ASS conditions.

2.2.3 Soils

Parts of the St Patricks Plains plateau area are devoid of soil, or carry only very thin veneers (<0.2m thick or so). Elsewhere, and particularly in and adjacent to marshes, wetlands and lagoons, profiles up to a metre or so thick have developed on the dolerite (and basalt) bedrock. These areas also roughly correspond to the mapped zones of potential ASS depicted in Figures 1 and 2.

Test pits ASS1 – ASS4 were also located within these areas. Table 1 summarises the soil profiles exposed in each pit, and the soil horizons from which the ASS samples collected. Test pit photographs showing sample locations are presented in Attachment 2.

From an ASS perspective, soil texture is an important controller on acid neutralising capacity (ANC). See Section 3.1.

2.3 Groundwater

Shallow groundwater occurs throughout the district, with water tables at depths typically less than a metre or so. The lagoons and wetlands occur where the water table intermittently or permanently lies at or above the land surface.

Shallow groundwater entered all four test pits, mostly from the topsoil horizons (Layers 1 and 2 in Table 1).

[6] Sutherland, FL and Hale, GEA 1970. Cainozoic volcanism in and around Great Lake, Central Tasmania. *Papers and Proceedings of the Royal Society of Tasmania*, vol. 104 , pp. 17-36

Table 1. Summary of test pits ASS1 – ASS4. See Figures 1 and 2 for locations, and Attachment 1 for test pit photographs.

Client Ark Energy
Location Proposed wind farm
St Patricks Plains
Date dug 18-Oct-22

Test pit	**ASS1**	**ASS2**	**ASS3**	**ASS4**
Depth dug (m)	1.5	1.5	1.6	1.3
Easting (GDA94)	485247	483924	486742	488138
Northing (GDA94)	5346265	5343372	5341902	5341730
Water inflow (depths in m)	Mainly from layers 1 and 2			
Standing water level (m)	Inflow during excavation; not stabilised			

				Interpretation					
No.	**Layer**	**Details**	**USCS classif**	**Horizon**	**AS/NZS1 547 soil category**	Figures are depths to top and bottom of layer, in metres			
1	**Sandy SILT**	Includes gravelly varieties; black; organic; locally with trace clay; occasional EW dolerite cobbles to 0.3m; low plasticity; many fine roots; gradational base; wet; friable to firm	OL	Peaty topsoil (A1 horizon)		0 to 0.2 ASS1(a) 0.1-0.2	0 to 0.4 ASS2(a) 0.1-0.2	0 to 0.4 ASS3(a) 0.1-0.2	0 to 0.4 ASS24a) 0.1-0.2
2	**Silty GRAVEL**	Includes sandy and clayey varieties; light yellowish grey, grey; low plasticity; gravel fine to medium; wet, friable; medium dense	GM	Topsoil (A2 horizon)		0.2 to 0.8 ASS1(b) 0.4-0.5m	0.4 to 0.7 ASS2(b) 0.5-0.6m	0.4 to 0.7 ASS3(b) 0.5-0.6m	0.4 to 0.6 ASS4(b) 0.5-0.6m
3	**Silty CLAY**	includes sandy and localy gravelly varieties; coarsely mottled light yellow and orange; occasional EW dolertie cobbles towards bas; M<>PL; St-VSt	CH	Subsoil (B horizon)	N/A	0.8 to 1.4 ASS1(c)	0.7 to 1.5 ASS2(c) 0.9-1.0m	0.7 to 1.6 ASS3(c) 1.0-1.1m ASS3(d) 1.5-1.6m	
4	**Silty GRAVEL**	brownish orange; some sand, some clay; nonplastic; some angular-subangular dolerite clasts to 0.5m; wet; Loose to medium dense	GM; loc. GC	Quaternary-age alluvium		1.4 to 1.5 ASS1(d) 1.4-1.5m			0.6 to 1.3 (slow digging at base) ASS4(c) 0.9-1.0m
5	**DOLERITE**	grey-brown; moderately weathered		Bedrock		1.5 R	1.5 R	1.6 R	

Notes and abbreviations

USCS = Unified Soil Classification System
Grey cells indicate a missing layer or layers in a test pit
Easting and Northing coordinates from Google Earth and hand-held GPS. Datum is GDA94.

