

1981/39. Sand and gravel reserves in the Flowerdale ballast pit

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Abstract

An *in situ* reserve of quartz sand and gravel of $3.675 \times 10^6 \text{ m}^3$ is estimated to occur on the 34 ha property at Flowerdale.

Adjustments to this estimate to minimise flooding, protect adjoining property, and for contingencies reduce the reserve to 2 to $2.5 \times 10^6 \text{ m}^3$.

It is important that this resource be properly managed to effect maximum recovery and minimise environmental damage.

INTRODUCTION

The Flowerdale ballast pit [CQ873617] was owned by the former Tasmanian Government Railways, and is now the property of the Australian National Railways Commission; it is currently being offered for sale by the Commission.

This resource assessment was carried out by the Department of Mines to form the basis of any sale negotiations which may take place. The work was jointly funded by the ANR and the Department of Mines.

Location (fig. 1)

The Flowerdale ballast pit occupies an area of 34 ha near the northern extremity of an extensive gravel deposit on the east bank of the Inglis River. This deposit extends for eight kilometres north-south and is two kilometres wide. The pit gateway is at an approximate elevation of 20 m A.S.L. and is about five kilometres west of the coastal town of Wynyard.

Production

From an estimated original configuration of the big hill on the western side of the property, the T.G.R. have removed around 500 000 m^3 of material. More than half of this amount would have been undersize for railway ballast, so it is assumed that the local building industry provided a market for much of the production.

At present mining is carried out by local contractors and the Wynyard Municipal Council. The current production is 2400 m^3 /month (based on royalty payments). The Inglis River gravel deposit is the main source of sand and gravel for the population centres of Burnie and Ulverstone, for the local building industry, and for road making authorities. Current production is about 100 000 m^3 per annum and more than half of this comes from the Besser Tasmania Pty Ltd operation near the southern end of the deposit, six kilometres south of the Flowerdale ballast pit.

Physical features of the property

Flowerdale ballast pit is about one kilometre long in a north-south direction and 0.5 km wide in an east-west direction. A north-flowing tributary of the Inglis River divides the pit into east and west areas. Alluvium and swamp comprise 4.4 ha, areas of back fill with wood waste comprise 2.7 ha, and a clay zone on the eastern side comprises 0.2 ha.

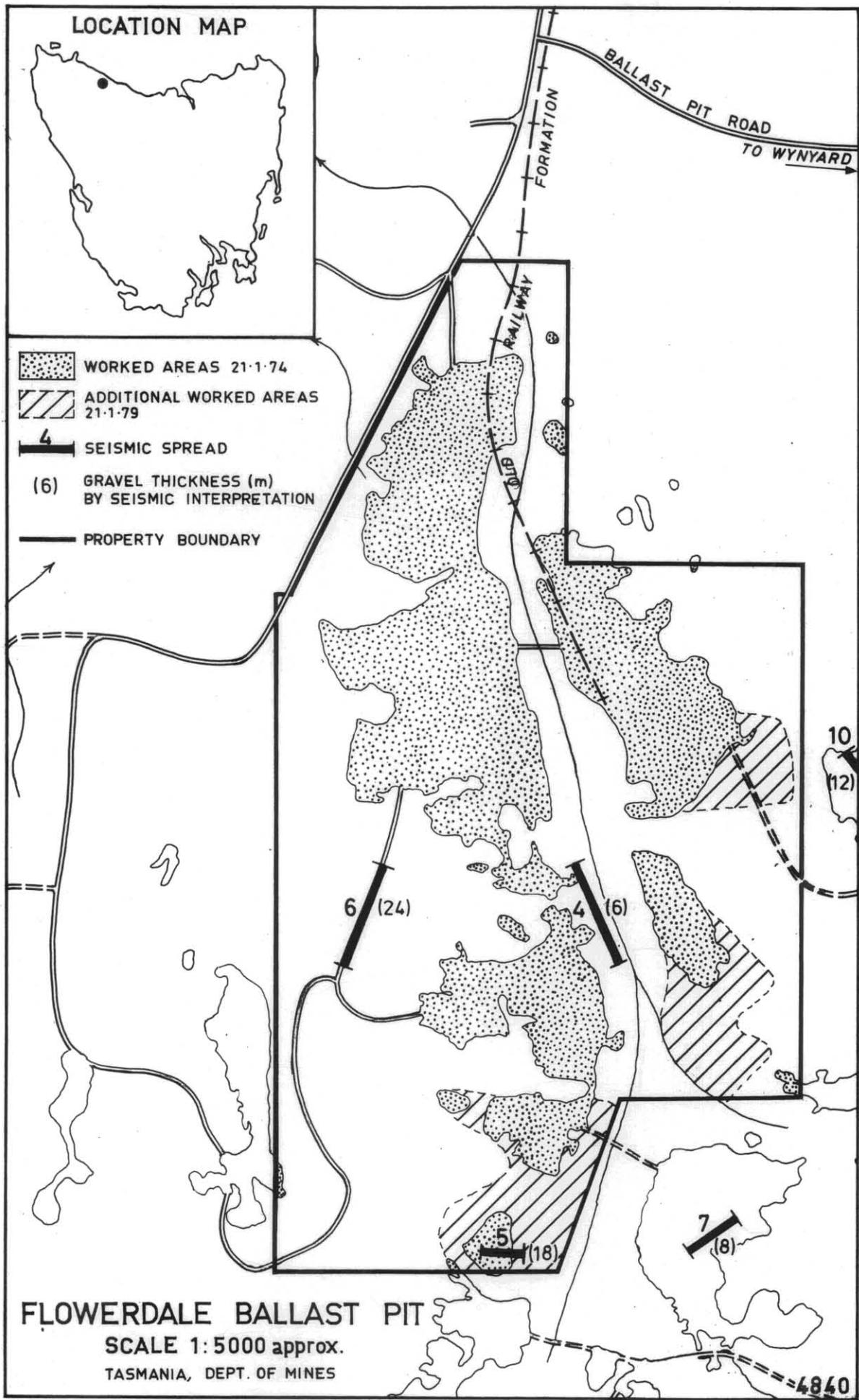
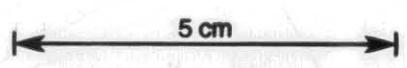


Figure 1.



