Objective	Task	Description	Mineral Management	Water Management Control Process	Water Volume
Isolate UMH aquifer within each 4 Year Operational Phase (Phase A through G).	1(a)	Excavate overburden and UMH around the perimeter of the mineral excavation phase down to a depth equal to the water saturated mineral. The depth will vary by season and phase.	Segregate mineral from overburden and stockpile and/or process accordingly	None required	
Install UMH Perimeter Bund Wall.	1(b)	Install well points and/or sumps along the perimeter of each phase to selectively dewater the UMH along the phase perimeter. Excavate UMH down to the upper surface of the Interburden in suitable section lengths (20m wide x 65m length) to allow for installation of the perimeter bund and back drain. Allow for a 1:4 grade haul road down to the upper surface of the interburden.		Actively dewater the UMH aquifer at a rate to allow placement of the perimeter bund keyed into the interburden. Depending on suspended load groundwater from the UMH will be discharged into a settlement lagoon followed by the UMH Recharge Lagoon, or directly to the UMH Recharge Lagoon.	**Confined m^3/day** / **Unconfined[1] m^3/day** Ro=200 59 – 149 / 72 - 144 Ro=100 149 - 299 / 92 - 288
	1(c)	Install UMH perimeter clay bund with a back drain, keying the bund into the overburden surface. <u>Bund crest elevations</u> will be as detailed below, which are above the highest UMH groundwater levels (AOD) recorded on the site (March 2014):		The back drain will control the maximum groundwater head outside of the Phase bund. Drain invert elevations (AOD, listed below) will vary for each Phase, but the intention is to manage the groundwater head at 1m below the maximum recorded water level for that Phase.	

Phase	Bund Crest (AOD)	Bund Length (m)[2]	Phase	Back Drain IL (mAOD)	Groundwater Level in the UMH (mAOD)[3]	Back Drain Flow (m^3/day and L/sec)[4]		
A	76m	770	A	74m	75.5 – 74	A	97-193[5]	1.1-2.2
B	76m	760	B	74.5	75.5 – 74	B	59-118	0.7-1.4
C	77m (west), 76m (east)	780	C	76m	76.8 – 74.5	C	64-128	0.7-1.5
D	77m (west), 76m (east)	570	D	76m	76.7 – 75.5	D	38-75	0.4-0.9
E	78m (west), 77m (east)	900	E	76.5m	77.6 – 77.0	E	85-169	1.0-2.0
F	78m (west), 77m (east)	560	F	76.5m	77.0 – 76.0	F	28-55	0.3-0.6
G	78m	620	G	76.5m	77.5 – 76.0	G	66-133	0.8-1.5

Objective	Task	Description	Mineral Management	Water Management Control Process	Water Volume
	1(d)	Repeat Tasks 1(a-c) for the remaining perimeter sections of each phase until a continuous clay bund has been constructed around the perimeter of the site. This scenario corresponds with the final reinstated site condition.		The perimeter back drains will control UMH groundwater levels during the site restoration stage to a maximum elevation of 76.5mAOD. The reinstatement back drain will be constructed in 2 halves with flow around the north and the south sides of the site to where ground levels will fall below 76.5mAOD. This approximates to the lateral extent of Phase E and G. It should be recognised that for the period of monitoring UMH groundwater only exceeded 76.5mAOD during the months of January to mid-March in 2014 following an extremely wet winter period. Water levels did not reach this elevation in 2015, which means that the E and G back drains would not have captured groundwater.	**Back Drain Flow (m^3/day and L/sec)[6]** E: 73-147, 0.8-1.7 G: 61-122[7], 0.7-1.4 E+G: 134-269, 1.6-3.1

[1] Calculated using Tab12. Well Points (UC) in 'Assessing the impacts of dewatering on water resources', Tier 1 Analytical Tools, Version 1.6; Environment Agency
[2] Length excludes the shared internal bund if it is to be removed (See Task 6)
[3] Seasonal high water level (March 2014)
[4] Calculations are based upon highest recorded groundwater level using March 2014 data (worse case). For significant period of the year there will be very little to no flow from the back drain.
[5] Calculated using Tab 8. Trench with Flow One Side (UC) in 'Assessing the impacts of dewatering on water resources', Tier 1 Analytical Tools, Version 1.6; Environment Agency
[6] As footnote 5 above.
[7] As footnote 1 above

