Our Ref: A099801/HRA

Date: 1st March 2019

GRS (Roadstone) Limited
10 Goldsmith Way,
Eliot Business Park,
Nuneaton,
Warwickshire,
CV10 7RJ

Dear Sir/ Madame,

2018 HYDROGEOLOGICAL RISK ASSESSMENT REVIEW, PASSENHAM QUARRY

Introduction

WYG Environment (WYG) has been commissioned to prepare and submit an Environmental Permit variation application on behalf of GRS (Roadstone) Ltd for a proposed extension of Passenham Quarry, Buckingham Road, Deanshanger, Milton Keynes, Buckinghamshire, MK19 6JT. Landfilling with inert materials at Passenham Quarry is to be extended in a single area outside the current permit boundary. This extension is shown edged red on David L Walker Ltd Drawing No. P14/5.6/1001 appended to this letter report. As part of this commission, WYG has reviewed the previous Hydrogeological Risk Assessment (HRA) for the Passenham Quarry site to determine whether it is still applicable and the WYG 2015 Hydrogeological Risk Assessment Review (Ref: A091151/ HRA).

Background

The original HRA for Passenham Quarry was undertaken by Environmental Simulations International (ESI) and ARUP in May 2005. Reviews of this HRA, made available to review by WYG, were undertaken by ESI in 2009 and 2015. The 2015 review concluded that the original model, environmental acceptance levels and conclusions of the original 2005 HRA were still valid. In addition, it was concluded that the site remained in compliance with the Landfill (England and Wales) Regulations 2002 and the Groundwater Regulations 1998. In 2015 WYG undertook a review of the HRA following proposed changes to the landfilling at Passenham Quarry that significantly increased the volumes of landfill material to the east and the west of the River Great Ouse. The WYG review identified that an increase in the size of the quarry did not propose a significant risk to Controlled Waters. WYG updated the maximum permissible landfill leachate concentrations and recommended amendments to the requisite surveillance at the site. It was concluded that due to inert nature of the quarry a permit under the Environmental Permitting Regulations was not required for leachate discharge. As the landfill only received inert wastes, the Water Framework Directive and the Groundwater Directive did not apply. Following the 2015 HRA Review, landfilling was only undertaken to the west of the River Great Ouse.

The proposed 2018 extension to Passenham Quarry will significantly increase the volume of the landfill material, to the east of the River Great Ouse. In view of this it was considered appropriate to undertake a review of the existing HRA and associated model for the site to determine whether this increased volume would result in any significant changes to the risk assessment. This approach, i.e. not to undertake a full HRA, was agreed in principal with the Environment Agency (telephone conversation between Gareth Barns (WYG) and Duncan Beaumont (Environment Agency) on 12th March 2018). The proposed area for the current extension is similar to the area to the east of the River Great Ouse proposed for extension in 2015.

The scope of the review is given below and the findings are presented in this letter report.

1. A summary of proposed changes to the quarry and landfilling operations that will impact upon the HRA
2. Details of modifications to input parameters of 2015 WYG HRA Review model
3. Summary of updated model outputs compared to original model outputs
4. Conclusions and Recommendations

It is advised that the 2005 ESI HRA and the 2015 ESI HRA Review are read in conjunction with this letter report. The findings and recommendations of the 2015 WYG HRA review are incorporated into this report and are updated where appropriate.

Summary of Proposed Changes and Environmental Setting

Passenham Quarry is located either side of the River Great Ouse, which flows north to south through the site. Approximately midway through the site the River Great Ouse bifurcates into two channels before joining together again to the north east of the site. Deanshanger Brook flows through a non-landfill area in the north-east of the site into the River Great Ouse north of the site. The River Great Ouse is considered the principal receptor.

The proposed extension relates to the quarry to the east of the River Great Ouse only. The quarry to the west of the River Great Ouse will be unchanged. The proposed extension will increase the extent of inert landfilling activities at the site by around a quarter.