These are excluded from the reserve estimate and constitute 21% of the total area.

GEOLOGY

Wynyard lies on a coastal plain which was formed during the Quaternary by marine erosion of Tertiary marine sediments (Gee, 1977). At the edge of this plain, 5 km west of Wynyard and 20-25 m A.S.L., bedrock (Lower Permian and Precambrian) is exposed in a cutting on Calder Road as it rises from the plain.

The north flowing Flowerdale, Inglis, Cam, Emu, and Blythe Rivers have all cut down through Tertiary basalt to expose bedrock and, in places, the underlying gravel.

Basalt is widespread in the area but does not occur anywhere on the property under investigation. A small area of basaltic soil was noted near the south-west corner of the property which is the highest point at 30 m above the gateway, and so is about 50-60 m A.S.L. Basalt occurs one kilometre either side of the gateway at 70 m A.S.L. and it seems likely that basalt covered the property in Tertiary times and has since been eroded.

Gravel is exposed over an east-west distance of 40 km and it is inferred that it once formed a continuous wedge of coalescing alluvial fans. Both pre- and post-basaltic drainage have reworked and redistributed the gravel, as evidenced by their present form and sedimentary features.

SEDIMENTARY CONTENT

The sequence consists of about 30 m of poorly sorted sand and gravel beds, individual units ranging up to seven metres but more usually 0.5-2.0 m thick. The finer grained members exhibit strong current bedding. Beds of three metres or more thick persist in working faces over 100 m, but the general continuity of beds was too poor for correlation between boreholes on a 100 m spacing.

Cemented layers are common and most workings on the property were found to have bottomed on one of them. These hard pans are leaching and precipitation layers formed at the water table. The presence of a near-surface hard pan and another at about eight metres depth are probably related to seasonal levels.

The hard pans are extremely tough; they were penetrated by drilling with difficulty, but an excavator was unable to break through them. They would probably require blasting in pit operations and would be of no value.

Red iron staining and black carbonaceous staining are common. The former is assumed to have originated from leaching of an original basalt cover and does not cause any problem unless it has aided cementation. It occurs mainly in the fine aggregate and washes out. Carbonaceous staining showed a greater tendency to be present in layers, suggesting that it may have been deposited by stream action. Carbonaceous hard pans are a common feature of gravel deposits in other areas and it is probable that both modes of deposition may be responsible for its presence. Carbonaceous matter would be undesirable in concrete aggregates, but road aggregate could tolerate the minor amounts which are present in this area.

Mineralogically, the deposit is composed of quartz and quartzite with

some agate, chert, and sandstone. Some schistose particles were noted, but these form a very minor fraction of the total.

Some plasticity testing was carried out on samples with high fines content. It was found that when the sub-seive fraction was less than 15%, the material was non-plastic, which indicates that much of the finer fraction is non-clay mineral.

PARTICLE SIZE DISTRIBUTION

All surface samples and those from drilling and test pitting were screen analysed. This data is given in Table 1 as cumulative mass percentage retained on BSS sieves 38.1 mm to 76 µm.

The raw data is summarised in the form of gravel (>2.00 mm), sand (2.00 mm - 0.0625 mm), and silt plus clay (<0.0625 mm), which are the limits of these size fractions on the Wentworth grade scale. The mean diameter of the gravel and sand fractions are also listed.

The surface sample data was first published in the Burnie Quadrangle Explanatory Notes (Gee, 1977) from samples taken in 1974. The limiting sizes used in this publication were the nearest screen sizes to the Wentworth sizes; 2.36 instead of 2.00 mm and 0.075 mm (75 µm) instead of 0.0625 mm. The Wentworth sizes are used for the borehole and test pit samples, but the effect in comparing them with the surface sample ratios is not considered significant.

Sample	Gravel >2 mm	Sand 2 mm-0.0625 mm	Clay & silt <0.0625 mm
borehole	44	48	8
surface	54	41	5
test pit	<u>25</u>	<u>64</u>	<u>11</u>
average	41 (9 mm)*	51 (0.41 mm)*	8
Besser Tas. Pty Ltd (production) (see Table 2)			
	68 (13 mm)	30 (0.42 mm)	2

* mean diameter of gravel and sand fractions.

The borehole and surface samples gave comparable results. The test pit results differ markedly because most of the pits were sunk on the western side of the property where the top 12 m is predominantly fine aggregate.

The average of these three results is compared with production figures kindly supplied by Mr R. Wright of Besser Tasmania Pty Ltd (Table 2). The Besser operation is 6 km south (upstream) and the higher energy levels of the depositional environment are clearly reflected in the greater proportion of gravel and the larger mean particle diameter, and in the lower fines content.

The comparison of sample analyses from the Flowerdale ballast pit with analysis of output from a commercial operation is not strictly valid. It is expected that the vigorous washing and screening of the Besser operation, if applied to the Flowerdale ballast pit samples, would assist in the break-down of friable particles and remove adhering fines from the sand and gravel fraction. This would result in a higher fines content and therefore

Table 2. SIZING ANALYSIS OF CURRENT PRODUCTION OUTPUT FROM THE WASHING AND SCREENING PLANT, BESSER P/L.