Excavability Equipment = 1.8t Kubota excavator; 0.45m GP bucket; 4 teeth; Operator: Seaton Waterfield
EAR = end as required; NR = no refusal; CR = close to refusal; R = refusal.

Samples ASS1(a), ASS1(b)… are soil samples for acid sulphate soil analysis

Weathering For rock only. F = fresh; SW = slightly weathered; MW = moderately weathered; HW = highly weathered;
EW = extremely weathered (ie soil properties; material can be remolded in the hand, with or without water)

Moisture D = dry; M = moist (M<=>PL = moisture less than, equal to or greater than Plastic Limit); W = wet.

Consistency Fb = Friable (crumbles to powder when scraped with thumbnail)
S = Soft (Easily penetrated by fist; 25 – 50kPa)
F = Firm (Easily penetrated by thumb; 50 – 100kPa)
St = Stiff (Indented with thumb; penetrated with difficulty; 100 – 200kPa)
VSt = Very stiff (Easily indented with thumbnail; 200 – 400kPa)
H = Hard (Indented by thumbnail with difficulty; >400kPa)

Rel density VL = Very loose (ravelling)
L = Loose (easy shovelling)
MD = Medium dense (hard shovelling)
D = Dense (picking)
VD = Very dense (hard picking)

2.4 ASS laboratory results

The full ALS report of ASS analyses is presented in Attachment 2.

3 DISCUSSION

3.1 Soil texture types and oxidisable sulphur triggers

From a textural perspective in relation to ASS analyses, ten of the 14 tested samples are visually judged to be coarse-grained (Table 2). One is medium-grained, and three (two are Layer 3 B horizons) are fine-grained. Different ASS trigger values apply to different soil textures.

Table 2. Action criteria for ASS soil analyses based on three broad soil texture categories. Reproduced without amendment from *Tasmanian Acid Sulfate Soil Management* Guidelines

Type of Material		Action Criteria 100-1000 tonnes disturbed		Action Criteria if more than 1000 tonnes disturbed	
Texture range. McDonald et al. (1990)	*Approx. clay ontent (%<0.002 mm)*	*Sulfur trail % S oxidisable (oven-dry basis) eg S_{TOS} or S_{POS}*	*Acid trail mol H+/ tonne (oven-dry basis) eg, TPA or TSA*	*Sulfur trail % S oxidisable (oven-dry basis) eg S_{TOS} or S_{POS}*	*Acid trail mol H+/ tonne (oven-dry basis) eg, TPA or TSA*
Coarse Texture Sands to loamy sands	≤5	0.03	18	0.03	18
Medium Texture Sandy loams to light clays	5-40	0.06	36	0.03	18
Fine Texture Medium to heavy clays and silty clays	≥40	0.1	62	0.03	29

3.2 Comments on ASS analyses

Table 3 summarises the ASS results in Attachment 2. Some relevant observations are:

- the reduction in pH from field pH [pH(F)] to oxidised pH [pH(Fox)] exceeds 3 pH units for three of the four surface soil samples (Layer 1 in Table 1). Generally, the higher the value, the higher the ASS potential.
- for relatively small ground disturbances in the 100 – 1000t range, the net acidity measured in sulphur units (%S) exceeds the trigger values for the texture type (Table 2) in five samples, and
- for larger ground disturbances of more than 1000t, the net acidity measured in sulphur units (%S) exceeds the trigger values for all tested samples (Table 2).

Table 3. Summary of ASS laboratory results for 14 samples from test pits ASS1 – ASS4. See Figures 1 and 2 for locations, and Attachment 2 for the ALS laboratory report.