The proposed extension (edged red) is located to the east of the current site (edged green on David L Walker Drawing P14/5.6/1001) with the River Great Ouse to the north of this area. There will be a 30m standoff between the maximum extent of landfilling activities and the River Great Ouse as shown on David L Walker Drawing No. P14/PL16/03 appended to this letter. Landfill operations on the current site also extend to within 30m of the River Great Ouse.

It is understood that the depth to which natural sand and gravels will be extracted in the extension areas prior to landfilling will be similar to the existing permit area (on average approximately 4m). The ground conditions in the areas of the proposed extension are similar to those in the existing landfill areas. These comprise River Terrace Deposits (sands and gravels, which are to be quarried and will comprise the sides of the landfill) overlying Boulder Clay (which will form the base of the landfill). Boulder Clay is present to the south of the proposed extension preventing groundwater inflow from the south of the site into the landfill. Outside of the quarry, the River Terrace Deposits are overlain by up to 2.1 of alluvium (silty clay). The River Great Ouse is situated within the alluvium.

It is also understood that as inert waste similar to that in the existing landfill will be used (i.e. clayey inert waste) with the clay base acting as a natural geological barrier. An artificial barrier will be placed on the side walls in line with the current requirements.

Summary of Updated Conceptual Site Model

WYG consider that the 2005 HRA conceptual site model is still applicable for the site. For ease of review of this letter report, the sources, pathways and receptors of the 2005 HRA Conceptual Site Model have been summarised below and shown on an annotated version of David L Walker Drawing P14/5.6/1001 appended to this report.

Sources:

- Western Quarry Site – Inert fill material in accordance with European Waste Catalogue (EWC) with no landfill cap or basal barrier system; and,
- Eastern Quarry Site - Inert fill material in accordance with European Waste Catalogue (EWC) with no landfill cap or basal barrier system.

Pathways:

A. Contaminant flow in groundwater from the south face of Western Quarry Site. This side of the quarry face is parallel to the direction of groundwater flow. The contaminant flux is assumed to be diluted by groundwater and rainfall;
B. Contaminant flow in groundwater from the east face of the Western Quarry Site. This is the hydraulically down-gradient face of the quarry closest to the River Great Ouse. The contaminant flux is assumed to be only diluted by infiltrating rainwater. As the landfill fully penetrates the aquifer thickness the contaminant flux will not be diluted by groundwater;
C. Contaminant flow in groundwater from the west face of the Eastern Quarry Site. The contaminant flux is assumed to be diluted by groundwater and rainfall;
D. Contaminant flow in groundwater from the north face of the Eastern Quarry Site. The contaminant flux is assumed to be diluted by groundwater and rainfall; and,
E. Contaminant flow in surface water run-off over the waste in the Eastern Quarry Site. Assumed that half of the surface water run-off will become contaminated. It is also assumed that the leachate will be diluted by rainfall.

Advection, dispersion and retardation of contaminants is assumed along the groundwater pathways. Groundwater flow in the Western Quarry Site has been identified to be towards the east. Groundwater flow in the Eastern Quarry Site has been identified to be towards the north-west.

Receptors:

- Groundwater adjacent to River Great Ouse on the east face of the Western Quarry Site (For Pathway A and B);
- Groundwater adjacent to River Great Ouse on the west boundary of the Eastern Quarry Site (For Pathway C);
- Groundwater adjacent to River Great Ouse on the north boundary of the Eastern Quarry Site (For Pathway D);
- River Great Ouse incorporating combined inputs of all groundwater pathways (For Pathway A, B, C and D), prior to dilution; and,
- Surface Water entering the River Great Ouse from surface water drains in the Eastern Quarry Site (For Pathway E).

Modifications of 2005 HRA model input parameters

The following section compares the proposed extension model input parameters with the original 2005 HRA model input parameters. Note that only parameters that have been modified are listed below. All other parameters are detailed in the 2005 HRA report. Note the site is irregular in shape. Dimensions given are approximate averages.