Fraction (mm)	Mass% retained -5 mm fraction	Mass% retained	Cumulative mass% retained
+22.5		14	14
+14		8	22
+ 8		28	50
+ 5		10	60
- 5		<u>40</u>	100
		<u>100</u>	
+ 2.36	18.2	7.3*	67.3
+ 1.18	15.1	6.0	73.3
+ 0.60	13.6	5.4	78.7
+ 0.30	31.3	12.6	91.3
+ 0.15	11.1	4.4	95.7
+ 0.075	6.5	2.6	98.3
- 0.075	<u>4.2</u>	<u>1.7</u>	100
	<u>100.0</u>	<u>40.0</u>	

* Mass% retained of -5 mm fraction expressed as percentage of total.

accentuate the contrast between the two areas.

SOURCES OF INFORMATION

(1) *Surface sampling.* Channel samples were cut in the working face of all existing gravel pits, whether working or abandoned, in the entire Inglis River deposit.

These results were published in 1977 (Gee, 1977), the Flowerdale ballast pit area being designated Locality 4. Seven channels were cut in the ballast pit; these results have already been discussed.

(2) *Seismic survey.* A number of seismic spreads were fired in most of the old gravel pits in an attempt to assess the quantity of material still available in abandoned areas. The location of these spreads, together with an interpretation of gravel thickness, is shown on Figures 2 and 3. In general, 12 m of gravel was estimated on the eastern side of the creek, 24 m on the west, and six metres on the floor of the pit at creek level. These estimates are comparable with drilling results. This survey was carried out by R. Castleden of the Department of Mines.

(3) *Drilling.* A 100 m drilling grid was laid out by surveyor G. Benn of the Department of Mines (fig. 2) and drilling was carried out using a truck mounted Mayhew 1000 rotary drill with a 170 mm tricone roller bit. Sampling was continuous using compressed air. The deepest hole was 18 m (fig. 3) and the bottom of the gravel was not reached in any hole. The reasons for lack of penetration were:

- (a) hole collapse, and
- (b) underground water causing sample contamination. A better penetration would have been achieved by casing the holes or using a churn drill and casing. Both these alternatives would have considerably increased the drilling time and cost.

(4) *Test pit excavation.* Test pits were dug in areas where for practical reasons it was not possible to drill, and in areas where it was desirable to collect additional samples. The method allows the taking of uncontaminated samples, but only at shallow depth. The deepest pit was eight metres, using a mechanical excavator, but holes in sand collapsed at three metres and cemented layers could not be penetrated. Eleven pits were dug and the results are included in Table 1c.

(5) An attempt was made to correlate surface mapping of beds with drilling and test pit results, but it was found that individual units were too discontinuous to allow this. It was decided therefore to base reserve estimates on the particle size distribution in the samples (Tables 1a, b, c; fig. 3).

RESERVE ESTIMATE (TABLE 3)

An estimated $3.675 \times 10^6 \text{ m}^3$ of sand and gravel occurs within the 34 ha property to creek level.

In order to derive a recoverable reserve estimate, the following adjustments have been made:

(1) It is not considered desirable to work this deposit to creek level as this may induce flooding of the area after heavy rain and the removal of the gravel would probably allow excessive run-off and cause flooding of agricultural land between this area and the Inglis River. Accordingly a two metre thickness or $0.5 \times 10^6 \text{ m}^3$ should be left above creek level. This would exclude blocks A, B, and C from the reserve.

(2) In order to confine workings to the property, it would be necessary to batter the workings at the boundary. The losses this would entail are indicated in Table 3 and amount to about $0.2 \times 10^6 \text{ m}^3$. This boundary area could be worked by agreement with the neighbouring property owners, but in this estimate, allowance is made for the boundary to remain intact.

Contingencies

The full depth was not reached by drilling and therefore the quality of material at a near-creek level is not known beyond what is exposed at the surface at this level.

The borehole spacing is such that one data point represents about $100\,000 \text{ m}^3$ of calculated reserve.

Table 3. CALCULATION OF RESERVES

Block	West		East		Area Loss ('000 m ²)					Volume ('000 m ³)		Batter loss ('000 m ³)	
	Area ('000 m ²)	Thickness (m)	Area ('000 m ²)	Thickness (m)	Alluvium	Swamp	Fill	Clay zone	Total loss ('000 m ²)	West	East	West	East
A	5	1	3	1	1				1	5	3	-	-
B	7	2	2	2	2		4		6	14	4	-	-
C	7	1	5	2	3		8		11	7	10	-	-
D	8	6	15	15	3	1	10	2	16	48	225	-	28.4
E	18	15	20	12	3	4	1		8	270	240	-	34.4
F	20	15	16	11	5	2	4		11	300	176	-	22.9
G	26	18	12	16	9	2			11	468	192	-	22.9
H	28	15	11	9	7				7	420	99	0.5	13.6
I	30	18	5	9	2				2	540	45	12.6	4.4
J	29	21	-	-					-	609	-	37.8	-
	<u>178</u>		<u>89</u>						<u>73</u>	<u>2681</u>	<u>994</u>	<u>50.9</u>	<u>126.6</u>

Total area (east + west + loss) = 340 000 m² (34 ha) of which 73 000 m² or 21% is unproductive and is excluded from the reserve calculation.

Total volume (east + west)
= 3.675 x 10⁶ m³
Total batter loss
= 0.177 x 10⁶ m³

TOTAL RESERVE: 3.675 x 10⁶ m³

Adjustment (x 10⁶ m³)

Reason

.476

Retention of bottom two metres (= 2 x Areas D-J)

.177

Boundary reserve (batter loss)

.653

ADJUSTED RESERVE = 3.675 - 0.653
= 3.022 x 10⁶ m³

LESS CONTINGENCY FACTOR (see text) = 2.0 to 2.5 x 10⁶ m³

In six of the 30 data points (20%) excessive fines were recorded. Much of this material could be washed free of fines or blended with fine-free material to produce satisfactory road aggregates. It is however probable that 20% of the reserve of sand and gravel is of slightly inferior quality for this reason.