Test pit			ASS1				ASS2			ASS3				ASS4		
Location (GDA94)			485247mE, 5346265mN				483924mE, 5343372mN			486742mE, 5341902mN				488138mE, 5341730mN		
Depth (m) dug			1.5				1.5			1.6				1.3		
Sample ID			ASS 1(a)	ASS 1(b)	ASS 1(c)	ASS 1(d)	ASS 2(a)	ASS 2(b)	ASS 2(c)	ASS 3(a)	ASS 3(b)	ASS 3(c)	ASS 3(d)	ASS 4(a)	ASS 4(b)	ASS 4(c)
Sample depth (m)			0.1-	0.4-	0.8-	1.3-	0.1-	0.5-	0.9-	0.1-	0.5-	1.0-	1.5-	0.1-	0.5-	0.9-
Texture range			1	1	3	2	1	1	1	1	1	3	3	1	1	1
	Units	LOR														
EA003 :pH (field/fox)																
pH (F)	pH Unit	0.1	5.3	5.5	5.9	6.2	5.7	6.6	6.8	6.1	6.4	6.2	6.2	5.8	6.2	6.5
pH (Fox)	pH Unit	0.1	2.3	3.3	4	4.5	2.4	3.9	6.3	3.5	3.8	4.1	4.6	2.7	3.5	5.5
pH(F) minus pH(Fox)	pH Unit		3.0	2.2	1.9	1.7	3.3	2.7	0.5	2.6	2.6	2.1	1.6	3.1	2.7	1.0
Reaction Rate	Reaction	1	3	4	2	2	3	2	4	3	2	2	2	3	2	4
EA033-A: Actual Acidity																
pH KCl (23A)	pH Unit	0.1	4.3	4.7	4.6	4.7	4.8	5.5	5.6	4.9	5.6	5.1	5.7	4.5	5.4	5.4
Titratable Actual Acidity (23F)	mole H+ / t	2	160	100	38	31	84	10	21	98	12	20	10	115	27	28
sulfidic - Titratable Actual Acidity (s-23F)	% pyrite S	0.02	0.26	0.16	0.06	0.05	0.13	<0.02	0.03	0.16	<0.02	0.03	<0.02	0.18	0.04	0.04
EA033-B: Potential Acidity																
Chromium Reducible Sulfur (22B)	% S	0.005	0.012	0.01	0.013	0.009	0.01	0.009	0.01	0.011	0.011	0.012	0.01	0.013	0.01	0.009
acidity - Chromium Reducible Sulfur (a-22B)	mole H+ / t	10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
EA033-D: Retained Acidity																
Net Acid Soluble Sulfur (20Je)	% S	0.02	0.07	----	----	----	----	----	----	----	----	----	----	----	----	----
acidity - Net Acid Soluble Sulfur (a-20J)	mole H+ / t	10	31	----	----	----	----	----	----	----	----	----	----	----	----	----
sulfidic - Net Acid Soluble Sulfur (s-20J)	% pyrite S	0.02	0.05	----	----	----	----	----	----	----	----	----	----	----	----	----
KCl Extractable Sulfur (23Ce)	% S	0.02	<0.02	----	----	----	----	----	----	----	----	----	----	----	----	----
HCl Extractable Sulfur (20Be)	% S	0.02	0.03	----	----	----	----	----	----	----	----	----	----	----	----	----
EA033-E: Acid Base Accounting																
ANC Fineness Factor		0.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	% S	0.02	0.32	0.17	0.07	0.06	0.14	0.02	0.04	0.17	0.03	0.04	0.02	0.2	0.05	0.05
Net Acidity (acidity units)	mole H+ / t	10	199	105	47	36	90	15	27	104	18	27	16	124	33	33
Liming Rate	kg CaCO3/t	1	15	8	3	3	7	1	2	8	1	2	1	9	2	2
Net Acidity excluding ANC (sulfur units)	% S	0.02	0.32	0.17	0.07	0.06	0.14	0.02	0.04	0.17	0.03	0.04	0.02	0.2	0.05	0.05
Net Acidity excluding ANC (acidity units)	mole H+ / t	10	199	105	47	36	90	15	27	104	18	27	16	124	33	33
Liming Rate excluding ANC	kg CaCO3/t	1	15	8	3	3	7	1	2	8	1	2	1	9	2	2

pH

[blue box] pH(F) minus pH(Fox) >=3 pH units

Texture range

1 Coarse texture (Sands to loamy sands; <=5% clay): oxidisable S trigger level = 0.03%

2 Medium texture (Sandy loams to light clays; 5-40% clay): oxidisable S trigger level = 0.06%

3 Fine texture (Medium to heavy clays,and silty clays; >=40% clay): oxidisable S trigger level = 0.1%

[red box] Exceeds oxidisable S trigger level for texture range for 100-1000t ground disturbance

[pink shading] Exceeds oxidisable S trigger level for texture range for >1000t ground disturbance