Table 1: Summary of Modified HRA input parameters

Parameter	Units	2005 Value	2018 Value	Justification
Western Quarry Area				
Waste Area	m^3	73,580	248,600	Estimated from site plans. Value the same as WYG 2015 HRA Report.
Waste Volume	m^3	214,000	722,970	Calculated from waste area and average waste thickness in 2005 HRA report. Value the same as WYG 2015 HRA Report.
Waste Width	m	240	750	Approximate width of landfill perpendicular to groundwater flow direction measured from site plans. Value the same as WYG 2015 HRA Report.
Waste Length	m	400	500	Approximate length of landfill parallel to groundwater flow direction measured from site plans. Value the same as WYG 2015 HRA Report.
Eastern Quarry Area				
Waste Area	m^3	142,290	200,290	2005 HRA value plus estimated area for extraction in extension area in April 2017 Environmental Statement for extension.
Waste Volume	m^3	338,000	488,000	2005 HRA value plus estimated total volume for extraction in 2018 extension area.

Parameter	Units	2005 Value	2018 Value	Justification
Waste Width	m	480	480	Approximate average width of landfill perpendicular to groundwater flow direction measured from site plans. 2005 value considered by WYG to be potentially overestimated. It is not considered necessary to increase this for the 2018 model.
Waste Length	m	500	550	Approximate average length of landfill parallel to groundwater flow direction measured from site plans
Aquifer Parameters – River Terrace Deposits				
Downgradient cross-section area in contact with Western Site	m^2	877.5	1,125.00	Represents area in River Terrace Gravels contaminant flux can flow for Pathway B. Estimated from waste width and saturated gravel depth GW02 and GW03 Value the same as WYG 2015 HRA Report model.
Side face cross-sectional area in contact with Western Site	m^2	300	800.00	Represents area in River Terrace Gravels contaminant flux can flow for Pathway A. Estimated from site plans and saturated gravel depth in boreholes from GW04, GW05 and GW03.
Saturated Gravel Depth in Western Site	m	2.15 (GW04 to GW05), 1.85 (GW05 to GW03)	1.75 (GW04 to GW05), 1.45 (GW05 to GW03)	Corrected to depth on logs. Area in water balance calculations. Values the same as WYG 2015 HRA Report model.
Saturated Gravel Depth in Eastern Site	m	2.5	1.62	Average thickness of Aquifer Deposits in South Eastern Quarry. Corrected to depth on logs. Value the same as WYG 2015 HRA Report model.
Receptor Parameters –Western Quarry Site				
Distance to River – Pathway A	m	230	280	Distance to the River Great Ouse from mid-point of the southern edge of the site. Equal to 30m stand-off plus half of landfill
Distance to River – Pathway B	m	30	30	Estimated distance from new eastern edge of landfill to the River Great Ouse, assuming 30m

Parameter	Units	2005 Value	2018 Value	Justification
Receptor Parameters –Eastern Quarry Site				
Distance to River – Pathway D	m	70	30	Stand-off distance from new extension area to River Great Ouse

The WYG 2015 RAM v2 model was updated with the model input parameters as defined above to create the 2018 RAM V3 model. RAM is a model developed by Environmental Simulations International Ltd, which is based upon the Environment Agency's Remedial Targets Methodology and is benchmarked against Golders' ConSim model. WYG note that V1 of the RAM model was created by ESI in 2005 and included pollutant linkages not considered in the final 2005 HRA report. WYG assume these were left over from a superseded iteration of the model. These superseded pollutant linkages were removed by WYG for V2 of the model.

Updated Model Outputs and Risk Assessment

The outputs of the Extension HRA compared against the 2005 HRA outputs and environmental assessment limits are presented in Tables 2 to 6. The outputs represent the predicted contaminant concentrations at the receptor compliance point for each pollutant linkage. Environmental Assessment Limits (EALs) were originally chosen as the minimum of Environmental Quality Standards (EQS) protective of freshwater and UK Drinking Water Standards (DWS). WYG have reviewed these and updated the ammonium DWS to match the UK 2016 Water Supply Regulations value of 0.5mg/l. Its EQS has been changed to match the UK 2015 Water Framework Directions Value of 0.3mg/l. Contaminants for which the model was run and assumed contaminant leachate concentrations are the same as in the original 2005 HRA.

