Spink Quarry, Knockbaun, Abbeyleix, Co. Laois

Spink Quarry

Environmental Impact Assessment Report

Appendix 6

Spink Geological Assessment (SLR 2020)

2021

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SPINK GEOLOGICAL ASSESSMENT

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APPENDICES

1.0 Introduction

SLR Consulting Ireland (SLR) were requested by Lagan Materials Ltd. (Lagan) to undertake a preliminary geological resource assessment of Spink Quarry and the lands immediately to the southeast of the extraction area during February 2020.

The assessment comprised a desktop review of previous exploration works, site inspection, rotary core drilling, petrographic analysis and chemical and physical testing. The geological assessment was primarily directed to confirming the quality and remaining extractable volumes of the Clay Gall Sandstone Formation and its likely potential for aggregate production. The assessment is also targeted at giving a preliminary assessment of the overlying and underlying formations for use in the manufacture of cement.

Four boreholes (20-SP-01, 20-SP-02, 20-SP-03 and 20-SP-04) were drilled in the Spink quarry lands, totalling 220m. Borehole lengths of 30m, 40m, 60m and 90m for boreholes 20-SP-01, 20-SP-02, 20-SP-03 and 20-SP-04 respectively and were targeted to identify the underlying geology and identify any potentially high-quality aggregates. The aim of these boreholes was to identify the aggregate extraction potential to extend the quarry.

This assessment has been undertaken by Professional Geologists EurGeol Tom Moore PGeo, EurGeol Dr. John Kelly PGeo, FIMMM, MIQ and IGI MIT, Ryan O'Donoghue.

2.0 Location Details

Spink Quarry is located about 10 kilometres east of Abbeyleix in Co. Laois. The quarry is located immediately off the main R430 Abbeyleix to Carlow road, see Figure 1.

The quarry site at Spink extends to approximately 8 hectares and was previously worked in the late 2000's. The study area included the main quarry area and the agricultural lands to the southeast.

3.0 Geological Setting

3.1 Regional Setting

The Geological Survey of Ireland (GSI) 1:100,000 mapping Sheet 19 (Geology of Carlow – Wexford) shows the site at Spink to be underlain by the Clay Gall Sandstone Formation, see Figure 3. The Clay Gall Sandstone Formation is described by the GSI as being between 30m to 50m in thickness and composed of medium to fine-grained quartz sandstones with minor feldspar content. It is also described by the GSI as being well-cemented with silica resulting in a non-porous rock of quartzitic character. The Clay Gall Sandstone Formation is overlain by the Coolbaun Formation and underlain by the Moyadd Coal Formation.

The Coolbaun Formation lies directly over the Clay Gall Sandstone further to the east and is composed of shales, siliceous sandstones with some coals and fireclays.

The Moyadd Coal Formation lies directly underneath the Clay Gall Sandstone and is described by the GSI as being 400-500m in thickness and composed of shales, siltstones and minor thin sandstones.

The Swan Sandstone Member lies within the Coolbaun Formation and is described by the GSI as being between 5m and 20m in thickness and composed of dark grey fine-grained siliceous sandstone.

Table 3-1
Lithological Succession in the Spink Area

AGE	FORMATION	THICKNESS
Westphalian (Carboniferous)	Coolbaun Formation	
	Clay Gall Sandstone	c. 50m
	Moyadd Coal Formation	400 - 500m
Namurian (Carboniferous)	Bregaun Flagstone Formation	c. 50m
	Killeshin Siltstone Formation	c. 275m

3.2 Spink Quarry Local Detail

The quarry is broadly rectangular in shape aligned in a northwest to southeast orientation and has not been worked for at least 10 years.

The available exposures show the underlying Moyadd Coal Formation exposed at the toe of the face in the extreme northwest with the overlying Coolbaun Formation exposed at the crest of the face in the south-eastern area. Almost all of the quarry is developed within the Clay Gall Sandstone with the entire sequence exposed on the weathered previously worked faces.

The bedding dip is typically towards the southeast and varies from <5° to 10° with local steepening in the northwest due to the presence of a small fault.

The exposed quarry faces show a massive thick uniform sandstone at the base of the formation with a more variable interbedded sandstone and siltstone unit towards the top of the formation.

4.0 Works Undertaken - 2020

4.1 Rotary Cored Boreholes

A total of four rotary cored boreholes (20-SP-01, 20-SP-01, 20-SP-03 and 20-SP-04) were drilled from northwest to southeast, perpendicular to strike, within the existing quarry and in the lands immediately to the southeast, see Figure 4. Boreholes 20-SP-01 and 20-SP-02 were drilled on the current quarry floor with a view to identifying the thickness of remaining Clay Gall Sandstone. The two boreholes further to the southeast were drilled in the lands above the quarry to identify the overburden thickness and thickness of Coolbaun Formation above the Clay Gall Sandstone.

Table 4-1
Spink Quarry 2020 Borehole Locations and Completion Details

Borehole ID	Easting	Northing	Elevation Estd(mOD)	Total Length (m)
20-SP-01	683287	653172	225	30.0
20-SP-02	683196	653275	225	40.0
20-SP-03	683063	653412	240	60.0
20-SP-04	682948	653591	247	90.0

4.1.1 20-SP-01

Borehole 20-SP-01 was drilled in the northwestern part of the site, as shown on Figure 4. It was drilled vertically to a depth of 30m bgl to identify the remaining reserves of Clay Gall Sandstone below the floor and intersect the contact with the underlying Moyadd Coal Formation. Table 4-2 and Figure 6 show the downhole litholgies encountered and the main stratigraphical contacts.

Initally, this borehole encountered uniform light to mid grey massive coarse grained Sandstone with rare clay galls (mudstone rip up clasts). The bottom section of the hole interesected dark grey to black mudstones of the Moyadd Coal Formation with a sharp contact between the two Formations.

Table 4-2
Borehole 20-SP-01 Summary Log

From (m)	To (m)	Formation	Lithology
0.00	19.80	Clay Gall Sandstone	Strong light to mid grey massive medium to coarse grained SANDSTONE with rare clay galls
19.80	30.00	Moyadd Coal Formation	Weak to moderately strong dark grey to black thinly bedded MUDSTONE with rare thin sandstones and siltstones

4.1.2 20-SP-02

Borehole 20-SP-02 was drilled at the eastern end of the quarry floor near the quarry sump, see Figure 4. As with the other holes it was drilled vertically to a depth of 40m bgl and as with 20-SP-01 the main aim was to identify the remaining reserves of Clay Gall Sandstone below the quarry floor and intersect the contact with the underlying Moyadd Coal Formation. Table 4-3 and Figure 6 show the downhole lithologies encountered and the main stratigrpahical contacts.

The sequence encountered in borehole 20-SP-02 is similar to borehole 20-SP-01 with the excpetion of the upper part where an interbedded sandstone and siltstone was encountered, typical of a fining upwards deltaic cycle. The remainder of the borehole encountered the massive light to mid grey medium to coarse grained sandstones typical of the lower part of the the Clay Gall Sandstone. The underlying contact with the Moyadd Coal Formation is similar being a sharp transition from light grey sandstones to find grained dark grey mudstones.

Table 4-3
Borehole 20-SP-02 Summary Log

From (m)	To (m)	Formation	Lithology
0.00	6.70	Clay Gall Sandstone	Strong light to mid grey massive medium to coarse grained SANDSTONE interbedded with moderately strong to strong mid to dark grey medium to thinly bedded SILTSTONE – Deltaic Cyclic Sandstone / Siltstone
6.70	31.00	Clay Gall Sandstone	Strong light to mid grey massive medium to coarse grained SANDSTONE with rare clay galls
31.00	40.00	Moyadd Coal Formation	Weak to moderately strong dark grey to black thinly bedded MUDSTONE with rare thin sandstones and siltstones

4.1.3 20-SP-03

Borehole 20-SP-03 was drilled further to the southeast on the partially stripped area above the existing quarry, see Figure 4. Due to the difference in elevation and the southeasterly geological dip, this borehole collared much higher in the sequence. The borehole initally encountered interbedded siltstones and mudstones with occasional sandstones of the Coolbaun Formation to 12.20m. Below this the upper part of the Clay Gall Sandstone consists of an interbedded sandstone and siltstone, typical of repeated fining upwards deltaic cycles. A 2m thick dark grey interbedded sandstone and siltstone was encountered in the middle of the Clay Gall Sandstone from 27.2m to 29.6m. Below this is the typical massive sandstone of the lower part of the Clay Gall Sandstone, as encoutnered in boreholes 20-SP-01 and 20-SP-02. A sharp contact with the underlying mudstones of the Moyadd Formation is at 56.0m.