<table>
<tr><th>Objective</th><th>Task</th><th>Description</th><th>Mineral Management</th><th>Water Management Control Process</th><th>Water Volume</th></tr>
<tr><td rowspan="1">Excavate Overburden and UMH for storage, blending and processing.</td><td>2</td><td>Overburden and UMH within the bunded area of each phase will be excavated down to the Interburden surface in areas equivalent to an annual operating period</td><td></td><td>Reduce and maintain groundwater levels in the UMH inside the Phase using ditches, and sump pumps to control water levels.

Maintenance pumping will also be required to capture and discharge flow generated by precipitation.

Each Phase will be dewatered at a sustainable rate equal to recharge plus the volume held in storage. Discharge rates will be managed according to the available recharge lagoon infiltration capacity, supplemented by recharge into the LMH aquifer within the confines of each phase as its worked.</td><td><table>
<tr><th>Phase</th><th>Water in Storage (m^3/day)</th><th>Precipitation Recharge (m^3/day)</th><th>Combined Discharge Requirement (m^3/day)</th></tr>
<tr><td>A</td><td>51</td><td>73</td><td>125</td></tr>
<tr><td>B</td><td>53</td><td>83</td><td>136</td></tr>
<tr><td>C</td><td>45</td><td>66</td><td>111</td></tr>
<tr><td>D</td><td>50</td><td>91</td><td>141</td></tr>
<tr><td>E</td><td>63</td><td>82</td><td>145</td></tr>
<tr><td>F</td><td>63</td><td>82</td><td>146</td></tr>
<tr><td>G</td><td>69</td><td>79</td><td>147</td></tr>
</table></td></tr>
<tr><td rowspan="2">Preparation for extraction of LMH mineral beneath the interburden.

It is advantageous if the interburden can be removed without a positive upward pressure from groundwater below.</td><td>3a</td><td>For site phases where the LMH groundwater levels are below the base of the Interburden for a significant seasonal period (unconfined aquifer conditions), then the interburden will be excavated from suitably sized working ‘cells’ with an approximate dimension of 75m x 75m.</td><td rowspan="2">Cohesive material from the interburden will be stockpiled for future bund construction, backfilling of the LMH excavation, or will be placed directly into previously excavated LMH ‘cells’.</td><td>Monitoring of groundwater levels indicates that no active groundwater pumping will be required from the LMH for Phase A and B (and possibly C, D and F, depending on seasonal conditions). This conclusion is drawn from Drawings B through K that illustrates geological cross sections for each Phase with the maximum and minimum seasonal water levels in both the UMH and the LMH aquifers). The maximum and minimum water levels are based upon the groundwater hydrographs in Appendix 6/3 of the Environmental Statement.</td><td>No water generating activities required</td></tr>
<tr><td>3b</td><td>For site phases where the LMH groundwater levels are above the base of the Interburden for a significant seasonal period (confined aquifer conditions), then the interburden will be excavated from suitably sized working ‘cells’.</td><td>Monitoring of groundwater levels indicates that active groundwater pumping will be required from the LMH aquifer during extraction of the interburden in Phase E and G (Phase c, D and F may or may not require active lowering of the water table – this will be determined at the time of working). For these 2 phases the working ‘cells’ will be reduced to a size of approximately 30m x 100m (3,000m^2)to limit the volume of water being pumped and recharged into the LMH Recharge Lagoon. Once the interburden has been removed from each ‘cell’ then pumping will be stopped and LMH aquifer water levels will be allowed to recover and re-equilibrate.
The volume calculations are sensitive to a number of assumptions, e.g., permeability and hydraulic connection with the Chalk being important.</td><td><table>
<tr><th>Phase</th><th>Pumping rate to lower water level to the base of the interburden[8]</th></tr>
<tr><td>A</td><td>Not required</td></tr>
<tr><td>B</td><td>Not required</td></tr>
<tr><td>C</td><td>155 – 310</td></tr>
<tr><td>D</td><td>215 – 431</td></tr>
<tr><td>E</td><td>278 – 558</td></tr>
<tr><td>F</td><td>472 – 945</td></tr>
<tr><td>G</td><td>405 – 811</td></tr>
</table></td></tr>
<tr><td>Extraction of LMH mineral.</td><td>4</td><td>‘Wet excavation’ of the LMH will occur once the interburden has been removed from the working ‘cell’.</td><td>LMH mineral will be excavated ‘wet’ from the working ‘cell’ for stockpiling and processing using long reach excavators</td><td>No active groundwater management is anticipated during the LMH mineral extraction operation.</td><td>No water generating activities required</td></tr>
</table>