The true particle size distribution of the material is likely to contain a higher fines content than indicated by the sizing analysis of samples.

Cemented layers are unusable and would constitute an estimated 2-3% of the total reserve. The proportion of iron stained material would be similar, but much of this material is usable as discussed elsewhere in this report.

The gravel:sand:silt and clay ratio indicates that 20% of the total reserve would not be used in the cement industry; up to 10% because it is too fine and 10-12% because it is too coarse and would require crushing before use. The oversize fraction (>21 mm) is screened out and stockpiled in the Besser operation. Presumably when all other sources of coarse aggregate are exhausted, this material could be crushed and used. The situation for road aggregates is slightly different and it is anticipated that most of the material which has a too high fines content for concrete products could be used for road making.

The choice of a contingency adjustment is subjective and different workers would arrive at different figures, but the writer is not aware of any deposit in which recovery of an estimated reserve has been 100%. Some losses are no doubt due to bad management, but some losses are inescapable and a percentage of between 20 and 30% appears realistic. This would result in a recovery of 2 to 2.5 million cubic metres.

MANAGEMENT

The Department of Mines is not involved in the matter of future ownership of this property. It does however strongly recommend that as this is a significant resource, State ownership is desirable in order to provide aggregates for the State's road building authorities.

An estimated 80% of the reserve in this property contains less than 10% fines and is suitable for the building industry. It would seem that the property could adequately serve both the industry and the State.

The future owner of this property will be required to apply for a Department of Mines mineral/stone lease and submit a programme for the management of mining operations, including details of mining methods, washing and screening plants, waste disposal, and rehabilitation.

The Inglis River gravel deposit has been mined haphazardly by a large number of small operators for many years. There are many disused and un-rehabilitated pits throughout the area and it is desirable to see this property mined efficiently and restored adequately.

REFERENCE

GEE, R.D. 1977. Geological atlas 1 mile series. Zone 7 Sheet 28 (8015N). Burnie. *Explan.Rep.geol.Surv.Tasm.*

[11 August 1981]

Table 1(a). BOREHOLE SAMPLES, FLOWERDALE BALLAST PIT.

Hole & lab. serial number	AMG co-ords (m)	Elevation (m)	Depth (m)	Description	SWL* (m)	Sizing analysis (mm) - cumulative% retained										Ratio G:S:S&C	Mean diameter (mm)	
						38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
A188 812404	387450E 5461780N	31.7	0-3	Green pebbly sand	5	0.3	15.2	41.5	62.2	70.1	74.5	77.3	82.6	90.3	94.4	71:24:5	10.9	0.32
			3-6	Light brown gravel														
			6-7	Fine brown gravel														
			7-8	Brown gravel														
			8-9	Brown pebbly sand														
			9-10	Brown gravel														
			10-12	Grey gravel														
B188 812405	387440E 5461680N	32.9	0-2	Gravel	5	10.3	35.4	52.7	61.8	69.3	75.2	82.6	91.7	95.0	64:31:5	9.4	0.42	
			2-4	Carbonaceous sandy gravel														
			4-12	Yellow sandy gravel														
B300 812406	387330E 5461690N	30.4	0-2	Carbonaceous pebbly sand grading to fine gravel at base	4	4.8	18.4	33.1	48.7	63.0	73.4	83.3	91.8	95.2	53:43:4	6.6	0.52	
			2-6	Carbonaceous fine gravel grading to medium gravel at base														
C188 812407	387440E 5461580N	34.1	0-6	Gravel cement- ed layer at 3 m	3	7.1	32.1	53.7	65.6	74.5	80.8	89.2	94.7	96.7	68:29:3	8.5	0.52	
			6-12	Fine gravel														
D0 812408	387600E 5461460N	50.5	0-12	Gravel	3	7.2	43.3	63.3	70.0	74.5	78.7	87.0	93.5	97.2	71:25:4	12.7	0.40	

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b1/b

Hole & lab. serial number	AMG co-ords (m)	Elevation (m)	Depth (m)	Description	SWL* (m)	Sizing analysis (mm) - cumulative% retained										Ratio G:S:S&C	Mean diameter (mm)	
						38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
D105 812409	387510E 5461470N	49.7	0-14	Clayey gravel	12	0.8	17.7	34.6	45.8	52.2	57.9	67.8	79.2	84.4	48:37:15	7.0	0.35	
D200 812410	387410E 5461480N	35.4	0-6	Gravel	6	8.8	36.8	58.6	68.5	74.5	79.0	85.0	91.6	94.6	70:25:5	9.3	0.41	
D300 812411	387300E 5461500N	33.0	0-3	Brown gravel	6	8.0	30.1	52.2	65.6	75.4	81.9	87.9	93.0	95.6	69:27:4	8.0	0.52	
E0 812412	387590E 5461360N	55.2	0-3	Grey sand		0.2	11.2	30.5	43.4	53.6	62.1	79.6	90.6	93.3	46:48:6	6.1	0.46	
			3-6	Buff pebbly sand														
			6-7	Buff fine gravel														
			7-9	Buff sand														
			9-12	Buff gritty sand														
E100 812413	387500E 5461370N	40.0	0-1	Yellow pebbly sand	6	0.5	10.8	31.2	50.8	58.6	64.4	69.5	80.8	89.2	93.2	61:33:6	10.1	0.37
			1-3	Carbonaceous gravel														
			3-6	Grey sandy gravel														
			6-12	Light brown gravel														
F0 812414	387580E 5461260N	59.2	0-2	Grey pebbly sand		0.16	13.3	35.6	48.3	56.8	64.2	76.7	87.6	91.6	51:41:8	6.4	0.42	
			3-4	Clayey pebbly sand														
			4-5	Pebbly sand														
			5-9	Gravel														
			9-11	Sandy gravel														
			11-12	Pebbly sand														