The equation used in the 2005 HRA report to calculate un-ionised ammonia concentrations at the receptor compliance point is considered unsuitable by WYG. In its place the following equation, obtained from the California State Water Resources Control Board website (www.waterboards.ca.gov), has been used to calculate the percentage of total ammonium which is un-ionised ammonia in the River Great Ouse:

$$\%NH_3 = \frac{100}{1 + 10^{(pKa - pH)}}$$

Where:

pH = pH value of sample

Acid Disassociation Constant, pKa = 0.09018 + 2729.92 / (273 + T)

T = Temperature as ^{o}C

A temperature of 10.31°C has been used which is the average surface water temperature recorded during 2013 monitoring of the River Great Ouse. An average pH of 8.15 has been used for the River Great Ouse in line with the 2005 HRA. Based on the above, it has been calculated that the fraction of un-ionised ammonia (NH3) forms just 2.59% of the total ammonium.

Table 2: Model Outputs - North Western Quarry, Pathway A (RAM Model Path 1)

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor	EALs	Units
Ammonia	1.44E-04 @ 4 years	2.30E-05 @5 year	0.015*	mg/l
Ammonium	3.01E-03 @ 4 years	8.892E-04 @ 5 year	0.3*	mg/l
Chloride	0.322@ 1 year	9.517E-02 @ 1 year	250**	mg/l
Potassium	7.05E-02 @ 1 year	2.081E-02 @ 1year	12**	mg/l
Calcium	1.01 @ 1 year	0.298 @ 1 year	250**	mg/l
Iron	1.42E-02 @ 1500 years	5.834E-03 @ 2000 year	0.2**	mg/l

Note: *EQS value; **DWS Value

Table 3: Model Outputs - North Western Quarry, Pathway B (RAM Model Path 2)

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor	EALs	Units
Ammonia	9.30E-04 @ 1 years	1.72E-04 @ 1 year	0.015*	mg/l
Ammonium	1.24E-02 @ 1 years	6.679E-03 @ 1 year	0.3*	mg/l
Chloride	1.33 @ 1 year	0.715 @ 1 year	250**	mg/l
Potassium	0.291 @ 1 year	0.1563 @ 1 year	12**	mg/l
Calcium	4.17 @ 1 year	2.238 @ 1 year	250**	mg/l
Iron	8.79E-02 @ 280 years	5.153E-2 @ 350 year	0.2**	mg/l

Note: *EQS value; **DWS Value

All predicted concentrations are below the EALs. The decrease in predicted receptor concentrations for Pathway A and Pathway B is considered likely due to the increased area of the down-gradient and southern boundary faces of the landfill.

Table 4: Model Outputs – South Eastern Quarry, Pathway C (RAM Model Path 3)

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor	EALs	Units
Ammonia	6.02E-04 @ 150 years	2.02E-04 @ 200 year	0.015*	mg/l
Ammonium	8.05E-03 @ 150 years	7.787E-03 @ 150 year	0.3*	mg/l
Chloride	3.33E@ 40 year	2.940 @ 40 year	250**	mg/l
Potassium	0.729 @ 40 year	0.643 @ 40 year	12**	mg/l
Calcium	10.4 @ 40 year	9.204 @ 50 year	250**	mg/l
Iron	No breakthrough @ 5000 years	No breakthrough @ 5000 years	0.2**	mg/l

Note: *EQS value; **DWS Value

Table 5: Model Outputs – South Eastern Quarry, Pathway D (RAM Model Path 4)

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor	EALs	Units
Ammonia	3.805E-04@ 1 year	2.93E-04 @ 1 year	0.015*	mg/l
Ammonium	5.092E-03 @ 1 year	1.133E-2 @ 1 year	0.3*	mg/l
Chloride	0.540 @ 1 year	1.211 @ 1year	250**	mg/l
Potassium	0.118 @ 1 year	0.265 @ 1 year	12**	mg/l
Calcium	1.69 @ 1 year	3.791 @ 1 year	250**	mg/l
Iron	4.12E-03 @ 125 year	3.76E-02 @ 30 year	0.2**	mg/l