Table 4-4
Borehole 20-SP-03 Summary Log

From (m)	To (m)	Formation	Lithology
0.00	2.70	Coolbaun Formation	Strong mid grey thin to medium bedded fine to medium grained SANDSTONE interbedded with moderately strong to strong mid to dark grey fine to medium grained SILTSTONE
2.70	12.20		Weak to moderately strong dark grey to black MUDSTONE interbedded with moderately strong to strong mid to dark grey fine to medium grained SILTSTONE
12.20	27.20	Clay Gall Sandstone	Strong light to mid grey massive medium to coarse grained SANDSTONE interbedded with moderately strong to strong mid to dark grey medium to thinly bedded SILTSTONE – Deltaic Cyclic Sandstone / Siltstone
27.20	29.60		Moderately strong, mid to dark grey SILTSTONE with interlaminated dark grey to black MUDSTONES
29.60	33.00		Strong light to mid grey massive medium to coarse grained SANDSTONE with rare clay galls
33.00	39.70		Strong light to mid grey massive medium to coarse grained SANDSTONE interbedded with moderately strong to strong mid to dark grey medium to thinly bedded SILTSTONE – Deltaic Cyclic Sandstone / Siltstone
39.70	56.00		Strong light to mid grey massive medium to coarse grained SANDSTONE with rare clay galls
56.00	60.00	Moyadd Coal Formation	Weak to moderately strong dark grey to black thinly bedded MUDSTONE with rare thin sandstones and siltstones

4.1.4 20-SP-04

Borehole 20-SP-04 was drilled on the edge of the agricultural land above the stripped area to the southeast, see Figure 4. Due to the geological dip and elevtion this borehole was driled to 90m with a view to coring the entire sequence. The borehole encountered interbedded mudstones, siltstones and sandstones of the Coolbaun Formation to 25.7m. The upper 2.7m recovered a more thickly bedded sandstone which may be the Swan Sandstone Member within the Coolbaun Formation, however not enough of the sequence was recovered to confirm.

Below the Coolbaun Formation the upper part of the Clay Gall Sandstone consists of an interbedded sandstone and siltstone, typical of repeated fining upwards deltaic cycles. A 2m thick dark grey interbedded sandstone and siltstone was encoutnered in the middle of the Clay Gall Sandstone from 48.0m to 51.2m. Below this is the typical massive sandstone of the lower part of the Clay Gall Sandstone as encountered in boreholes 20-SP-01, 20-SP-02 and 20-SP-03. A sharp contact with the underlying mudstones of the Moyadd Formation is at 72.0m.

Table 4-5
Borehole 20-SP-04 Summary Log

From (m)	To (m)	Formation	Lithology
0.00	2.70	Coolbaun Formation	Moderately strong, thickly bedded to massive, greenish brown fine to medium grained SANDSTONE
6.10	13.00		Weak to moderately strong dark grey to black MUDSTONE
13.00	21.60		Strong mid grey thin to medium bedded fine to medium grained SANDSTONE interbedded with moderately strong to strong mid to dark grey fine to medium grained SILTSTONE
21.60	25.70		Weak to moderately strong dark grey to black MUDSTONE interbedded with moderately strong to strong mid to dark grey fine to medium grained SILTSTONE
25.70	48.00	Clay Gall Sandstone	Strong light to mid grey massive medium to coarse grained SANDSTONE interbedded with moderately strong to strong mid to dark grey medium to thinly bedded SILTSTONE – Deltaic Cyclic Sandstone / Siltstone
48.00	51.20		Moderately strong, mid to dark grey SILTSTONE with interlamianted dark grey to black MUDSTONES
51.50	72.00		Strong light to mid grey massive medium to coarse grained SANDSTONE with rare clay galls
72.00	90.00	Moyadd Coal Formation	Weak to moderately strong dark grey to black thinly bedded MUDSTONE with rare thin sandstones and siltstones

4.2 Drillcore Testing

4.2.1 Introduction

A selection of 27 No. drill core samples were taken from boreholes 20-SP-01, 20-SP-02, 20-SP-03 and 20-SP-04.

Geochemical analyses were carried out on 27 of those samples (ICP-MS, ICP-AES) to determine geochemical properties, with X-Ray Fluorescence also carried out on 14 of these samples. The suite of major elements determined is Al_2O_3, BaO, CaO, Cl, Cr_2O_3, Fe_2O_3, K_2O, MgO, MnO, Na_2O, P_2O_5, SO_3, SiO_2, SrO, TiO_2 and Loss On Ignition, of which Al_2O_3, SiO_2, K_2O, Na_2O, CaO, Fe_2O_3, MgO and SO_3 are of significant interest.

A detailed petrography and X-Ray Diffraction was carried out on 1 sample to confirm the lithology and mineralogy of a representative Clay Gall Sandstone sample identified during the core logging.

Three >10.0m intervals selected to be representative of the main lithological types were sent for strength and durability testing including Los Angeles Value, Magnesium Sulfate Soundness, Polished Stone Value, Aggregate Abrasion Value, Water Absorption and Flakiness Index. These tests are designed to characterise the bulk strength and durability properties of the main lithologies and identify the aggregate potential of each.

Drill core test result certificates are presented in Appendix 03 and summarised in the tables below.

4.2.2 Chemical Analyses Results

Table 4-6 shows the results of the chemical tests carried out on the selected samples. For the purposes of the chemical analysis the results have been reported separately for each formation, with the maximum, minimum and average values determined where appropriate.

4.2.3 Coolbaun Formation

The test results indicate that the Total Sulfur content for all lithologies encountered within the Coolbaun Formation are exceptionally low for this type of lithological sequence with all of the results ranging from 0.02 to 0.04% for the total sulfur and an average value of 0.03%.

The Aluminium Oxide (Al_2O_3) for this Formation varied between 20.91% (for a mudstone) and 10.84% (for a Sandstone) with and average of 16.76%. The Iron Oxide (Fe_2O_3) varied from 7.79% (for a mudstone) and 4.75% (for a sandstone) with an average of 6.85%. The Magnesium Oxide (MgO) varied from 2.21% (for a mudstone) to 0.96% (for a sandstone) with an average of 1.79%. The Silica Oxide (SiO_2) varied from 77.13% (for a sandstone) to 57.44% (for a mudstone) with an average of 64.22%.

From the XRF results the Ma (Al_2O_3/Fe_2O_3), the Ms ($SiO_2/(Al_2O_3+Fe_2O_3)$ and the Sodium Equivalent NaEq (Na2O3+(K2O*0.658)) were calculated and tabulated in Table 4-7 below. The Ma ranged from 2.28 to 2.51 with an average of 2.44, the Ms ranged from 2.00 to 4.95 with an average of 2.86, with the NaEq ranging from 2.45 to 3.78 with an average of 3.27.

4.2.4 Clay Gall Sandstone

15 No. samples of Clay Gall Sandstone were sent for geochemical analyses with the total sulfur values typically low at between 0.01% and 0.19%, with an average of 0.05, indicating little if any pyrite is present.

For comparison two samples of Clay Gall Sandstone were sent for XRF analyses with the results shown in Table 4-8 below. The Al_2O_3 average was low at 7.34%, along with Fe_2O_3 at 3.63% and MgO at 0.77% with the SiO_2 unsurprisingly high at 83.19% due to the sandstone dominated lithologies. The average Ma was 2.00, with the average Ms at 8.10 and the average NaEq at 1.77%.

4.2.5 Moyadd Coal Formation

The chemical analyses of the Moyadd Coal Formation indicated two distinct units, an upper and lower unit to differing chemical signatures.

The Moyadd Upper had total sulfur values ranging between 0.1% and 0.16% with an average of 0.13%. The average Al_2O_3 was 16.37%, with the average Fe_2O_3 at 6.85%. The average MgO was 1.49% with the average SiO2 at 63.37%. The average Ma was 2.39%, with the average Ms at 2.73% and the average NaEq at 3.11%.

The Moyadd Lower unit had much higher total sulfur values at 1.19% and 1.13%. The Al_2O_3 ranged from 10.64% to 11.14%, with the Fe_2O_3 ranging from 4.99% to 5.10%. The MgO value ranged from 1.08% to 1.11% and the SiO_2 value ranged from 72.61% to 73.67%. The Ma ranged from 2.13 to 2.18, the Ms ranged from 4.47 to 4.71 and the NaEq ranged from 1.97 to 2.05.