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b1/01

Hole & lab. serial number	AMG co-ords (m)	Elevation (m)	Depth (m)	Description	SWL* (m)	Sizing analysis (mm) - cumulative% retained										Ratio G:S:S&C	Mean dia- meter (mm)	
						38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
F100 812415	387480E 5461270N	42.8	0-10	Red clayey pebbly sand	3	6.6	20.5	32.7	41.4	50.9	59.1	72.9	84.4	90.6	44:47:9	8.3	0.41	
G0 812416	387570E 5461160N	59.2	0-3	Clayey pebbly sand			2.8	12.8	24.7	32.6	39.4	45.8	58.1	71.8	27:47:26	4.7	0.35	
			3-13	Yellow pebbly sand			7.0	17.7	25.7	35.0	50.7	71.3	86.2	91.9	29:63:8	5.9	0.43	
			13-14	Sandy gravel			0.5	57.4	67.3	73.1	79.2	89.3	94.9	96.6	69:28:3	6.2	0.47	
							<u>weighted mean</u>								31:57:11	5.7	0.41	
G98 812419	387480E 5461170N	46.4	0-1	Pebbly sand	8	4.3	16.3	29.4	39.4	47.9	55.0	75.0	88.0	91.8	42:50:8	7.4	0.48	
			1-2	Gravel														
			2-12	Sandy gravel														
G206 812420	387370E 5461180N	42.8	0-2	Pebbly sand	5	2.3	15.3	32.1	46.2	57.4	68.0	81.0	88.7	92.2	50:43:7	6.5	0.51	
812421			2-4	Gravel														
			4-6	Clayey pebbly sand		0.2	3.4	9.8	18.3	26.6	36.6	46.1	54.9	72.5	88.3	30:60:10	6.7	0.30
			6-7	Clayey sandy gravel														
812422			7-12	Clayey pebbly sand		5.2	14.8	21.9	27.3	32.5	39.2	52.4	78.7	89.3	29:61:10	9.0	0.28	
							<u>weighted mean</u>								36:55:9	7.6	0.36	
G300 812433	387270E 5461190N	60.4	0-4	Pebbly sand		0.5	5.5	18.0	29.2	38.5	56.4	78.6	89.2	95.1	32:64:4	5.1	0.38	
			4-6	Carbonaceous sand														
G385 812434	387190E 5461200N	60.7	0-6	Grey pebbly sand			2.0	8.5	15.1	20.7	26.6	33.8	75.1	90.2	17:75:8	4.9	0.22	
H0 812425	387560E 5461060N	53.7	0-2	Brown pebbly sand	11	2.1	17.8	34.2	45.0	51.4	58.0	73.6	88.2	92.1	47:46:7	7.8	0.38	
			2-5	Brown gravel														
			5-6	Brown pebbly sand														
812426			6-11	Brown pebbly sand		1.1	6.8	14.2	18.8	23.1	26.5	48.3	89.5	95.0	20:75:5	8.1	0.27	

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b1/11

Hole & lab. serial number	AMG co-ords (m)	Elevation (m)	Depth (m)	Description	SWL* (m)	Sizing analysis (mm) - cumulative% retained										Ratio G:S:S&C	Mean diameter (mm)	
						38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
H0 812427			11-12	Brown gravel	0.5	5.5	23.7	45.1	54.5	61.7	67.4	80.3	92.7	95.3	57:39:4	8.1	0.43	
			12-18	Brown sandy gravel								<u>weighted mean</u>			39:56:5	8.0	0.37	
H90 812428	387470E 5461070N	41.5	0-1	Sandy gravel		Abandoned due to blow out. See excavation pit 8.												
H210 812428	387350E 5461080N	45.4	0-1	Sandy gravel	9	1.8	14.7	26.4	32.1	36.6	40.4	60.2	88.6	92.3	33:60:7	9.4	0.32	
			1-2	Clayey sandy gravel														
			2-3	Clayey sand														
812429			3-5	Pebbly sand														
			5-9	Carbonaceous pebbly sand		9.1	22.1	27.3	30.0	31.9	36.1	78.2	94.1	96.3	31:66:3	12.9	0.31	
												<u>weighted mean</u>			31:65:4	12.0	0.31	
			9-12	Sandy gravel														
H300 812430	387260E 5461090N	52.1	0-4	Light grey sand			1.0	6.9	11.4	19.6	37.3	66.9	83.9	89.4	14:76:10	2.5	0.42	
			4-6	Brown sand														
H400 812431	387160E 5461100N	62.3	0-3	White sand		0.9	3.3	6.8	12.2	21.5	51.9	83.1	89.9	8:83:9	4.3	0.32		
			3-5	Green pebbly sand														
812432			5-6	Buff pebbly sand		7.5	23.6	37.3	49.2	57.8	76.2	87.0	90.5	41:50:9	5.4	0.16		
												<u>weighted mean</u>			24:67:9	4.8	0.24	
I204 812433	387340E 5460980N	47.2	0-12	Pebbly sand	5	10.7	42.0	62.7	68.0	72.8	76.8	85.3	93.0	95.5	70:26:4	10.6	0.40	
I300 812434	387250E 5461000N	57.7	0-3	White sand			6.9	19.5	36.4	53.8	76.4	83.6	88.1	25:64:11	3.6	0.55		
			3-4	Light green pebbly sand		3.6	19.5	34.0	48.5	59.6	74.1	86.5	91.1	38:54:8	2.5	0.40		
812435			4-11	Brown pebbly sand														
												<u>weighted mean</u>			34:57:9	2.8	0.44	