[8] Calculated using Tab 1. Thiem (C) in ‘Assessing the impacts of dewatering on water resources’, Tier 1 Analytical Tools, Version 1.6; Environment Agency

Objective	Task	Description	Mineral Management	Water Management Control Process	Water Volume	
Recharge into UMH aquifer	5a	Water generated by the following tasks will be discharged to the UMH recharge lagoon: • Task 1 (b) Dewatering UMH during placement of perimeter bunds • Task 1 (c) Back drain discharge once UMH perimeter bunds are in place • Task 2 Maintenance water management (storage in UMH and precipitation) during all excavations	None required associated with this stage. Care will be taken to ensure both lagoons do not accumulate silt with the potential for decreasing infiltration rates	Lagoon recharge capacity is controlled by the physical properties of the aquifer, as well as with season due to changes in the water level at the time of discharge. A range of potential recharge values have been calculated using the Theim equation and the following assumptions: K = 4m to 8m/d (from piezometer test data) Ro = 200m, acting as a locally confined aquifer by the overburden Minimum head change in lagoon 2m (winter conditions) Maximum head change in lagoon 2.7m (summer conditions)	K = 4m/d 160 – 289m^3/day	K = 8m/d 322 – 579m^3/day
Recharge into LMH aquifer	5b	Water generated by the following task will be discharged to the LMH recharge lagoon. • Task 3 (b) Lowering of the piezometric surface of the LMH aquifer to the base of the interburden • Tasks 1(b), (c), 2, if required		The Theim equation has also been used to calculate the recharge capacity for the LMH lagoon with the following assumptions: K = 10m to 20m/d (from piezometer tests) Ro = 1000m Maximum available head change in the LMH lagoon is 6m	K = 10m/d 1,158m^3/day	K = 20m/d 2,316m^3/day
Removal of internal bund walls in neighbouring Phases.	6	Internal bund walls will be removed during construction of neighbouring phases that share a bund. Clay material won from the bund will be reused for subsequent bund preparation works.	Mineral will be excavated beneath the former bund for processing	Once the internal perimeter bund has been removed there may be groundwater seepage from the adjacent reinstated UMH in the adjacent phase.	Negligible quantity assumed	
Final Restoration	7	Perimeter bund drainage	None	The perimeter drain for Phase E and G will remain in place during the restoration stage and discharge into the interior of the restored site within shallow swales and hedgerow boundary ditches that will eventually discharge into the combined UMH recharge lagoon (see Task 8 below). Following a period of water level review, the perimeter drain around Phase A, B, C (part of), D and F will be removed.	136m^3/d – 269m3/d[9]	
Combined Lagoons	8	Create a pathway for surface water (comprising a) Rainfall runoff b) Groundwater fed runoff (Phase E and G) All to be recharged into the UMH and LMH lagoons (combined as a single UMH lagoon).	None	The LMH lagoon will be reinstated to the upper surface of the interburden. The bund between the the UMH and LMH lagoon will be removed so forming a single UMH lagoon. a) RW runoff for the reinstated site will be at the greenfield rate b) The Phase E & G drain will be set at 76.5mAOD and is designed to capture rising groundwater, if any c) Combined lagoon recharge capacity	The combined flow to the infiltration lagoon will comprise:	
					a) RW runoff b) E & G GW runoff	36 – 41,000m^3 134 – 269m^3/day
					Combined lagoon recharge capacity	
					K = 4m/d 370 – 666m^3/day	K = 8m/d 740 – 1,333m^3/day
				The combined lagoon will have a storage capacity equal to its area X the available rise in water head from the static water level up to the spill point at 75.5mAOD The static water level recorded at the lagoon area ranges seasonally from 72.8m to 74mAOD so a rise in available head of 2.7m to 1.5m.	167,000m^3 to 93,000m^3	