Table 4-6
Sulfur, Sulfate and Organic Carbon Results

Hole ID	Sample No.	Formation	Lithology	From (m)	To (m)	Total Sulfur % S	Total Sulfate % SO4	Organic C %
20-SP-01	36060	Clay Gall	Sandstone	3.50	3.65	0.08	0.01	
20-SP-01	36061	Clay Gall	Sandstone	6.55	6.70	0.01	<0.01	
20-SP-01	36062	Moyadd	Mudstone	21.00	22.50	0.1		0.86
20-SP-02	36063	Clay Gall	Sandstone	2.10	2.35	0.02	<0.01	
20-SP-02	36064	Clay Gall	Sandstone	12.00	12.20	0.02	<0.01	
20-SP-02	36065	Clay Gall	Sandstone	25.40	25.60	0.01	<0.01	
20-SP-02	36066	Moyadd	Mudstone	33.00	34.60	0.16		0.82
20-SP-03	36067	Coolbaun	Mudstone / Siltstone	3.00	4.60	0.04		0.49
20-SP-03	36068	Coolbaun	Mudstone / Siltstone	6.00	7.60	0.03		0.44
20-SP-03	36069	Coolbaun	Mudstone	9.00	10.60	0.03		0.40
20-SP-03	36070	Clay Gall	Mudstone / Siltstone	13.60	13.75	0.19	<0.01	
20-SP-03	36071	Clay Gall	Siltstone / Sandstone	16.60	16.75	0.08	0.01	
20-SP-03	36072	Clay Gall	Sandstone	21.00	21.30	0.02	<0.01	
20-SP-03	36073	Clay Gall	Siltstone / Sandstone	28.60	28.80	0.05	<0.01	
20-SP-03	36074	Clay Gall	Siltstone / Sandstone	36.00	36.10	0.03	<0.01	
20-SP-03	36075	Clay Gall	Sandstone	46.40	46.60	0.04	<0.01	
20-SP-04	36076	Moyadd	Mudstone / Siltstone	58.10	60.00	0.13		0.74
20-SP-04	36077	Coolbaun	Sandstone	3.00	6.00	0.02		0.09
20-SP-04	36078	Coolbaun	Mudstone / Siltstone	6.00	9.00	0.04		0.57
20-SP-04	36079	Coolbaun	Mudstone / Siltstone	12.00	15.00	0.04		0.46
20-SP-04	36080	Coolbaun	Mudstone / Siltstone / Sandstone	18.00	21.00	0.04		0.47
20-SP-04	36081	Clay Gall	Sandstone	33.00	33.15	0.04	0.01	

Hole ID	Sample No.	Formation	Lithology	From (m)	To (m)	Total Sulfur % S	Total Sulfate % SO4	Organic C %
20-SP-04	36082	Clay Gall	Dark Sandstone	36.00	36.15	0.07	<0.01	
20-SP-04	36083	Clay Gall	Siltstone / Sandstone	51.00	51.20	0.07	<0.01	
20-SP-04	36084	Clay Gall	Sandstone	68.80	69.00	0.02	<0.01	
20-SP-04	36085	Moyadd	Mudstone	75.00	78.00	1.19		0.95
20-SP-04	36086	Moyadd	Mudstone	81.00	84.00	1.13		1.01

Table 4-7
Major Element Geochemical Results – Coolbaun Formation

Hole ID	Sample No.	Formation	Lithology	From (m)	To (m)	Total Sulfur %	Al2O3	Fe2O3	MgO	SiO2	Ma	Ms	Na Eq
20-SP-03	36067	Coolbaun	Mudstone / Siltstone	3.00	4.60	0.04	16.78	6.93	1.88	63.41	2.42	2.67	3.28
20-SP-03	36068	Coolbaun	Mudstone / Siltstone	6.00	7.60	0.03	17.37	7.51	1.98	61.42	2.31	2.47	3.32
20-SP-03	36069	Coolbaun	Mudstone	9.00	10.60	0.03	20.91	7.79	2.21	57.44	2.68	2.00	3.78
20-SP-04	36077	Coolbaun	Sandstone	3.00	6.00	0.02	10.84	4.75	0.96	77.13	2.28	4.95	2.45
20-SP-04	36078	Coolbaun	Mudstone / Siltstone	6.00	9.00	0.04	15.88	6.42	1.62	65.27	2.47	2.93	3.20
20-SP-04	36079	Coolbaun	Mudstone / Siltstone	12.00	15.00	0.04	18.18	7.23	1.94	61.69	2.51	2.43	3.50
20-SP-04	36080	Coolbaun	Mudstone / Siltstone / Sandstone	18.00	21.00	0.04	17.34	7.35	1.96	63.15	2.36	2.56	3.39
Max						**0.04**	**20.91**	**7.79**	**2.21**	**77.13**	**2.51**	**4.95**	**3.78**
Min						**0.02**	**10.84**	**4.75**	**0.96**	**57.44**	**2.28**	**2.00**	**2.45**
Average						**0.03**	**16.76**	**6.85**	**1.79**	**64.22**	**2.44**	**2.86**	**3.27**

Table 4-8
Major Element Geochemical Results – Clay Gall Sandstone

Hole ID	Sample No.	Formation	Lithology	From (m)	To (m)	Total Sulfur %	Al2O3	Fe2O3	MgO	SiO2	Ma	Ms	Na Eq
20-SP-01	36060	Clay Gall	Sandstone	3.50	3.65	0.08	5.53	2.87	0.60	86.65	1.93	10.32	1.47
20-SP-02	36063	Clay Gall	Sandstone	2.10	2.35	0.02	9.14	4.39	0.94	79.72	2.08	5.89	2.08
Average						**0.05**	**7.34**	**3.63**	**0.77**	**83.19**	**2.00**	**8.10**	**1.77**

Table 4-9
Major Element Geochemical Results – Moyadd Coal Formation

Hole ID	Sample No.	Formation	Lithology	From (m)	To (m)	Total Sulfur %	Al2O3	Fe2O3	MgO	SiO2	Ma	Ms	Na Eq
20-SP-01	36062	Moyadd - Upper	Mudstone	21.00	22.50	0.1	16.82	6.73	1.51	62.44	2.50	2.65	3.10
20-SP-02	36066	Moyadd - Upper	Mudstone	33.00	34.60	0.16	16.78	6.8	1.48	62.89	2.47	2.67	3.14
20-SP-04	36076	Moyadd - Upper	Mudstone / Siltstone	58.10	60.00	0.13	15.5	7.03	1.49	64.79	2.20	2.88	3.09
Average						**0.13**	**16.37**	**6.85**	**1.49**	**63.37**	**2.39**	**2.73**	**3.11**
20-SP-04	36085	Moyadd - Lower	Mudstone	75.00	78.00	1.19	10.64	4.99	1.08	73.67	2.13	4.71	1.97
20-SP-04	36086	Moyadd - Lower	Mudstone	81.00	84.00	1.13	11.14	5.1	1.11	72.61	2.18	4.47	2.05
Average						**1.16**	**10.89**	**5.05**	**1.10**	**73.14**	**2.16**	**4.59**	**2.01**

4.2.6 Detailed Petrographic Analysis and XRD

One sample of typical sandstones from the Clay Gall Formation was selected for detailed petrographic assessment and XRD, the table below outlines the findings.

Table 4-10
Petrography Results

Hole ID	Sample No.	From (m)	To (m)	Description	Quartz	Feldspar	Mica / Sericite	Chlorite	Dolomite
20-SP-02	36063	2.10	2.35	Fine to medium grained SANDSTONE	78%	10%	8%	2%	1%

4.2.7 Strength and Durability Testing

The results of the aggregate testing are shown below in Table 4.11. Testing was carried out by Celtest with the following results tabulated below

- Water Absorption (WA)
- Los Angeles Value (LA)
- Magnesium Sulfate Soundness (MSS)
- Aggregate Abrasion Value (AAV)
- Polished Stone Value (PSV)
- Flakiness Index (FI)

Table 4-11
Strength and Durability Results

Hole ID	Sample No.	Lithology	From (m)	To (m)	WA	LA	MSS	AAV	PSV	FI
20-SP-01	36279	Sandstone	4.00	14.90	0.9	18	1	3.5	58	32
20-SP-02	36280	Sandstone	6.40	17.50	0.7	15	1	4.5	58	33
20-SP-03	36281	Deltaic Cyclic Sandstone	14.70	25.80	0.8	16	1	6.8	68	53

The results above show a great deal of consistency between the lower massive sandstone unit of the Clay Gall Formation, tested in borehole 20-SP-01 and 20-SP-02, with the Water Absorption, Los Angeles Value and Magnesium Sulfate Soundness values showing a strong durable aggregate. The PSV for both of these samples is 58.

The upper part of the Clay Gall tested in 20-SP-03 indicates a slightly weaker unit with a higher flakiness index as a result of the interbedded siltstones and mudstones. However, this grading and mineralogical variation appears to generate a higher PSV.

This testing was carried out on core crushed to the required size fraction for each test and not processed aggregate stockpiles. The laboratory certificates are included in Appendix 05.

6.0 Discussion

The four boreholes (20-SP-01, 02, 03 and 04) were drilled both in the existing quarry and in the agricultural land to the southeast. The aim of the drilling was to identify potential resources underlying the existing quarry and new resources to the southeast of the existing extraction area. The investigation was also targeted at a preliminary assessment of the suitability of the overlying and underlying formations for use in the manufacture of cement.

Each of the boreholes encountered a similar sequence, collaring in varying parts of the stratigraphy. Boreholes 20-SP-01 and 20-SP-02 in the quarry floor encountered the lower part of the Clay Gall Sandstone into the underlying Moyadd Coal Formation. The upper boreholes, further to southeast, encountered the entire sequence including the overlying Coolbaun Formation, the entire Clay Gall Sandstone Formation and the underlying Moyadd Coal Formation.