39-12

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Hole & lab. serial number	AMG co-ords (m)	Elevation (m)	Depth (m)	Description	SWL* (m)	Sizing analysis (mm) - cumulative% retained										Ratio G:S:S&C	Mean dia- meter (mm)	
						38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
I400 812436	387150E 5461010N	66.7	0-2	Sand														
			2-6	Buff clayey sand		0.6	2.4	7.8	16.5	26.2	44.6	66.6	79.8	10:71:19	3.6	0.31		
			6-9	Yellow sand														
			9-10	Coarse sand														
			10-12	Fine sandy gravel														
J204 812437	387330E 5460890N	46.5	0-12	Grey sandy gravel	3	17.4	36.7	49.1	57.7	65.6	72.4	83.2	91.4	94.1	60:35:5	11.1	0.43	
J300 812438	387240E 5460900N	64.6	0-3	White sand														
			3-6	Brown sand		0.3	3.7	10.8	19.5	28.5	41.4	74.0	87.5	14:75:11	3.8	0.29		
			6-7	Coarse brown sand														
812439			7-12	Fine brown sandy gravel		0.6	10.2	33.2	53.5	65.8	78.6	86.9	90.8	40:52:8	3.8	0.57		
														<u>weighted mean</u>	25:65:10	3.8	0.41	
J400 812440	387140E 5460910N	68.6	0-2	Sand	7													
			2-5	Carbonaceous clayey gravel		0.3	1.9	4.2	6.4	9.8	15.9	29.3	69.2	84.1	7:78:15	5.7	0.24	
			5-12	Pebbly clayey sand														

* Standing water level (depth at which water was struck)

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Table 1(b). SURFACE SAMPLES (1974 PROGRAMME), FLOWERDALE BALLAST PIT

Sample	Thickness (m)	Depth (m)	Description*	Sizing analysis (mm) cumulative% retained							Ratio G:S:S&C	Mean diam. (mm)				
				38.1	19.05	9.53	4.75	2.36	1.18	0.6		0.3	0.15	0.075	Gravel	Sand
4.1	0.61	0 - 0.61	VMPS					5.1	8.1	18.8	42.5	67.2	74.9	5:70:25	3.2	0.33
	1.04	0.61- 1.65	G	1.3	21.9	49.5	58.2	64.7	70.3	74.3	81.9	88.1	90.6	65:26:9	13.9	0.47
	1.14	1.65- 2.79	S					3.3	12.8	37.2	71.7	84.5	90.1	3:87:10	3.2	0.50
	0.96	2.79- 3.75	SG	0.6	6.4	20.9	29.6	37.7	46.6	63.6	84.7	92.2	30:62:8	6.5	0.38	
	1.67	3.75- 5.42	PS					11.9	16.6	23.3	66.3	93.4	95.8	12:84:4	3.2	0.35
	0.48	5.42- 5.90	SG	0.4	8.3	30.9	41.8	50.0	58.1	86.1	94.2	96.4	42:54:4	4.6	0.35	
	1.62	5.90- 7.52	G	7.6	35.1	58.8	70.1	76.3	79.7	82.8	91.0	96.4	97.6	76:21:3	16.0	0.47
	5.12	7.52-12.64	G	4.3	27.7	47.0	59.1	67.3	74.7	84.4	89.9	92.7	59:34:7	8.6	0.54	
	1.98	12.64-14.62	PS	1.5	2.5	3.7	4.5	5.0	5.7	7.1	29.4	84.8	94.0	5:89:6	18.4	0.27
	3.52	14.62-18.14	G	17.2	43.5	61.2	70.8	76.7	81.3	87.8	93.8	95.9	71:25:4	10.0	0.50	
													<u>weighted mean</u>	47:47:6	8.0	0.44
4.2	1.19	0 - 1.19	SG	0.9	9.4	23.6	37.5	50.2	67.1	86.9	89.8	91.9	38:54:8	6.0	0.71	
	1.52	1.19- 2.71	MPS					12.1	30.5	55.0	81.8	86.9	89.7	12:78:10	3.2	0.71
	2.33	2.71- 5.04	G	8.5	33.1	52.0	61.5	68.6	75.5	85.5	91.3	93.5	62:32:6	10.0	0.54	
	5.12	5.04-10.16	G	1.3	12.1	39.5	55.0	64.5	69.7	78.1	88.7	91.8	55:37:8	6.5	0.50	
	0.20	10.16-10.36	PS	1.8	7.7	14.8	20.1	25.5	32.7	61.9	89.5	92.7	20:73:7	7.5	0.35	
	1.45	10.36-11.81	G	14.8	44.7	60.0	67.8	75.1	82.6	91.9	96.0	97.5	68:30:2	11.3	0.62	
													<u>weighted mean</u>	50:43:7	7.0	0.54
4.3	1.77	0 - 1.77	G	3.4	17.2	40.9	54.1	59.7	64.5	69.6	83.0	90.4	94.1	60:33:7	13.0	0.44
	2.16	1.77- 3.93	MS					2.4	6.2	23.1	75.3	91.5	94.5	2:93:5	3.2	0.27
	1.12	3.93- 5.05	G	4.4	20.7	48.4	64.6	70.3	73.0	76.0	91.4	96.6	97.8	71:27:2	13.0	0.44
													<u>weighted mean</u>	38:57:5	7.5	0.31
4.4	2.33	0 - 2.33	G	2.0	18.4	52.1	66.9	71.7	75.5	78.8	86.8	92.3	94.3	72:23:5	13.0	0.47
	0.66	2.33- 2.99	SG					14.1	12.8	32.5	67.2	85.8	91.6	4:88:8	3.2	0.44
	1.62	2.99- 4.61	S			4.3	24.5	35.1	42.1	46.5	75.3	94.7	97.2	35:62:3	5.7	0.38
	2.54	4.61- 7.15	G	4.7	35.4	67.2	78.2	82.5	85.3	87.6	94.4	98.4	99.0	83:16:1	16.0	0.50
													<u>weighted mean</u>	61:35:4	10.6	0.44
4.5	3.05	0 - 3.05	G	0.9	10.3	38.3	54.1	63.0	68.4	81.3	90.7	94.1	54:40:6	6.0	0.50	
	1.52	3.05- 4.57	S					2.1	6.2	23.1	75.3	91.5	94.5	2:93:5	3.2	0.44
													<u>weighted mean</u>	37:57:6	4.9	0.27
4.6	4.50	0 - 4.50	G	2.5	35.1	59.6	71.7	77.6	81.5	84.2	91.3	95.4	96.8	78:19:3	14.9	0.50

