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Red John Pumped Storage Hydro Scheme

Volume 5, Appendix 5.2: Material Management Appraisal

ILI (Highlands PSH) Ltd.

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Quality information

Prepared by	Checked by	Verified by	Approved by
James Scott Engineer	David Lee Principal Engineer	Ian Gillies Director	David Lee Principal Engineer

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Appendix 5.2 Material Management Appraisal

5.1 Introduction

5.1.1 This Materials Management Appraisal (MMA) report has been undertaken to provide an engineering justification for the management of materials that will be excavated to create the infrastructure associated with the Development. This MMA should be read in conjunction with Chapter 5: Geology and Ground Conditions (Environmental Impact Assessment; Volume 2).

5.1.2 The MMA outlines the volumes of material that are anticipated to be associated with various components of the Development. The general philosophy behind the project material management is that the main component, the Headpond, will be created by undertaking a large balanced cut and fill exercise that will be supplemented with material that is generated from the underground excavation activities.

5.1.3 Any surplus or low quality material that is generated during this process will be reused on-site as part of the Development as demonstrated in this appraisal.

5.1.4 This MMA has been informed by initial intrusive Site Investigation (SI) works that were undertaken in August 2018. It is anticipated that this appraisal will be updated during the detailed design stage, post consent, as further information about the ground conditions is ascertained through further SI works.

5.1.5 Peat is present within the Development Site, however, the management of it has been excluded from this appraisal as it is covered separately in Appendix 5.3: Outline Peat Management Plan. In addition, the management of material from forestry clearance activities are also excluded as this covered in Chapter 12: Forestry (Volume 2) and the Construction Environmental Management Plan (CEMP) (Appendix 3.1).

5.1.6 The following sections show the processes that have been used to calculate the volumes of material anticipated to be encountered during the construction of the project.

5.2 Sources of Information

5.2.1 A number of sources of information have been used to undertake this appraisal, these are detailed below.

- ICE Earthworks A guide 2nd Edition;
- Autodesk Civil 3D Model of the Headpond design;
- Site Visits;
- Phase 1 Peat Probing;
- Initial Site Investigation (SI) Works; and
- Desktop Study of the Geological Setting of the Development (as detailed in Chapter 5: Geology and Ground Conditions, Volume 2).

5.3 Appraisal

5.3.1 The volume of material that will be generated from the construction of the Development has been calculated from the 3D model and from engineering estimates. In both cases, the volumes calculated will have to be bulked or compacted to reflect the actual volumes that will be generated/used during construction. Table 5.1, details the bulking and compaction factors that have been used.

Table 5.1 Bulking and Compaction Factors for Rocks and Soils

Component	Bulking	Compaction
Sedimentary Rock	1.72	0.72
Cohesive Soils	1.30	0.75
Topsoil	1.40	0.80

5.3.2 The bulking and compaction factors are based upon assumptions made following the initial SI works and standard values detailed in ICE Earthworks: A Guide 2nd Edition, 2015.

5.3.3 Volume 2, Chapter 4: Approach to EIA outlines the enveloping which have been applied to elements of the Development. Note, all final figures within this appraisal have also been rounded to the nearest ten thousand m, m^2 or m^3.

Material Generated

5.3.4 From the 3D model, the volume generated from the excavation of the Headpond at the surface has been determined as detailed in Table 5.2.

5.3.5 Within the headpond area, peat will be encountered and will have to be excavated. The peat has been removed from the volume of excavated material in this appraisal, as shown in Table 5.2. The calculated volume of peat and how it will be handled, stored and reused is detailed in Appendix 5.3: Outline Peat Management Plan.

Table 5.2 Headpond Excavation

	Headpond Excavation
Total Excavated Volume (m^3)	2,900,000
Volume of Peat (m^3)	-146,777
Excavated Volume (m^3)	2,753,223
Bulking Factor	1.72
Total (m^3)	**4,740,000**

5.3.6 The other two main excavation components can be described together as ‘below ground excavation’ and split into ‘Waterways’ and ‘underground infrastructure’. The Waterways are all the ‘wet’ underground components such as the High-Pressure and Low-Pressure Tunnels and Power Cavern pipework, and the underground infrastructure are the ‘dry’ underground components such as the Power Cavern and Access Tunnels.

5.3.7 Table 5.3 shows a summary of the material that is estimated to be excavated during the construction of the waterways. The High-Pressure and Low-Pressure Tunnels are anticipated to be excavated using a large diameter tunnel boring machine (TBM), and the surge infrastructure and Power Cavern pipework are anticipated to be constructed using conventional drill and blast.

5.3.8 The excavated area has been estimated based on the internal diameter plus the assumptions that are stated below for the different excavation methods.