The recent drilling has confirmed up to 30m of coarse-grained massive sandstone of the Clay Gall Sandstone Formation is available below the quarry floor in places, thinning to the northwest to effectively zero as the underlying contact with the Moyadd Coal Formation is exposed at the base of the northern quarry face. The typical gentle dip steepens to the north as a result of a fault exposed in the northern face, see Figure 5.

The core recovered from beneath the quarry floor shows a thickly to massive bedded, medium to coarse grained sandstone. The petrography and chemical results indicate low pyrite contents. The aggregate test results from below the quarry floor indicate a PSV of 58 for both tested samples, slightly lower than the aggregate testing history at the quarry. However, most of the previous extraction is from the upper and middle parts of the Clay Gall Sandstone. A sample tested from the upper part of the sequence returned a value of 68, however due to the more variable nature of this part of the formation this result may not be fully representative. The other strength and durability tests on the sandstone immediately below the quarry floor were excellent. All of the testing was carried out directly on core crushed to appropriately sized chips and not the typical crushed and screened aggregate stockpiles. The slightly lower PSV results from the lower sandstone may be due to the more consistent uniform grainsize of the lower sandstone. Aggregate testing on a processed sample from an entire face may yield a slightly higher result.

The upper part of the Clay Gall Sandstone, encountered in boreholes 20-SP-03 and 20-SP-04 showed a more variable sequence of interbedded sandstones and siltstones, interpreted to be stacked cyclic fining upwards deltaic sequences. Due to the higher siltstone content there is likely to be a higher degree of waste material in the production of surface dressing chips from this part of the sequence. Judging by the exposure in the existing quarry faces, most of the production in the quarry to date has been from the upper part of the Clay Gall Sandstone, with the exception of the most northerly face.

The overlying Coolbaun Formation encountered above the Clay Gall Sandstone in the boreholes to the south of the existing quarry is composed of interbedded siltstones and mudstones with occasional sandstones. The abundance of mudrocks, mudstones and siltstones, would likely make this Formation unsuitable for the production of specified aggregates and will likely be used more as a general fill material and / or for use in the manufacture of cement. The XRF results returned relatively high alumina contents averaging at 17%, including a low alumina sandstone value. However, the Sodium Equivalent value averaging at 3.27% indicates a relatively high alkali content. Due to the geological dip, the thickness of Coolbaun Formation overlying the Clay Gall increases to the southeast with the top of the Clay Gall further below ground level.

The underlying Moyadd Coal Formation is separated into two units based on the geochemical signature. The upper unit lying directly below the Clay Gall Sandstone and encountered in all four boreholes consists of a dark grey to black, thinly bedded Mudstone with relatively low total sulfurs (0.1% to 0.16%) for this type of lithology. A mudstone unit of this type is unsuitable for the manufacture of certified aggregates due to the weak water absorbent nature of the material. The alumina content of 16.37% would typically be regarded as suitable for cement however, the sodium equivalent (NaEq) value of 3.11% is high.

The Lower Moyadd Unit (again consisting of a thinly bedded mudstone) has much higher total sulfur values, averaging at 1.16%, too high for specified aggregate production.

The aggregate quality assessment indicates that the sandstones are strong to very strong and are likely to be of high quality, similar or of greater consistency to those previously worked in the quarry and should be capable of producing a surface dressing chip similar to that previously produced. These lithologies should be capable of producing aggregates compliant with the specifications below:

- TII Series 500, 600 and 800 unbound fill materials
- SR21: 2014 + A1: 2016 Annex E Guidance on the use of I.S. EN 13242 unbound fill materials
- S.R. 16 Guidance on the use of I.S. EN 12620:2002 Aggregates for concrete products

7.0 Resource & Reserves

7.1.1 Reporting Terminology

The mineral reserves and resources have been reported using the Pan-European Reserves & Resources Reporting Committee (PERC) mineral reporting code. They have been sub-divided into appropriate categories, based on levels of geological knowledge and confidence that can be determined from the available geological data.

The mineral deposit has been defined as reserves or resources, based on legal, environmental, ownership, social and statutory factors (e.g. planning status). Image 1 below shows the definitions of the PERC Code and the differences between Indicated and Measured Resources and Probable and Proven Reserves.

Image 1
PERC Definitions

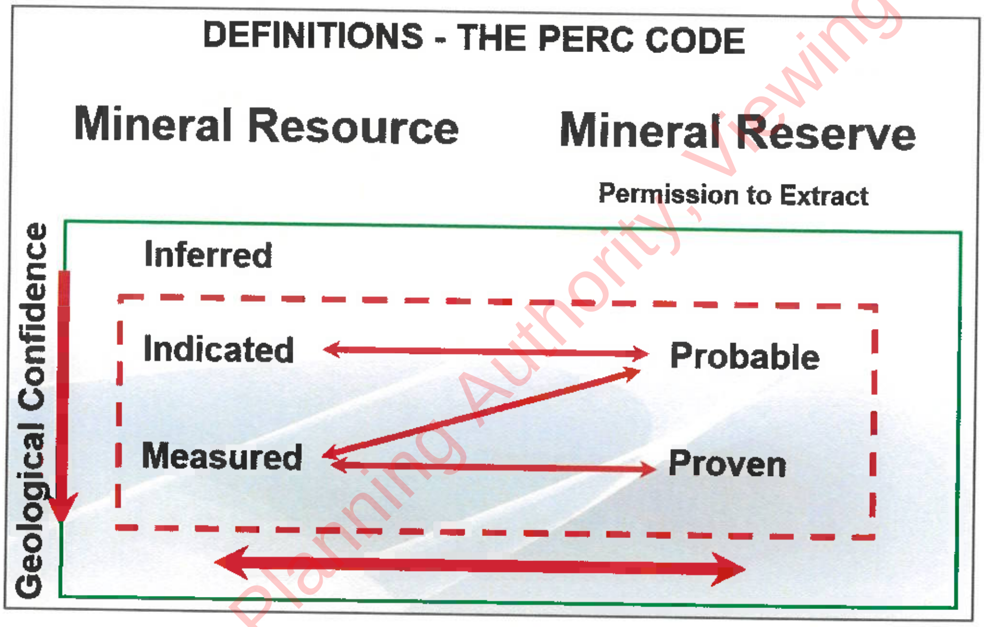


Table 7-1 outlines how the modified PERC reporting code has been applied to these assessments.

Table 7-1
Categorisation of Mineral Reserves and Resources

RESERVE/ RESOURCE CATEGORY	DEFINITION	DESCRIPTION
Proven Reserve	Economically mineable part of a measured mineral resource. Includes diluting materials and allowances for losses, which may occur as the material is mined. Takes into account modifying factors such as legal, environmental, social and governmental status.	Well defined by intrusive ground investigation, sampling and testing at appropriate resolution (e.g. c.100m spacing). Previous successful exploitation at this location and stratigraphic level. Has planning permission for extraction. Minerals owned by Lagan or Lagan has leasehold rights to 'win and work' the minerals.
Probable Reserve	Economically mineable part of an indicated mineral resource, and some circumstances measured mineral resource. Includes diluting materials and allowances for losses, which may occur as the material is mined. Takes into account modifying factors such as legal, environmental, social and governmental status.	Lower level of geological confidence than a proven mineral reserve. Less well defined by intrusive ground investigation. Drilling, sampling and testing on a limited number of locations and inferred over larger distances (e.g. >150m). Has planning permission for extraction. Minerals owned by Lagan or Lagan has leasehold rights to 'win and work' the minerals
Measured Resource	Part of a mineral resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. Reliable exploration sampling and testing using appropriate techniques. Spacing is close enough to confirm geological and grade continuity.	Well defined by intrusive ground investigation, sampling and testing at appropriate resolution. Previous successful exploitation at this location and stratigraphic level, (e.g. drilled and sampled on a tight grid <100m or large exposed face sampled at high frequency). Does not have planning permission for extraction. Minerals owned by Lagan or Lagan has leasehold rights to 'win and work' the minerals
Indicated Resource	Part of a mineral resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. Cannot define grade but can assume continuity.	Defined by intrusive ground investigation and or face sampling on a widely spaced grid or inappropriately to define a measured mineral resource. Does not have planning permission for extraction. Minerals owned by Lagan or Lagan has leasehold rights to 'win and work' the minerals
Inferred Resource	Part of a mineral resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. Inferred from geological evidence but has no verification of grade or continuity or continuity	Not defined by any intrusive ground investigation or inferred from very wide drill hole spacing, which does not verify continuity, (e.g. inferred from BGS mapping and drill hole spacing >300m). Does not have planning permission for extraction.