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Sample	Thickness (m)	Depth (m)	Description*	Sizing analysis (mm) cumulative% retained										Ratio G:S:S&C	Mean diam. (mm)	
				38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
4-7	1.78	0 - 1.78	G	4.8	28.2	48.6	62.1	69.1	73.9	77.4	85.1	92.6	95.5	69:27:4	13.9	0.44
	0.51	1.78- 2.29	S					1.0	1.2	1.6	39.4	89.4	94.3	1:93:6	3.2	0.27
	1.83	2.29- 4.12	G	1.7	14.6	37.8	52.0	60.8	65.7	69.3	86.1	95.1	96.8	61:36:3	11.3	0.44
	0.43	4.12- 4.55	S					1.5	1.8	4.2	36.0	92.1	97.0	1:96:3	3.2	0.29
											<u>weighted mean</u>			52:44:4	10.0	0.38

* S = sand, G = gravel, P = pebbly, M = muddy, V = very.

Table 1(c). EXCAVATION PIT SAMPLES, FLOWERDALE BALLAST PIT

39-15

Pit & lab. serial number	Depth (mm)	Thickness (mm)	Description	Sizing analysis (mm) cumulative% retained										Ratio G:S:S&C	Mean diam. (mm)	
				38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand
1	0- 150	150	Soil													
	150- 400	250	Gravel													
	400- 800	400	Cemented gravel													
812371	800-3900	3100	Sand					0.1	0.3	0.5	1.3	42.8	73.5	0:74:26	-	0.16
	3900-4400	500	Carbonaceous													
812372	4400-7600	3200	Orange clayey sand					0.2	0.5	1.0	3.8	69.7	81.0	0:81:19	-	0.20
812373	7600-8700	1100	Grey granule sand			1.0	6.5	25.5	57.3	76.2	86.5	91.4	93.6	35:59:6	4.0	0.80
812374	8700-10400	1700	Clayey gravel	3.0	20.2	43.1	58.5	68.2	74.9	78.7	82.5	85.0	61:24:15	6.9	0.35	
											<u>weighted mean</u>		15:66:19	1.7	0.32	
2	0- 700	700	Sand						0.2	9.6	76.2	91.7	0:92:8	-	0.19	
812359	700-1200	500	Carbonaceous cemented sand													
	1200-1950	750	Brown sand													

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39-16

Pit & lab. serial number	Depth (mm)	Thickness (mm)	Description	Sizing analysis (mm) cumulative% retained										Ratio G:S:S&C	Mean diam. (mm)		
				38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3	0.15	0.075		Gravel	Sand	
2																	
812360	1950-2600	650	White gravel	7.3	16.7	23.1	30.0	37.6	45.4	55.5	81.5	89.8	92.5	40:53:7	12.4	0.46	
812361	2600-3250	650	White sandy clay					3.6	5.3	6.5	9.1	14.9	31.6	62:30:8	-	0.08	
	3250-4800	1550	Sandy clay														
														<u>weighted mean</u>	34:58:8	2.0	0.18
3																	
812368	0- 800	800	Sand					0.2	0.6	1.2	35.4	82.5	90.6	0:91:9	-	0.33	
812369	800-3500	2700	Pebbly sand	1.1	3.3	15.2	28.3	44.1	65.0	91.4	96.7	98.2	33:65:2	4.5	0.68		
812370	3500-4100	600	Carbonaceous sand		0.8	2.1	4.5	8.0	13.9	32.5	71.6	81.9	6:80:14	3.9	0.19		
	4100-5500	1400	Orange clayey sand										<u>weighted mean</u>	18:74:8	3.6	0.41	
4																	
	0- 450	450	Gritty sand	1.6	3.5	3.8	4.5	5.0	5.6	9.5	28.1	75.9	5:75:20	12.4	0.13		
812362	450- 550	100	Cemented sand														
812363	550-1500	950	White sand	1.9	6.9	13.7	20.5	27.7	35.5	54.9	73.6	85.5	23:64:13	6.31	0.30		
812364	1500-1800	300	Carbonaceous sand				6.3	12.2	21.7	54.7	72.8	83.4	8:75:17	-	0.31		
812365	1800-2250	450	Yellow sandy clay					1.3	2.4	3.6	6.0	23.7	35.4	2:33:65		0.18	
812366	2250-4200	1950	Yellow clayey gravel			13.0	34.2	44.2	49.7	55.9	74.0	81.4	85.6	46:40:14	6.8	0.30	
812367	4200-7800	3600	Light grey gravel	1.1	11.7	34.4	49.6	56.9	62.3	69.1	88.3	94.8	96.7	59:38:3	13.6	0.45	
	7800-7900	100	Carbonaceous cemented gravel										<u>weighted mean</u>	43:45:12	10.5	0.35	
5	0-2000	2000	Gravel	Not tested - suspected hillwash. Struck water at 2 m on cemented													
	2000-	?	Carbonaceous cemented sand	layer													
6	0-2000	2000	Sandy gravel	4.9	15.3	27.7	35.1	40.1	45.1	53.3	76.6	89.8	35:55:10	8.0	0.31		
812358				Water coming in at 2 m.													