[9] Refer back to task 1(d)

Assumptions and Example Calculations

Task 1b Install well points to dewater UMH along the alignment of the perimeter bund for each phase.

Water volumes have been estimated using the analytical tool 'Assessing the impacts of dewatering on water resources', Tier 1 Analytical Tools, Version 1.6; Environment Agency, specifically Tab 12 solution Well Points (UC).

An example of the output is provided in the spreadsheet image below. Significant assumptions are:

- Aquifer thickness is a maximum for each phase
- Hydraulic conductivity (K) = 4m/d and 8m/d
- Ro = 200m
- Drawdown requirements vary according to average aquifer thickness in each phase
- Length of trench= 65m along which dewatering is undertaken.

12) Partial penetration by a double row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

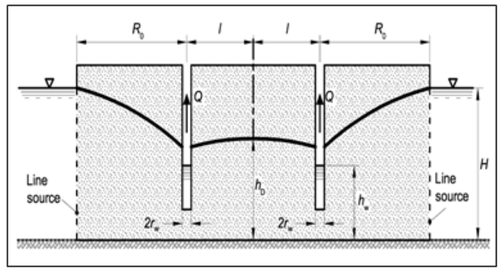
Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7.5	m	6	6	m
Height of water table at well	h_w	0.3	m	0.3	0.3	m
Conductivity						
Hydraulic conductivity of aquifer	K	4	m/d	10	10	m/d
Length of trench	x	65	m	65	65	m
Distance to line source, equal to radius of influence	R_0	200	m	100	400	m
Total discharge from wellpoints	**Q**	72.22	m^3/d	23.03	361.10	m^3/d

Height of WT at centre of dewatered area

$$h_D = h\left[\frac{C_1C_2}{R_0}(H-h)+1\right]$$

Distance to centre of dewatered area	l	10	m
	l/h	33.3333	
Coefficient 1	C_1	1.01	
Radius of each well	r_w	0.05	m
	r_w/H	0.00667	
Coefficient 2	C_2	1.37	
Height of WT at centre of dewatered area	h_D	0.31	m



(Figures adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

(Mansur & Kaufman, 1962)

Task 1c Calculation of Back Drain Flow for each Phase

Water volumes have been estimated using the analytical tool 'Assessing the impacts of dewatering on water resources', Tier 1 Analytical Tools, Version 1.6; Environment Agency, specifically Tab 8 Trench with Flow One Side (UC).

An example of the output is provided in the spreadsheet image below. Significant assumptions are:

- Aquifer thickness is a maximum for each phase
- Drawdown is between 0.5m and 1.5m and varies for each phase
- Hydraulic conductivity (K) = 4m/d and 8m/d
- Ro = 200m
- The length of the active perimeter for each phase is different and varies between 570m and 900m in length along which a flow is generated. The example below is for Phase A.

8) Partial penetration by a single row of wellpoints of an unconfined aquifer fed from a single line source

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{2R_0}(H^2-h_w^2)\right]$$

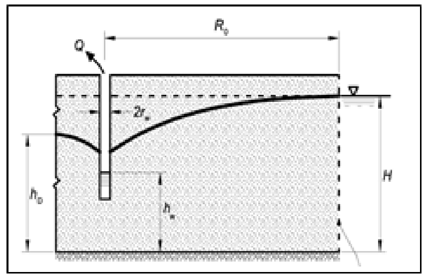
Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	6	m	48	52	m
Height of water table at well	h_w	4.5	m	43	47	m
Conductivity						
Hydraulic conductivity of aquifer	K	4	m/d			m/d
Radius						
Length of trench	x	770	m			
Radius of influence	R_0	200	m	250	400	m
Is R_0/H greater than or equal to 3 ?		Yes		Yes	Yes	
Total discharge from wellpoints	**Q**	96.72	m^3/d	######	######	m^3/d