RESERVE/ RESOURCE CATEGORY	DEFINITION	DESCRIPTION
Prospects	An area of land that is not currently owned by the mineral operator, although the mineral deposit may be well defined with potential to be 'upgraded' to reserve/resource category subject to economic factors	Land and/or minerals not owned, or leased

7.2 Volume Assessment

For the purposes of the report the extraction design and volume calculation has been divided into two phases. Phase 1 is the existing extraction area with available bedrock below the quarry floor requiring minimal stripping. Phase 2 is the lands to the southeast that have not been actively developed to date with the exception of a partially stripped area (Area 1), see Figure 7.

7.2.1 Proven Reserve – Phase 1 - Area 3

With the current permitted extraction level to 220mOD the Phase 1 – Area 3, see Figure 7, is considered a Proven Reserve with extractable bedrock above the permitted level within the designated area. The design includes for this face to be developed down to the current floor level where the base of the Clay Gall Sandstone is exposed in this area. A total of 32,000m^3 of extractable bedrock is estimated to be in this area to the base of the Clay Gall Sandstone. An average of 5m of overburden including stockpiles has been estimated in this area.

Table 7-2
Volume Assessment – Proven Geological Reserve

Area	Clay Gall Sandstone Total		Overburden
Phase 1 - Existing Extraction Area	**m³**	**t**	**m³**
Area 3	**32,000**	**83,200**	44,000

7.2.2 Measured Resource - Phase 1 – Existing Extraction Area

The recent drilling has confirmed a reasonable thickness of Clay Gall Sandstone below the current quarry floor, thickening to the southeast with the geological dip. The lower part of the Clay Gall Sandstone appears to consist of the most uniform and massive sandstone before becoming more variable higher in the sequence.

The two boreholes drilled on the quarry floor (20-SP-01 and 20-SP-02) encountered the same sequence and both encountered the underlying Moyadd Coal Formation marking the end of the measured resource below the quarry floor.

Phase 1 has been divided into three separate areas with the volume reported for each, see Figure 7 and Table 7.3 below. Area 1 is a single 15m bench in the central part of the extraction area to 209mOD as shown on Figure 7 and 8. Area 2 extends to 199mOD due to the favourable geological dip along a deeper level of extraction in this area. Area 3 removes the remaining reserves close to the north western boundary of the site, see Section 7.2.1.1.

Design criteria consisted of:

- Typical Standoff to any Site Boundary - 10m
- Quarry Face Heights - 15m where possible
- Additional Existing Extraction Area B Lower Bench - 10m
- Final Bench Widths – 7.5m
- Final Floor Level 199mOD Phase 1 and 177mOD Phase 2 – see Figure 7,
- No allowance made for removal of stockpiles existing on the site
- No Allowance for waste, quarry infrastructure, haul roads etc.
- No Allowance made for weathering
- Aerial Imagery Date - April 2019
- Rock density in situ of 2.6t/m^3

Table 7-2 below summarises the measured resource gross volumes and tonnages available.

Table 7-3
Volume Assessment – Measured Geological Resource

Area		Clay Gall Sandstone Total		Overburden
Phase 1 - Existing Extraction Area		m^3	t	m^3
Area 1		500,550	1,301,430	
Area 2		440,000	1,144,000	
	Total	940,550m^3	2,445,430Mt	

7.2.3 Phase 2 – Southeast Area

The Southeast Area covers a partially stripped area next to the existing quarry and agricultural land further to the southeast.

The boreholes further to the south (20-SP-03, 20-SP-04), although encountering the entire Clay Gall Sandstone at over 40m in thickness had significant thicknesses of interbedded mudstones / siltstones and sandstones of the Coolbaun Formation overlying. The geological bedding dip towards the southeast increases the volume of poorer quality Coolbaun Formation overlying the Clay Gall Sandstone.

The volumes of both Clay Gall Sandstone and Coolbaun Formation are listed separately in Table 7-4 below.

As with Phase 1, this area has been divided into three separate areas, labelled A, B and C. Area A is the previously partially stripped area that would involve the least amount of stripping to access the available good quality rock below. Area B is the surrounding unstripped lands to the northeast and southwest of this area. Area C is the remainder of the site to the southeast extending to the site boundary. This area extends slightly outside the survey area, so assumed ground levels were used.

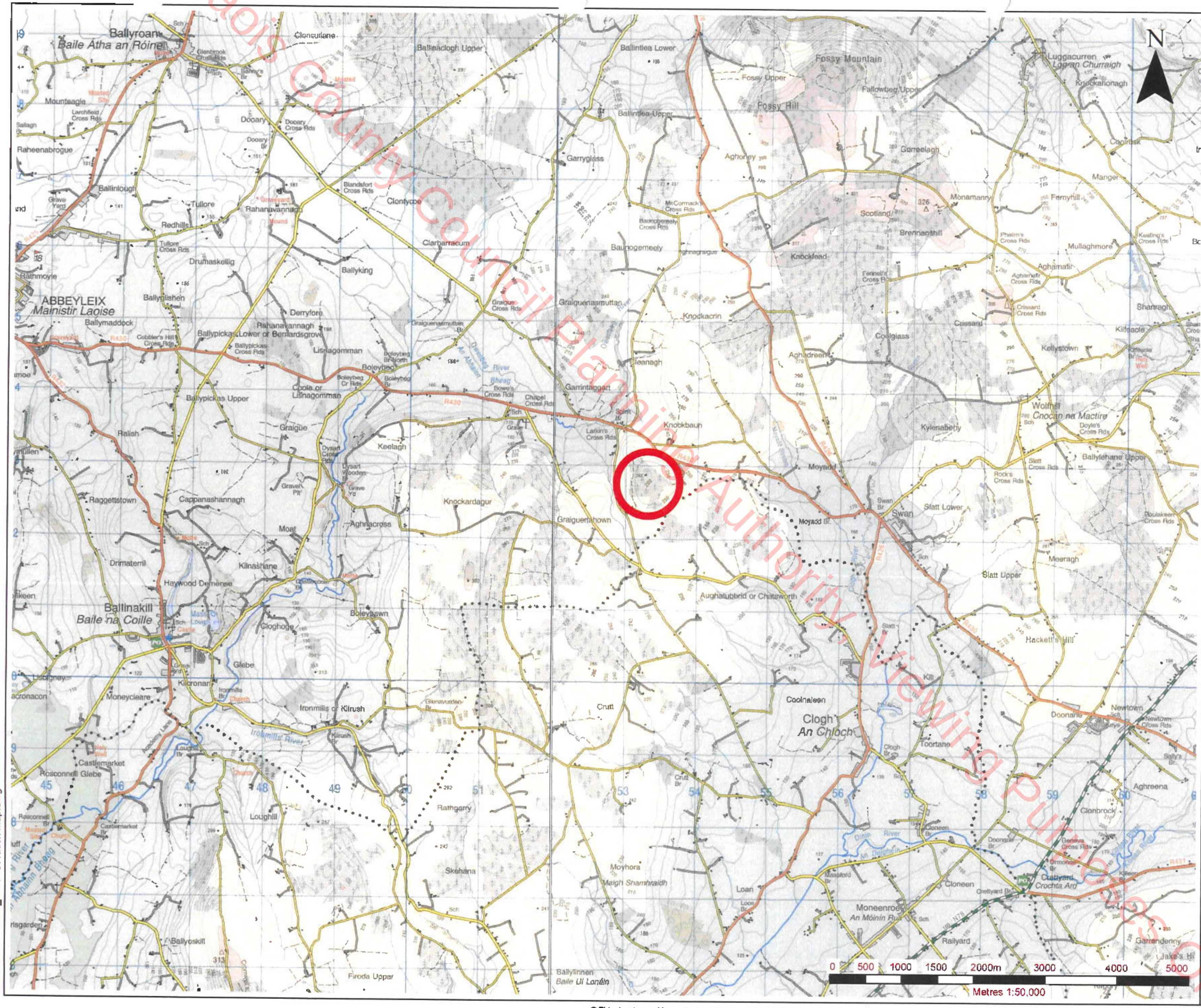
Table 7-4
Volume Assessment – Phase 2

Area	Clay Gall Sandstone Total		Coolbaun Formation Total	
Phase 2 – Southeast Area	m³	t	m³	t
Area A	**654,107**	**1,700,679**	336,660	875,316
Area B	**1,170,083**	**3,042,216**	707,550	1,839,630
Area C	**1,326,686**	**3,449,384**	660,000	1,716,000
Total	**3,150,876m³**	**8,192,278Mt**	**1,704,210**	**4,430,946**

8.0 Conclusions

- The recent core drilling has identified a significant thickness of Clay Gall Sandstone still remaining below the current quarry floor.
- Boreholes 20-SP-01 and 20-SP-02 encountered a similar sequence of thickly to massively bedded medium to coarse grained sandstones above the mudstone rich Moyadd Coal Formation.
- The thickness of remaining Clay Gall Sandstone below the quarry floor increases to the southeast with the geological dip.
- The sandstones identified below the quarry floor are likely to produce high quality aggregates suitable for most end uses, including the production of surface dressing chips. Aggregate testing of a processed stockpile should be carried out to confirm the PSV.
- The upper part of the Clay Gall Sandstone encountered in boreholes 20-SP-03 and 20-SP-04 is more variable with interbedded sandstone and siltstones, typical of fining upwards deltaic sequences.
- In this area, the Coolbaun Formation consisting of interbedded mudstones / siltstones and sandstones, overlies the Clay Gall Sandstone, the overall depth to the base of the Coolbaun increasing to the southeast with the geological dip.
- The dominance of mudstones and siltstones in the overlying Coolbaun Formation would make this only suitable for the production of general fill products. Dependent on the local geochemistry areas may be suitable for use in cement manufacturing.
- The geochemical results from the underlying Moyadd Coal Formation suggest that the upper unit, although having a high alumina content, has an alkali content that may be unacceptable for use in the manufacture of cement. The lower unit has lower alkali levels.
- The Measured Mineral Resource of Clay Gall Sandstone underlying the existing extraction area is approximately 2.4Mt.
- Observations from within the quarry, review of available geological data/publications and the results from the drilling indicate that the forested land to the southwest of the existing quarry are underlain by Clay Gall Sandstone and initial inspection from the boundary suggests that any overburden is relatively thin. Ground Investigation would be required to confirm this interpretation.