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Pit & lab. serial number	Depth (mm)	Thickness (mm)	Description	Sizing analysis (mm) cumulative% retained								Ratio G:S:S&C	Mean diam. (mm)			
				38.1	19.05	9.53	4.75	2.36	1.18	0.6	0.3		0.15	0.075	Gravel	Sand
7	0-1500	1500	Sand	Fill												
813141	0-1100	1100	Carbonaceous pebbly sand with cemented layer near top	1.3	5.4	10.2	15.5	19.7	26.0	52.5	84.5	93.1	17:77:7	6.4	0.29	
813142	1100-1700	600	Yellow clayey sand				0.7	3.1	11.0	39.4	76.8	86.8	1:87:12	-	0.28	
	1700-4800	3100	Buff clayey sand										<u>weighted mean</u>	4:85:11	1.5	0.28
9	0- 200	200	Black soil													
	200- 500	300	White cemented sand	Could not penetrate cemented layer												
10	0- 800	800	Red and white pebbly clay													
	800-3000	2200	Red clay with small rounded grits	Could not penetrate clay												
11	1 m trench dug to locate gravel/clay contact															

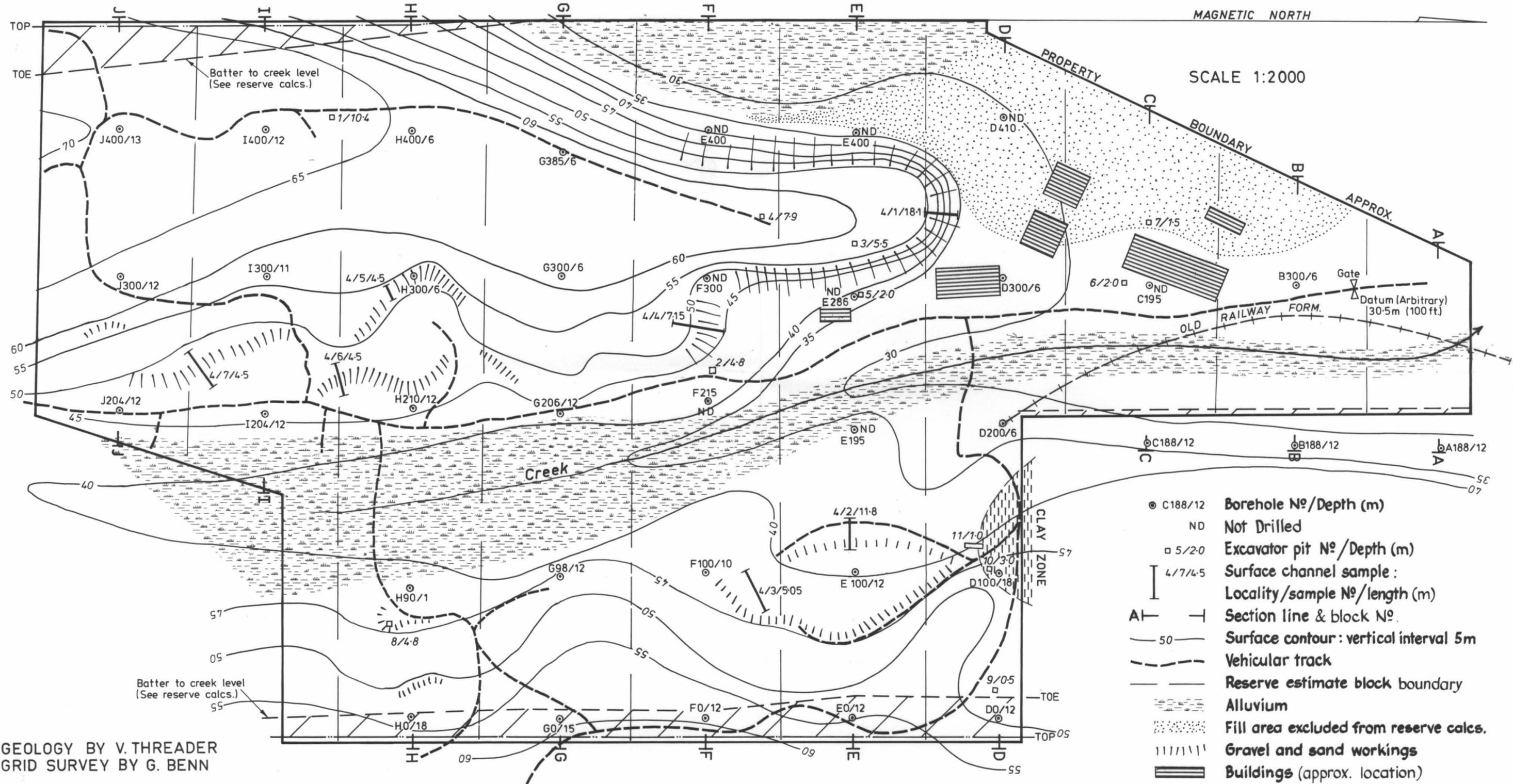
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FLOWERDALE BALLAST PIT

5 cm

5 cm



- C188/12 Borehole No/Depth (m)
- ND Not Drilled
- 5/20 Excavator pit No/Depth (m)
- | 4/7/45 Surface channel sample : Locality/sample No/length (m)
- A-I Section line & block No.
- 50 — Surface contour : vertical interval 5m
- - - Vehicular track
- - - Reserve estimate block boundary
- ▨ Alluvium
- ▨ Fill area excluded from reserve calcs.
- ▨ Gravel and sand workings
- ▨ Buildings (approx. location)

GEOLOGY BY V. THREADER
 GRID SURVEY BY G. BENN