4 CONCLUSIONS

Based on the reconnaissance survey,

- the limited-sampling ground truthing has supported the ASS potential of soils depicted in overlays on www.thelist.tas.gov.au.
- at all four test pits, and by reasonable inference in similar soils across the proposal footprint, topsoils (at least the Layer 1 A1 horizon, and possibly the Layer 2 A2 horizon) are at least low ASS potential, and may be higher; some subsoils may also qualify as ASS,
- subject to follow-up ASS sampling and analysis over the footprint of the proposed wind farm, parts of the infrastructure footprint will need ASS management. A sufficiently-detailed survey will be required to estimate depths and volumes of ASS soil, and
- depending on follow-up soil survey results, regulators may require an approved ASS Management Plan which sets out detailed protocols (eg material handling procedures, lime addition) appropriate to the various levels of ground disturbance proposed.

Attachment 1

(5 pages including this page)

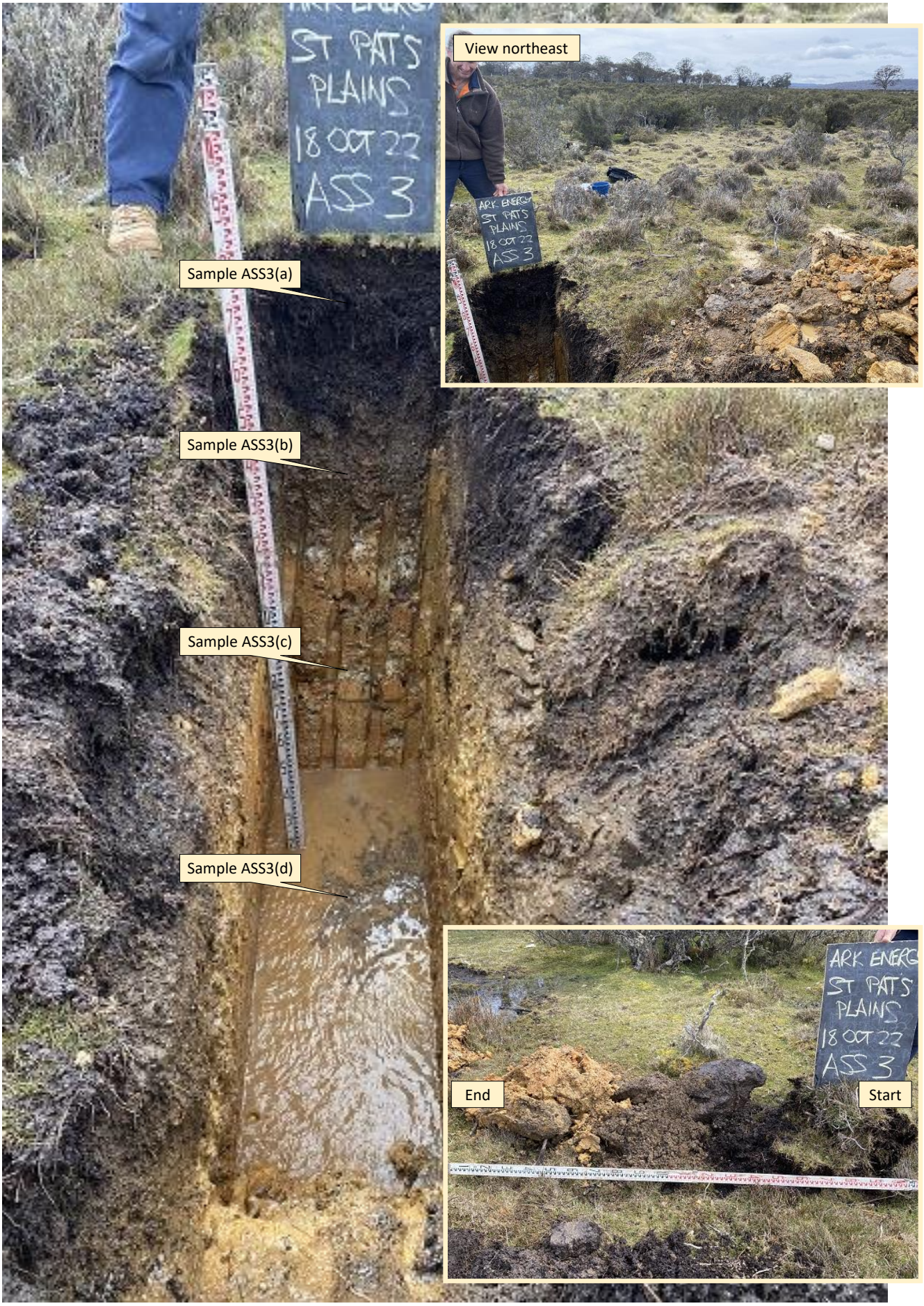
Test pit photographs

The scale in some of these photos is graduated into red- and black-numbered segments each one metre long. The numbers are decimetres.