FIGURES



NOTES

1. Extract from Ordnance Survey Map No. 60 & 61.

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SITE LOCATION

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LAGAN QUARRIES

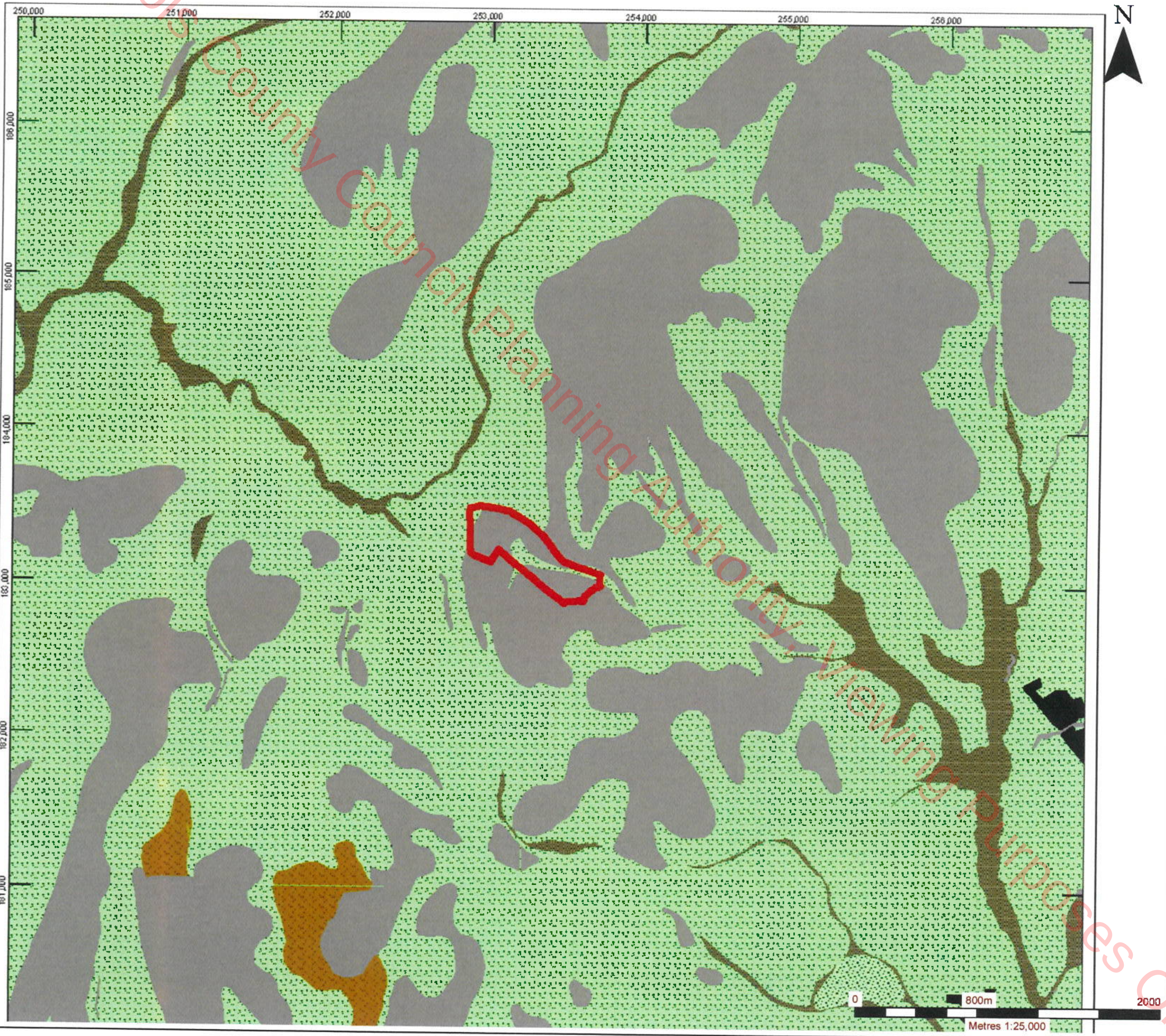
SPINK QUARRY,
SPINK, CO. LAOIS

SITE LOCATION MAP

FIGURE 1

Scale	Date
1:50,000 @ A3	MAY 2020

00586.00002.0.FIG_1.Site Location Map.dwg



NOTES

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SITE LOCATION

TEAGASC MAPPING
SUPERFICIAL DEPOSITS

- Blanket Peat
- Alluvium
- Till - Namurian Clasts
- Outcrop & Subcrop
- Made Ground

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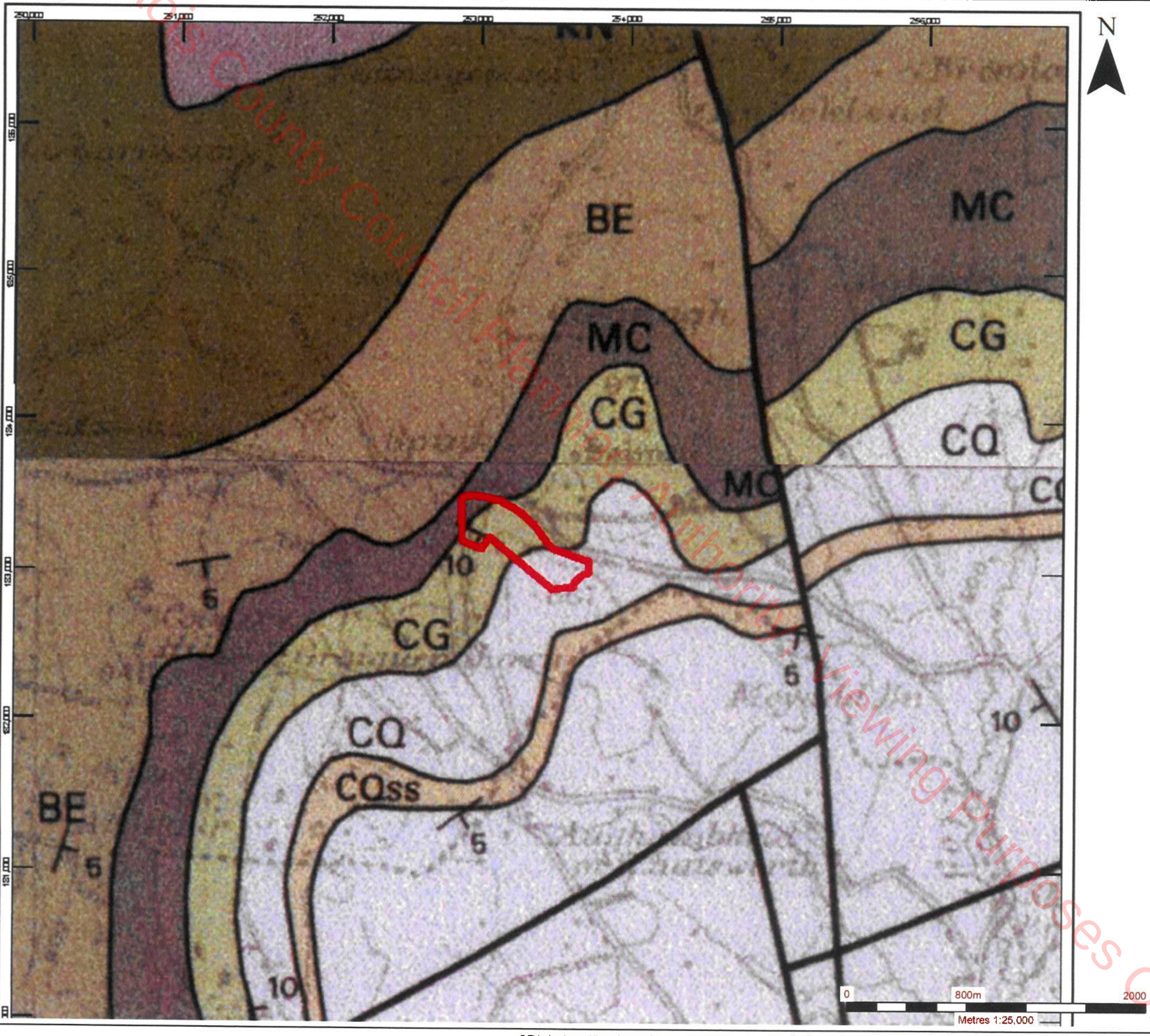
SOILS MAPPING