Note:*EQS value; **DWS Value

For Pathway C and D, the 2018 predicted receptor concentrations are only marginally different to 2005 predicted concentrations, with **all predicted concentrations below EALs**. Differences for Pathway C are likely due to the small modifications of waste area, waste volumes and saturated gravel depth in the model. The increase in predicted concentration for Pathway D is considered likely due to the decreased distance between the source and the Great River Ouse, which has decreased the amount that contaminant concentrations have been diluted by infiltrating rainwater.

Table 6: Model Outputs – South Eastern Quarry, Pathway E (RAM Model Path 5)

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor	EALs	Units
Ammonia	1.42E-04 @ 1 year	9.21E-05 @ 1 year	0.015*	mg/l
Ammonium	1.90E-03 @ 1 year	3.563E-03 @ 1 year	0.3*	mg/l
Chloride	0.203 @ 1 year	0.3812 @ 1 year	250**	mg/l
Potassium	4.44E-02 @ 1 year	8.34E-02 @ 1 year	12**	mg/l
Calcium	0.636 @ 1 year	1.193 @ 1 year	250**	mg/l
Iron	1.51E-02 @ 1 years	2.84E-02 @ 1 year	0.2**	mg/l

Note:*EQS value; **DWS Value

All predicted concentrations are below the EALs. For Pathway E, the 2015 predicted receptor concentrations are approximately double the 2005 predicted receptor concentrations. This is considered likely to be a function of the increased area of the landfill.

The results from both Pathway A, B, C and D were combined to determine cumulative affect at the River Great Ouse from groundwater sources, using equation 2 from the 2005 HRA Report:

$$C_{TOTAL} = \frac{\sum_{i=1}^{i=n} C_i \, Q_i}{\sum_{i=1}^{i=n} Q_i}$$

where C_{TOTAL} is the total concentration in mg/l due to the mixing of n separate contaminated flows, with concentrations of C mg/l and flow-rates of each pathway entering the river Q m^3/s. Note these combined values presented in Table 7 are for a hypothetical location within the River Terrace Deposits at the entry to the River Great Ouse and do not take into account dilution in the river. Peak concentrations from each pathway are used in the calculation. This is considered conservative as peak concentrations for each pathway are unlikely to all occur at the same time.

Table 7: Combined Model Outputs for Pathway A, B, C and D

Parameter	2005 Model Predicted Receptor Concentration	Updated 2018 Model Predicted Receptor Concentration	EALs	Units
Ammonia	7.12E-05	7.61E-05	0.015*	mg/l
Ammonium	9.54E-04	3.14E-03	0.3*	mg/l
Chloride	0.102	0.353	250**	mg/l
Potassium	2.24E-02	7.72E-02	12**	mg/l
Calcium	0.320	1.106	250**	mg/l
Iron	7.58E-03	1.074E-02	0.2**	mg/l

Note:*EQS value; **DWS Value

The results of the combined model outputs for Pathways A, B, C and D are below EALs for all contaminants modelled. The updated 2015 model predicted receptor concentrations are within an order of magnitude of the original 2005 values.

In summary the updated 2018 model predicted receptor concentrations are below EALs for the combined groundwater pathway and the surface water pathways. Therefore, the risks to the River Great Ouse from the current and future landfilling activities at the site are not considered to be significant.

The results from the model have been used to determine maximum permissible landfill soil-leachate concentrations for the contaminants modelled. Above these soil-leachate concentrations, contaminants are predicted to breach the EALs at the compliance point. These values are presented in Table 8 below.