Table 5.3 Below Ground Excavation – Waterways

	High-pressure Tunnel	Low-pressure Tunnel	Surge Chamber - High Pressure	Surge Chamber - Low Pressure	Power Cavern Pipework
Internal Diameter (m)	9.0	9.0	15.0	15.0	N/A
Excavated Area (m^2)	78.54	78.54	221.67	221.67	N/A
Lining Surface Area (m^2)	11.81	11.81	19.35	19.35	N/A
Length (m)	1,000	1,600	40	40	N/A
Lining Volume (m^3)	11,812	18,900	774	774	N/A
Excavation Volume (m^3)	78,540	125,664	8,867	8,867	5,000
Bulking Factor	1.72	1.72	1.72	1.72	1.72
Bulked Volume (m^3)	136,000	217,000	16,000	16,000	9,000
Total (m^3)	390,000				

Assumptions

The dimensions stated above are based on initial design and are approximate values based on a reasonable maximum component size.

- *Tunnel lining for the TBM = 400 mm*
- *Grouting / rock squeeze = 100 mm*
- *Drill and Blast lining = 400 mm*
- *Drill and Blast overbreak = 500 mm*

5.3.9 Table 5.4 shows a summary of the material that is estimated to be excavated during the construction of the underground infrastructure. It is assumed all of the components stated below will be excavated using conventional drill and blast. The construction and access adits, as shown on Figures 2.16 and 2.17 (Volume 3), are shaped as a wide horseshoe arch. However, for the purposes of this calculation, the sections have been assumed to be square giving an equivalent area.

5.3.10 The excavated area has been estimated based on the internal dimensions plus the assumptions that are stated below for the different infrastructure components.

Table 5.4 Below Ground Excavation – Underground Infrastructure

	Power Cavern	Transformer Cavern	Cable Gallery x2	Construction Tunnel	Access Tunnel
Width (x)	25	20	10	8	6
Height (y)	50	30	5	6	5
Excavated Area (m²)	1,404	704	132	80	56
Lining Surface Area (m²)	76	51	16	11.84	9.44
Length (m)	120	120	50	1800	1700
Lining Volume (m³)	9,120	6,120	800	21,312	16,048
Excavation Volume (m³)	168,480	84,480	6,600	144,000	95,200
Bulking Factor	1.72	1.72	1.72	1.72	1.72
Bulked Volume (m³)	289,800	145,400	11,400	247,700	163,800
Total (m³)	**860,000**				

Assumptions

- *Power Cavern, Transformer Cavern, Cable Gallery is Drill and Blast and lining = 500 mm*
- *Power Cavern, Transformer Cavern, Cable Gallery is Drill and Blast and overbreak = 500 mm*
- *Construction and Access Tunnels is drill and blast and lining = 400 mm*
- *Construction and Access Tunnels is drill and blast and overbreak = 500 mm*

5.3.11 In addition to the excavation of the Headpond, Waterways and the underground infrastructure, excavation works will be undertaken at the Tailpond Inlet / Outlet. Table 5.5 shows the estimated volume of material that will be generated from works at the Inlet / Outlet of the Tailpond.

Table 5.5 Tailpond Inlet / Outlet Excavation

	Inlet / Outlet Tailpond
Excavated Volume (m³)	120,000
Bulking Factor	1.30
Bulked Total (m³)	156,000

Assumptions

- *Volume is estimated from the excavation works required at the Tailpond*
- *The majority of the material is assumed to be cohesive in nature, sandy clay with gravel, and would be unable to be used in the Headpond Embankment structure.*

5.3.12 In addition to the excavation works described above, stripping of surface vegetation will also be required. The main area where surface vegetation will have to be stripped is the Headpond which will require vegetation to be cleared before the excavation works commence. The model of the Headpond assumed that on average 500 mm of organic material and topsoil would not be able to be used for the construction of the Headpond embankment. Table 5.6 shows the estimated volume of material that is generated from the vegetation strip.

Table 5.6 Headpond Vegetation Strip

	Headpond
Depth (m)	0.5
Excavated Area (m²)	930,000
Excavation Volume (m³)	465,000
Bulking Factor	1.40
Total (m³)	**651,000**

5.3.13 Table 5.7 summarises the total volumes of material that will be excavated during construction.

Table 5.7 Total Excavated Volume (Bulked)

	Surface Excavation Headpond (Table 5.2)	Below Ground Excavation (Table 5.3 & 5.4)	Inlet / Outlet (Table 5.5)	Vegetation Strip (Table 5.6)	Total
Excavated Volume (m³)	4,740,000	1,250,000	156,000	651,000	**6,797,000**

5.4 Reuse of Excavated Material

5.4.1 The main construction component that will utilise the material excavated during construction is the Headpond Embankment. The 3D model includes the Embankment and Table 5.8 details the volume required for construction as derived from the model. The volume taken from the 3D model represents a compacted volume of material, therefore, the actual volume of material required is greater as detailed in Table 5.8.