FIGURE 2

Scale	Date
1:25,000 @ A3	MAY 2020

00586.00002.0.FIG_2.Soils Mapping.dwg



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WESTPHALIAN	CQ	Coolbaun Formation Shale and mudstone with thin coals
	SS	Swan Sandstone Member Laminated dark-grey siliceous sandstone
	CG	Clay Gall Sandstone Formation Feldspathic quartzitic sandstone
	MC	Moyadd Coal Formation Shale, siltstone & minor sandstone
NAMURIAN	BE	Bregaun Flagstone Formation Thick flaggy sandstone and siltstone
	KN	Killeshin Siltstone Formation Muddy siltstone & silty mudstone
	LS	Luggacurren Shale Formation Mudstone & shale with chert & limestone
	NAM	Namurian (undifferentiated) Black shale

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GEOLOGY MAPPING

FIGURE 3

Scale	Date
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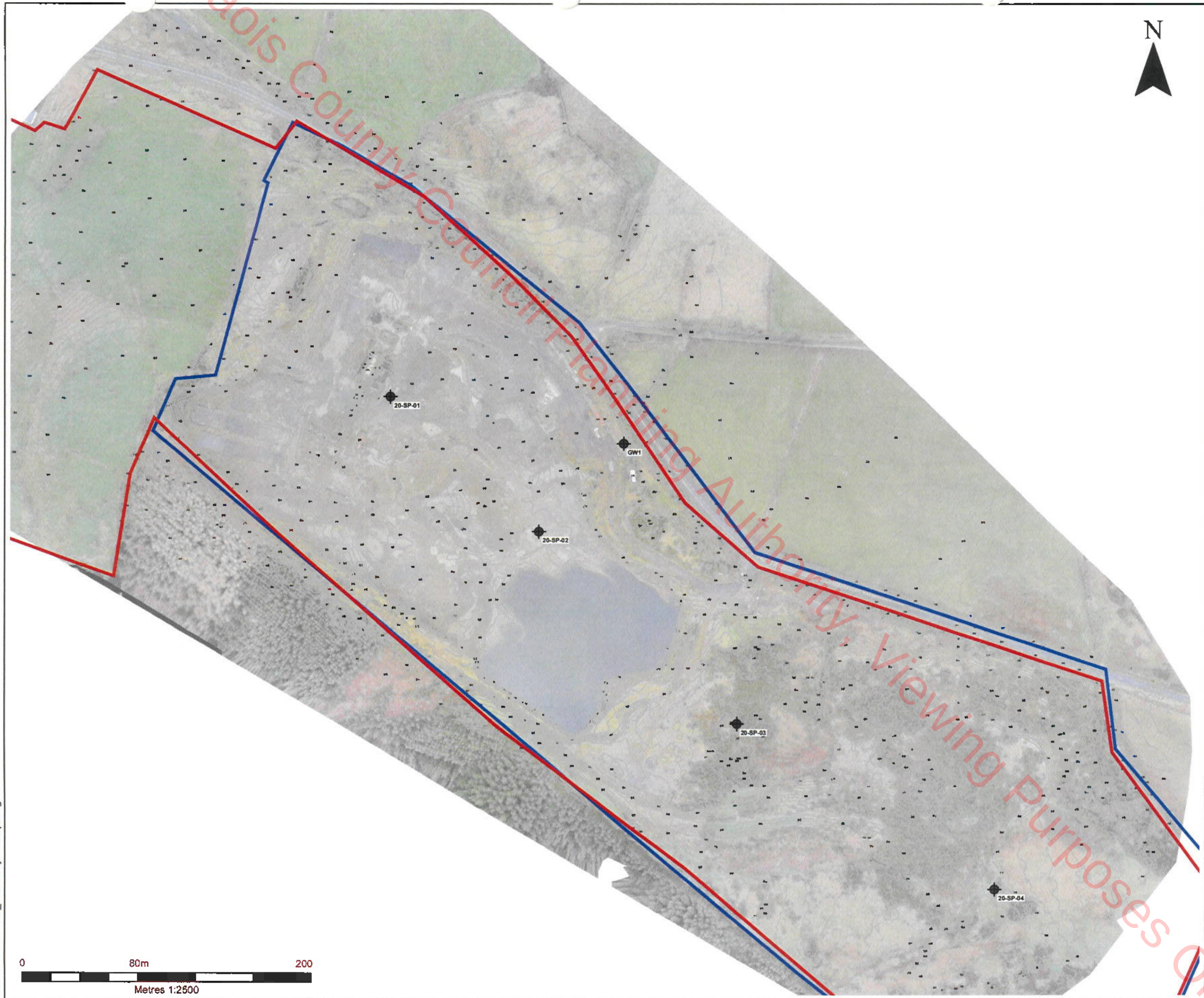
00586.00002.0.FIG_3.Geology Mapping.dwg



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All Dimensions and Levels are to be checked on site.

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LEGEND

LAND OWNERSHIP BOUNDARY (c. 19.8 Hectares)

PLANNING BOUNDARY (c. 25.8 Hectares)

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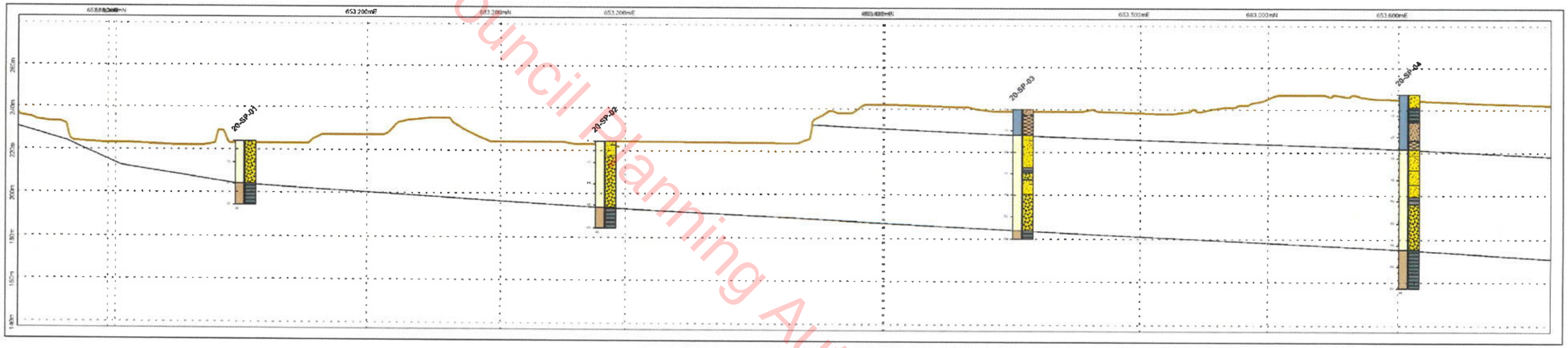
SITE LAYOUT MAP

FIGURE 4

Scale	Date
1:2,500 @ A3	MAY 2020

00586.00002.0.FIG_4.Site Layout Map.dwg



Formations

- Coolbaun Formation
- Clay Gall Sandstone Formation
- Moyadd Coal Formation

Lithology

- Massive Sandstone
- Cyclic Sandstone
- Deltaic Cyclic Sandstone / Siltstone
- Siltstone / Sandstone
- Mudstone / Siltstone
- Dark Mudstone / Siltstone
- Mudstone