There are three photos at each test pit. The main photo shows the soil profile in the pit. The two inset photos show (a) a general view showing the pit in relation to general site features, and (b) the soils excavated from the pit (laid out in the order they were excavated).


View west
ARK ENERGY
ST PATS PLAINS
18 OCT 22
ASS 1
Sample ASS1(a)
Sample ASS1(b)
Sample ASS1(c)
Sample ASS1(d)
Start
End


View north
ARK ENERGY
ST PATS
PLAINS
18 OCT 22
ASS2
Sample ASS2(a)
Sample ASS2(b)
Sample ASS2(c)
End
Start


ST PATS
PLAINS
18 OCT 22
ASS 3
Sample ASS3(a)
Sample ASS3(b)
Sample ASS3(c)
Sample ASS3(d)
View northeast
ARK ENERGY
ST PATS
PLAINS
18 OCT 22
ASS 3
End
Start


ST PAT'S
PLAINS
18 OCT 22
ASS4
View southeast
Sample ASS4(a)
Sample ASS4(b)
Sample ASS4(c)
End
Start

Attachment 2

(7 pages including this page)

ALS Chain of Custody Form (1 page)
ALS laboratory report EM2220953 for ASS analyses (5 pages)

(Pages 6 – 10 of the ALS laboratory report are purposely omitted. They relate to surface water and groundwater analyses and are described in a separate report.)

CHAIN OF CUSTODY

ALS Environmental

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
☑MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
☐NEWCASTLE 5 Rose Gum Road Warabrook NSW 2304 Ph: 02 4968 9433 E: samples.newcastle@alsglobal.com
☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com
☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com
☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
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☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: William C Cromer Pty Ltd	TURNAROUND REQUIREMENTS : Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)
OFFICE: 74A Channel Highway, Taroona, Tasmania 7053	(Standard TAT may be longer for some tests e.g., Ultra Trace Organics)	Custody Seal Intact? Yes No N/A
PROJECT: ARK ENERGY	ALS QUOTE NO.: EN_222_20	Free ice / frozen ice bricks present upon receipt? Yes No N/A
ORDER NUMBER: ARK ENERGY 01 OCT 2022	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Bill Cromer CONTACT PH: 0408 122 127; 03 6227 8970	OF: 1 2 3 4 5 6 7	Other comment:
SAMPLER: W. Cromer SAMPLER MOBILE: 0408 122 127	RELINQUISHED BY:	RECEIVED BY:
COC emailed to ALS? (YES / NO) EDD FORMAT (or default): Default	*W. Cromer*	
Email Reports to (will default to PM if no other addresses are listed): billcromer@bigpond.com	DATE/TIME: c 1400hrs 18 October 22	DATE/TIME:
Email Invoice to (will default to PM if no other addresses are listed): billcromer@bigpond.com		

	RELINQUISHED BY:	RECEIVED BY:
	DATE/TIME:	DATE/TIME:

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: For waters: measured in field - pH, EC, DO, Redox, Turbidity, Temperature

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION		ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).								Additional Information
LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE (refer to codes below)	TOTAL CONTAINERS	Ag Schedule B + D	ASS Fast Screen pHf & pHfox	ASS chromium suite						Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
	ASS 1 (d)	18/10/22:0755	S		1		1	1						
	ASS 2 (a)	18/10/22:0845	S		1		1	1						
	ASS 2 (b)	18/10/22:0847	S		1		1	1						
	ASS 2 (c)	18/10/22:0850	S		1		1	1						
	ASS 3 (a)	18/10/22:1105	S		1		1	1						
	ASS 3 (b)	18/10/22:1100	S		1		1	1						
	ASS 3 (c)	18/10/22:1125	S		1		1	1						
	ASS 3 (d)	18/10/22:1130	S		1		1	1						
	ASS 4 (a)	18/10/22:1205	S		1		1	1						
	ASS 4 (b)	18/10/22:1210	S		1		1	1						
	ASS 4 (c)	18/10/22:1215	S		1		1	1						
				TOTAL	11	0	11	11						