Table 8: Maximum Permissible Landfill Leachate Concentrations

Parameter	Max Allowable Source Term NW Quarry Area 2005 Model	Max Allowable Source Term NW Quarry Area Updated 2018	Max Allowable Source Term SE Quarry Area 2005 Model	Max Allowable Source Term SE Quarry Area Updated 2018
Ammonium	16[1]	44.9	24.9	26.5
Chloride	20,000	37.435	8,030	9,099
Potassium	20,000[1]	1,756	385	436

Parameter	Max Allowable Source Term NW Quarry Area 2005 Model	Max Allowable Source Term NW Quarry Area Updated 2018	Max Allowable Source Term SE Quarry Area 2005 Model	Max Allowable Source Term SE Quarry Area Updated 2018
Calcium	964[1]	37,435	8,030	9,099
Iron	17	30.0	388[1]	43.4

Note: The max allowable concentrations for the North West Quarry area have been calculated using the maximum predicted concentrations for each parameter from Pathway A and B. The max allowable concentrations for the North West Quarry area have been calculated using the maximum predicted concentration for each parameter from Pathway C, D and E.

[1]WYG consider that these values were potentially incorrectly reported in the 2005 HRA. Potassium and calcium values are potentially the wrong way round. The iron value has been calculated not taking into account Pathway E.

Recommendations and Conclusions

This HRA review has identified that an increase in size of Passenham Quarry landfill in line with the proposals set out in Drawing P14/5.6/1001 and Drawing No. P14/PL16/03 would not pose a significant risk to the River Great Ouse.

It is recommended that the 2018 model maximum permissible concentrations (Table 8) or the site Waste Acceptance Criteria, whichever are lowest, are used to determine acceptable landfill soil-leachate concentrations.

It is recommended that the requisite surveillance for the site as summarised in the ESI HRA 2015 Review remains the same with the following amendments:

1. Groundwater monitoring boreholes GW07 and GW11 are in the centre of the proposed enlarged South Eastern Quarry landfill area, as shown on ESI Drawing ESID 11a appended to this letter. It is recommended that these boreholes are replaced by BH17 and BH18 (drilled by T Bedford Ltd in April 2015), as shown on WYG Drawing A091151/ENG.02 (Revision 2) appended to this letter, so that the background groundwater quality is sufficiently characterised.
2. Groundwater monitoring boreholes GW03 and 05 are in the centre of the North Western Quarry landfill area. It was recommended in the WYG 2015 HRA review that these are replaced by BH13A and BH14 (drilled by T Bedford Ltd in April 2015), as shown on WYG Drawing A091151/ENG.02 (Revision 2) appended to this letter, which are hydraulically up-gradient of the new landfill area so that the background groundwater quality is sufficiently characterised.
3. No groundwater monitoring boreholes are currently present hydraulically down-gradient of the new landfill areas in the North Western Quarry area. It was recommended in the WYG 2015 HRA

review that BH16 (drilled by T Bedford Ltd in April 2015) is added to the surveillance regime and should be used as a compliance borehole.

4. It was recommended in the WYG 2015 HRA review that surface water monitoring point SW05 should be moved upstream (around NG ref 477450, 238500) of the new landfill areas so that it will continue to measure the background river quality.

If the recommendations above are undertaken to the requisite surveillance the monitoring will be considered to be compliant with the Landfill Directive. Due to the inert nature of the quarry a permit under the Environmental Permitting Regulations is not required for leachate discharge. As the landfill is only to receive inert wastes the Water Framework Directive and Groundwater Directive do not apply.

We trust that this report fulfils your requirements.

Yours Sincerely,

Gareth Barns
Senior Geo-Environmental Consultant
For and on behalf of WYG

Paul Brown
Associate Director

Appended Material:
David L Walker Drawing P14/5.6/1001 – Southern Extension Area – Site Plan
David L Walker Drawing P14/5.6/1001 – Southern Extension Area – Site Plan. Annotated to show conceptual site model sources pathways and receptors
David L Walker Drawing P14/PL16/03 – Proposed Working Plan
ESI Drawing ESID 11a – Surface water and groundwater monitoring points
WYG Drawing A091151/ENG.02 (Revision 2) – Proposed Borehole Locations
Electronic PDF copies of updated HRA model