Table 5.8 Embankment Volume

	Embankment
Volume (m³)	3,472,976
Compaction Factor	0.72
Total Bulked (m³)	**4,820,000**

Assumptions

- *The majority of the makeup of the embankment will be made with sedimentary material. Thus a compaction factor for sedimentary material has been used, as shown in Table 5.1.*

5.4.2 The design of the Headpond is essentially a cut and fill exercise with the aim to balance the two. The majority of the material used to construct the Headpond Embankment will come from the surface excavation works carried out at the Headpond. However, it is anticipated that not all of the material will be suitable for use in the Embankment.

5.4.3 Table 5.9 provides a breakdown of the cut and fill exercise undertaken for the embankment using only the surface excavated material from the Headpond.

Table 5.9 Surface Excavation – Material Reuse

Surface Excavated Material (m³)	Percentage of Reuse (%)	Material to be used in Embankment (m³)	Surplus (m³)	Wastage / Loss @ 2% (m³)	Volume of Embankment (m³)	Deficit of Material for the Embankment (m³)
4,740,000	87	4,123,800	616,200	82,476	4,820,000	-778,676

Assumptions

- *Reuse of material from the Headpond excavation = 87% is based on engineering judgement.*
- *Wastage of material from processing (as dust and particulates), transportation (as dust), and runoff (as suspended solids) has been estimated at 2% based on the ICE Earthworks, A guide 2nd Edition. This material has been assumed to be lost and is not included in the rest of this MMA.*
- *Lining foundations 'transition zone' of the embankment, as shown in Figure 2.9 (EIA Report Volume 3), has been included in 'Volume of Embankment' as it is assumed that the 'transition zone' will be made up of high-quality material that is anticipated to be sourced from the excavation activities;*
- *The lining on the inside face of the Headpond has not been included in the 'Volume of Embankment' as it is assumed that this material will be constructed with concrete.*

5.4.4 As demonstrated in Table 5.9 there is a shortfall in the volume of material required to build the Headpond Embankment from the surface excavated material alone. To make up this shortfall, the material excavated from below ground will be used.

5.4.5 Table 5.10 provides a breakdown of how the material excavated from below ground will be utilised.

Table 5.10 Underground Excavation – Material Reuse

Underground Excavated Material (m³)	Percentage of Reuse (%)	Material to be used in Embankment (m³)	Surplus (m³)	Wastage / Loss @ 2% (m³)	Remaining Volume of Embankment (m³)	Excess (m³)
1,250,000	95	1,187,500	62,500	23,750	778,676	385,074

Assumptions

- *Reuse of material generated from the tunnelling works in the Headpond = 95% is based on engineering judgement.*
- *Wastage of material from processing (as dust and particulates), transportation (as dust), and runoff (as suspended solids) has been estimated at 2% based on the ICE Earthworks, A guide 2nd Edition. This material has been assumed to be lost and is not included in the rest of this MMA.*

5.4.6 Table 5.10 shows there will be an excess of approximately 385,074 m³ of material suitable for use within the Headpond Embankment. The total volume of excess material following excavation of all works and construction of the Headpond embankment is shown in Table 5.11. The volume has been calculated based on the total surplus material and any excess material as shown in Table 5.9 and Table 5.10.

Table 5.11 Total Excess Material

Surface Excavation Surplus (m³) (Table 5.9)	Underground Excavation Surplus (m³) (Table 5.10)	Underground Excavation Excess (m³) (Table 5.10)	Total Excess Material (m³)
616,200	62,500	385,074	1,063,774

5.4.7 The surplus material detailed in Table 5.11 represents material that is unsuitable for use in the construction of the Headpond embankment. The excess material represents material that is suitable for use in the construction of the Headpond embankment but will not be used as the volume of suitable material is greater than the volume required.

5.5 Landscape Embankment

5.5.1 During the design, the requirement for a landscaping embankment to mitigate visual impact was identified. The Landscaping Embankment is not an engineering requirement for the Headpond and the basis for its purpose is detailed in Chapter 11: Landscape and Visual (Volume 2).

5.5.2 Therefore, its design and the material used to construct it can vary from the Headpond Embankment as it does not require the same safety requirements under the Reservoirs Act. As such it was determined that the Landscape Embankment could be constructed using the excess material generated from the major excavation works.

5.5.3 A Landscaping Embankment was designed to the north and west of the Headpond. Table 5.12 details the size and volume of the proposed Landscape Embankment.