0 20 40 60 80m 120 160 200

Metres 1:2000

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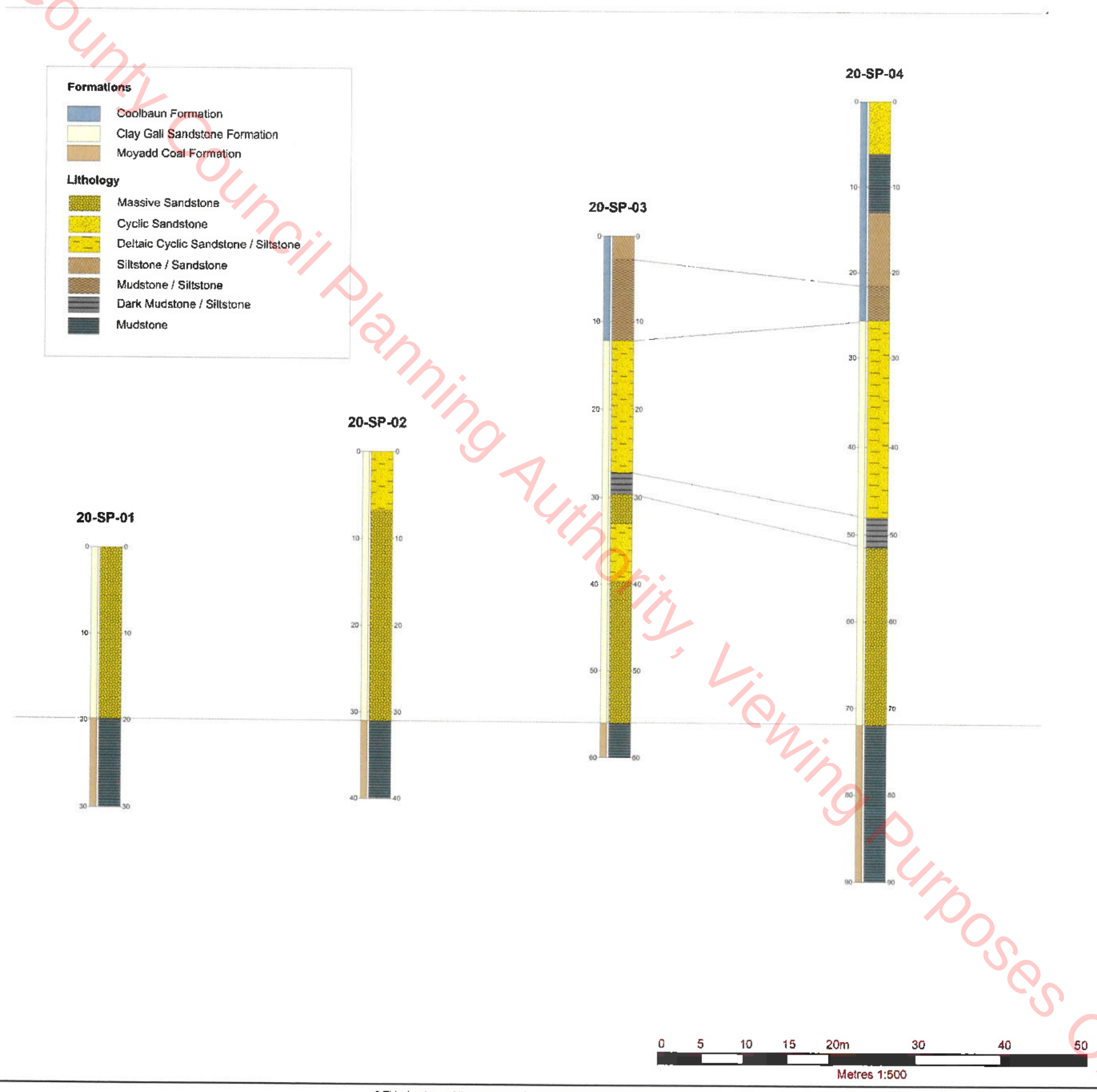
CROSS SECTIONS

FIGURE 5

Scale	Date
1:2,000 @ A3	MAY 2020

00586.00002.0.FIG_5.Cross Sections.dwg



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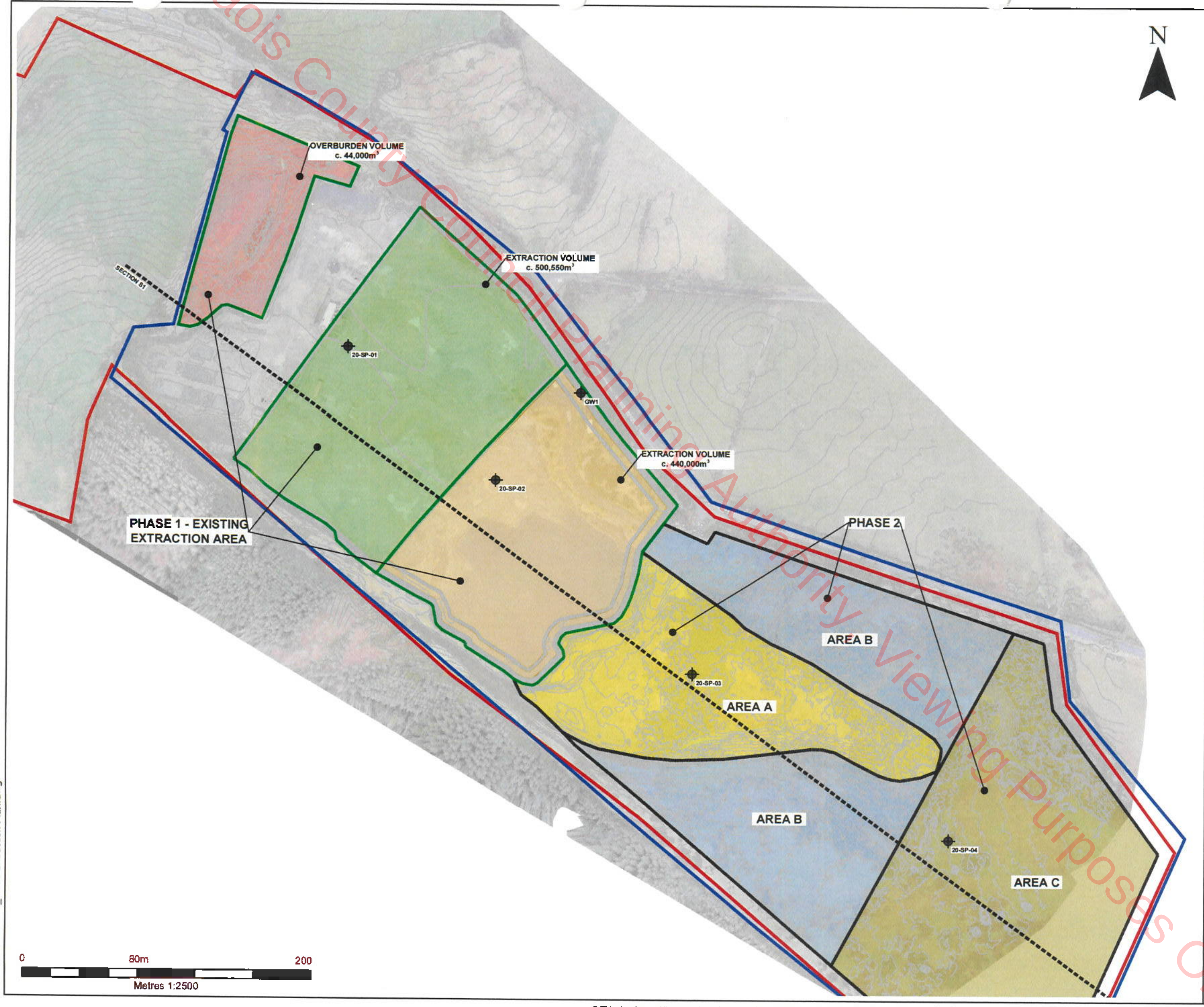
SPINK BOREHOLE CORRELATION

FIGURE 6

Scale	Date
1:500 @ A3	MAY 2020

00586.00002.0.FIG_6.Spink Borehole Correlation.dwg



00586.00002.0.FIG_x.Site Extraction Plan.dwg

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All Dimensions and Levels are to be checked on site.

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- LAND OWNERSHIP BOUNDARY (c. 19.6 Hectares)
- PLANNING BOUNDARY (c. 25.8 Hectares)
- PHASE 1 AREA 1
- PHASE 1 AREA 2
- PHASE 1 AREA 3
- PHASE 2 AREA A
- PHASE 2 AREA B
- PHASE 2 AREA C

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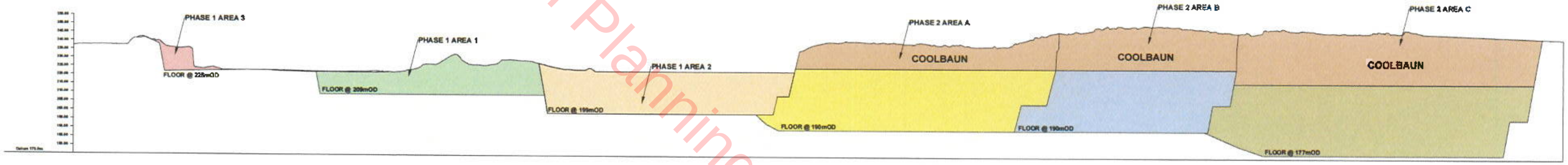
DESIGN

FIGURE 7

Scale	Date
1:2,500 @ A3	MAY 2020

NOTES
REFER TO FIGURE 7 FOR LOCATION OF CROSS SECTION



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DESIGN CROSS SECTION

FIGURE 8

Scale 1:1,250 @ A1

Date MAY 2020

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