Water Container Codes: P - Unpreserved Plastic; N - Nitric Preserved Plastic; ORC - Nitric Preserved ORC; SH - Sodium Hydroxide/Cd Preserved; S - Sodium Hydroxide Preserved Plastic; AG - Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM2220593**	Page	: 1 of 11
Client	: **WILLIAM C CROMER PTY LTD**	Laboratory	: Environmental Division Melbourne
Contact	: MR BILL CROMER	Contact	: Shirley LeCornu
Address	: 74A CHANNEL HIGHWAY TAROONA TASMANIA 7053	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: 03 6227 8970	Telephone	: +6138549 9630
Project	: ARK ENERGY	Date Samples Received	: 19-Oct-2022 12:10
Order number	: ARK ENERGY 01 OCT 2022	Date Analysis Commenced	: 20-Oct-2022
C-O-C number	: ----	Issue Date	: 31-Oct-2022 17:54
Sampler	: W.CROMER		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 22		
No. of samples analysed	: 22		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results
- Surrogate Control Limits

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Arenie Vijayaratnam	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Dilani Fernando	Laboratory Coordinator	Melbourne Inorganics, Springvale, VIC
Xing Lin	Senior Organic Chemist	Melbourne Organics, Springvale, VIC

Page	:	2 of 11
Work Order	:	EM2220593
Client	:	WILLIAM C CROMER PTY LTD
Project	:	ARK ENERGY

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EP080: Where reported, Total Xylenes is the sum of the reported concentrations of m&p-Xylene and o-Xylene at or above the LOR.
- As per QWI – EN55-3 Data Interpreting Procedures, Ionic balances are typically calculated using Major Anions - Chloride, Alkalinity and Sulfate; and Major Cations - Calcium, Magnesium, Potassium and Sodium. Where applicable and dependent upon sample matrix, the Ionic Balance may also include the additional contribution of Ammonia, Dissolved Metals by ICPMS and H+ to the Cations and Nitrate, SiO2 and Fluoride to the Anions.
- ED093F : EM2220593 #6 results for dissolved cations have been confirmed by re-preparation and re-analysis.
- EA015H: EM2220593 #1,#4,#6:TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- ASS: EA033 (CRS Suite): ANC not required because pH KCl less than 6.5
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- Ionic balances were calculated using: major anions - chloride, alkalinity, sulfate and NOx; and major cations - calcium, magnesium, potassium and sodium for sample #6.
- ED045G: The presence of Thiocyanate, Thiosulfate and Sulfite can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime (CaCO3) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.
- ASS: EA003 (NATA Field and F(ox) screening): pH F(ox) Reaction Rate: 1 - Slight; 2 - Moderate; 3 - Strong; 4 - Extreme
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

William C Cromer Pty Ltd
www.williamccromer.com

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	ASS 1 (a)	ASS 1 (b)	ASS 1 (c)	ASS 1 (d)	ASS 2 (a)
			Sampling date / time	18-Oct-2022 07:30	18-Oct-2022 07:32	18-Oct-2022 07:45	18-Oct-2022 07:55	18-Oct-2022 08:45
Compound	CAS Number	LOR	Unit	EM2220593-009	EM2220593-010	EM2220593-011	EM2220593-012	EM2220593-013
				Result	Result	Result	Result	Result
EA003 :pH (field/fox)								
pH (F)	----	0.1	pH Unit	5.3	5.5	5.9	6.2	5.7
pH (Fox)	----	0.1	pH Unit	2.3	3.3	4.0	4.5	2.4
Reaction Rate	----	1	Reaction Unit	3	4	2	2	3
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	4.3	4.7	4.6	4.7	4.8
Titratable Actual Acidity (23F)	----	2	mole H+ / t	160	100	38	31	84
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	0.26	0.16	0.06	0.05	0.13
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.012	0.010	0.013	0.009	0.010
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-D: Retained Acidity								
KCl Extractable Sulfur (23Ce)	----	0.02	% S	<0.02	----	----	----	----
HCl Extractable Sulfur (20Be)	----	0.02	% S	0.03	----	----	----	----
Net Acid Soluble Sulfur (20Je)	----	0.02	% S	0.07	----	----	----	----
acidity - Net Acid Soluble Sulfur (a-20J)	----	10	mole H+ / t	31	----	----	----	----
sulfidic - Net Acid Soluble Sulfur (s-20J)	----	0.02	% pyrite S	0.05	----	----	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	0.32	0.17	0.07	0.06	0.14
Net Acidity (acidity units)	----	10	mole H+ / t	199	105	47	36	90
Liming Rate	----	1	kg CaCO3/t	15	8	3	3	7
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.32	0.17	0.07	0.06	0.14
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	199	105	47	36	90
Liming Rate excluding ANC	----	1	kg CaCO3/t	15	8	3	3	7