Table 5.12 Landscaping Embankment Volume

	Landscape Embankment
Surface Area (m²)	336,135
Volume (m³)	1,392,000

5.6 Balance of Material

5.6.1 The purpose of this appraisal is to show that, from the major engineering works, there is little or no excess material that will be left on-site or will require disposal off-site. One of the main components which allows this to happen is the Landscape Embankment. Table 5.13 shows the balance of excavated material from the main construction components.

Table 5.13 Balance of Excavated Material

Description	Volume (m^3)	Compaction Factor	Compacted Volume	Reference
Total Excess Material	1,063,774	0.72	765,917	Table 5.11
Total Vegetation Strip	651,000	0.8	520,800	Table 5.6
Inlet / Outlet Tailpond	156,000	0.75	117,000	Table 5.5
Compacted Volume of Material Available for Landscape Embankment			***1,403,717***	
Volume of Landscape Embankment			-1,392,000	Table 5.12
Volume of Material Unable to be Used			**12,000**	

Assumptions

- *All material for the activities described can be used within the Landscape Embankment structure.*
- *The Compaction Factor has been taken from Table 5.1.*

5.7 Additional Material Sources – Insufficient Material

5.7.1 The balance of excavated material is based on a number of assumptions. If following detailed design, further SI and even during construction there was anticipated to be insufficient material to construct the Headpond Embankment, further material could be excavated from within the Headpond. The Headpond would essentially act as a large borrow pit that can be adjusted in design to accommodate the material needs for the project.

5.7.2 During construction there will also be a possibility to update the design if it was found that anticipated material volumes were not as expected. This would be an iterative design process based upon the material being excavated from the underground and Headpond works. This means the design can be informed early on in the construction process so if there is a shortfall it is not discovered at the end of the construction phase.

5.7.3 It should be noted that the decisions stated above will not affect the installed capacity or the Developments ability to operate.

5.8 Additional Material Uses – Excess Material

5.8.1 As shown in Table 5.13, it is anticipated that there may be 12,000 m^3 of surplus material that may need to be transferred off-site or an alternative on-site use found. However, this is obviously based upon a number of assumptions as detailed above.

5.8.2 As a result of these assumptions, there is a possibility there may be more or even less unsuitable / excess material than is anticipated. Post consent, once further SI works have been undertaken, the detailed design will be undertaken which will look to balance the materials in the same way the preliminary design has done. As above, the design of the Headpond can be manipulated as required as a result of excess material potentially being generated, and this would be the primary method of managing the potential for excess material (in the same way is it for insufficeint material).

5.8.3 Another alternative is that the Landscape Embankment can be adjusted to accommodation more or less excavated material but still maintain its mitigative purpose. This is discussed further in Chapter 11: Landscape and Visual (Volume 2). Therefore, it is anticipated that the excess material that is currently shown can be designed out.

5.8.4 If both of these detailed design options is not available, or if additional unsutiable excess material is identified, there are a number of other possible beneficial uses that the unsuitable material could be used for as detailed in Table 5.14.

Table 5.14 Additional Material Uses

Component	Purpose	Type of Material	Estimated Volume (m³)
Compounds	Reinstating, bunding and dressing	Vegetation, topsoils, general soils	10,000
Headpond Berm	Creating a wave berm instead of a wave wall around the top of the embankment	General soils, rock and stone	8,000
Access Tracks	Reinstating, dressing verges and narrowing	Vegetation, topsoils, general soils	5,000
Access and recreational tracks	Resurfacing, replacement and improvements	Crushed stone	5,000

Assumptions

- *The type of surplus material will be able to be used for the various construction components.*

5.9 Conclusion

5.9.1 This appraisal has been undertaken to demonstrate how the significant volume of excavated material generated during construction will be managed on-site.

5.9.2 It is anticipated that a total volume of approximately 6,797,000 m³ of material will be excavated during construction. This material will primarily be used to construct the Headpond Embankment with the remainder being used for the Landscape Embankment. This will result in approximately 12,000 m³ of excess / unsuitable material at the end of construction which is less than 1 % of the total excavated material.

5.9.3 Although this appraisal shows a volume of excess / unsuitable material, it is anticipated that following further SI works a detailed design will be undertaken which will design out any excess / unsuitable material.

5.9.4 Should there still be excess / unsuitable material other on-site uses, which have been identified in this appraisal, will be utilised.

5.9.5 As a result of this MMA, it is not anticipated that any excess / unsuitable material will have to be left on-site. Should any material have to be exported off-site it is anticipated to be a relatively small volume, the impact of transporting excess / unsuitable material off-site is detailed in the Construction Traffic Management Plan (CTMP). A Framework CTMP is available in Appendix 15.1.