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Work Order	:	EM2220593
Client	:	WILLIAM C CROMER PTY LTD
Project	:	ARK ENERGY

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

			Sample ID	ASS 2 (b) Saved	ASS 2 (c)	ASS 3 (a)	ASS 3 (b)	ASS 3 (c)
			Sampling date / time	18-Oct-2022 08:47	18-Oct-2022 08:50	18-Oct-2022 11:05	18-Oct-2022 11:00	18-Oct-2022 11:25
Compound	CAS Number	LOR	Unit	EM2220593-014	EM2220593-015	EM2220593-016	EM2220593-017	EM2220593-018
				Result	Result	Result	Result	Result
EA003 :pH (field/fox)								
pH (F)	----	0.1	pH Unit	6.6	6.8	6.1	6.4	6.2
pH (Fox)	----	0.1	pH Unit	3.9	6.3	3.5	3.8	4.1
Reaction Rate	----	1	Reaction Unit	2	4	3	2	2
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	5.5	5.6	4.9	5.6	5.1
Titratable Actual Acidity (23F)	----	2	mole H+ / t	10	21	98	12	20
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	0.03	0.16	<0.02	0.03
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.009	0.010	0.011	0.011	0.012
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	<10
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	1.5
Net Acidity (sulfur units)	----	0.02	% S	0.02	0.04	0.17	0.03	0.04
Net Acidity (acidity units)	----	10	mole H+ / t	15	27	104	18	27
Liming Rate	----	1	kg CaCO3/t	1	2	8	1	2
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.02	0.04	0.17	0.03	0.04
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	15	27	104	18	27
Liming Rate excluding ANC	----	1	kg CaCO3/t	1	2	8	1	2

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Work Order : EM2220593
Client : WILLIAM C CROMER PTY LTD
Project : ARK ENERGY

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	ASS 3 (d) Saved	ASS 4 (a)	ASS 4 (b)	ASS 4 (c)	----
			Sampling date / time	18-Oct-2022 11:30	18-Oct-2022 12:05	18-Oct-2022 12:10	18-Oct-2022 12:15	----
Compound	CAS Number	LOR	Unit	EM2220593-019	EM2220593-020	EM2220593-021	EM2220593-022	-------
				Result	Result	Result	Result	---
EA003 :pH (field/fox)								
pH (F)	----	0.1	pH Unit	6.2	5.8	6.2	6.5	---
pH (Fox)	----	0.1	pH Unit	4.6	2.7	3.5	5.5	---
Reaction Rate	----	1	Reaction Unit	2	3	2	4	---
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	5.7	4.5	5.4	5.4	---
Titratable Actual Acidity (23F)	----	2	mole H+ / t	10	115	27	28	---
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	0.18	0.04	0.04	---
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	0.010	0.013	0.010	0.009	---
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	<10	<10	<10	<10	---
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	1.5	1.5	1.5	1.5	---
Net Acidity (sulfur units)	----	0.02	% S	0.02	0.20	0.05	0.05	---
Net Acidity (acidity units)	----	10	mole H+ / t	16	124	33	33	---
Liming Rate	----	1	kg CaCO3/t	1	9	2	2	---
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	0.02	0.20	0.05	0.05	---
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	16	124	33	33	---
Liming Rate excluding ANC	----	1	kg CaCO3/t	1	9	2	2	---