Height of WT downstream of slot

$$h_D = h_w\left[\frac{1.48}{R_0}(H-h_w)+1\right]$$

Height of WT downstream of slot	h_D	4.55	m



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

(Mansur & Kaufman, 1962)

Task 1d Final Restoration Phase – Back Drain Flow

It is proposed that an active back drain will remain upon completion of all mineral excavation works. The intention is to maintain a maximum UMH groundwater head below that recorded on site during the maximum water level recorded on site in March 2014.

The invert elevation of the back drain will be set at 67.5mAOD and will surround the perimeter to a point where ground surface levels are also at 67.5mAOD. At this location the drain will 'daylight' at the surface and a flow will discharge to the interior of the restored site. Flow will occur approximately between January and March although whether a flow occurs will be dictated by groundwater levels in the aquifer which are controlled by seasonal rainfall events. Flow has been calculated using the same formula illustrated in Task 1c as shown below for the location of the back drain around Phase G.

8) Partial penetration by a single row of wellpoints of an unconfined aquifer fed from a single line source

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{2R_0}(H^2-h_w^2)\right]$$

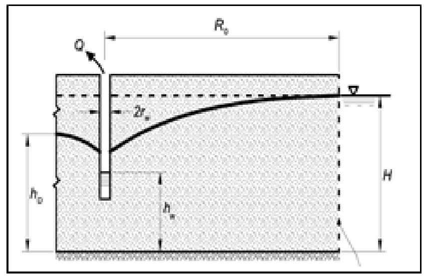
Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7.5	m	48	52	m
Height of water table at well	h_w	6.5	m	43	47	m
Conductivity						
Hydraulic conductivity of aquifer	K	4	m/d			m/d
Radius						
Length of trench	x	570	m			
Radius of influence	R_0	200	m	250	400	m
Is R_0/H greater than or equal to 3 ?		Yes		Yes	Yes	
Total discharge from wellpoints	**Q**	61.13	m^3/d	######	######	m^3/d

Height of WT downstream of slot

$$h_D=h_w\left[\frac{1.48}{R_0}(H-h_w)+1\right]$$

Height of WT downstream of slot h_D 6.5481 m



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

(Mansur & Kaufman, 1962)

Task 2 Operational discharge estimates to dewater the UMH once the perimeter drain is installed plus an estimate of rainfall recharge

Once the perimeter bund of each phase is constructed there will be a requirement to dewater the UMH within the phase. Each phase is approximately 4 years of operation so the total volume of water to be removed prior to mineral excavation will be the volume of water held in storage at the time of perimeter bund completion plus recharge. The table below presents the calculations:

- Precipitation (PPT) – 662mm/year

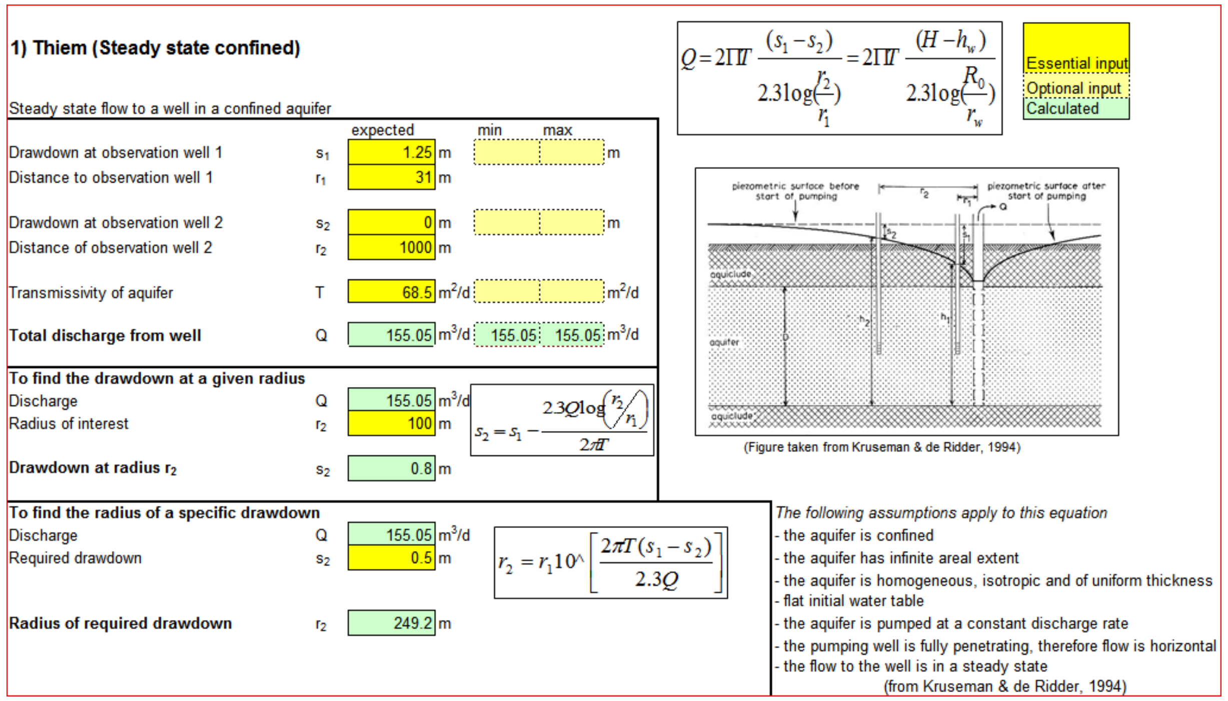
Phase Area		Groundwater in Storage					Recharge		
Phase	**Area (m^2)**	**Saturated Thickness (m)**	**Porosity**	**Water Volume in Storage (m^3)**	**Annual Water Volume in Storage (m^3)**	**Daily Water Volume (m^3)**	**Ave Annual PPT (m^3)**	**Ave Daily PPT**	**Combined Flow to Discharge per day (Storage + Recharge) (m^3)**
A	62274	6	0.2	74729	18682	51	26797	73	125
B	70505	5.5	0.2	77556	19389	53	30338	83	136
C	56335	5.8	0.2	65349	16337	45	24241	66	111
D	77532	4.7	0.2	72880	18220	50	33362	91	141
E	69380	6.6	0.2	91582	22895	63	29854	82	145
F	69239	6.8	0.2	94165	23541	64	29794	82	146
G	66805	7.5	0.2	100208	25052	69	28746	79	147

Note: Average annual PPT is calculated using an assumption that 65% of PPT is recharged.

Task 3b **Lower Mineral Horizon (LMH) Groundwater Lowering**

The example calculation illustrates the volume of water discharge generated to lower the confined aquifer water level to the base of the interburden. The need for pumping at all, and the amount of pumping required will vary according to the water level in the aquifer and the aquifers physical parameters. Water volumes have been estimated using the analytical tool 'Assessing the impacts of dewatering on water resources', Tier 1 Analytical Tools, Version 1.6; Environment Agency, specifically Tab 1 Theim (Steady State Confined). The important assumptions used in this calculation are that:

- The aquifer is assumed to be the LMH and not the Chalk + LMH (the chalk surface is characterised as a putty chalk with a relatively low hydraulic conductivity)
- Hydraulic conductivity (K) of the LMH has been assumed to be in the range of 10m/day and 20m/day
- The cell to be dewatered is equivalent to an area of 3,000m^2 (a circle with a radius of 31m)



Phase	Water Elev (high) = H	Top of Chalk (ave)	Base of Interburden (Ave) = h	Mineral Thickness	Sat Thickness	Required head change	K	T	r	Q (m3/d)
C	70	61.9	68.75	6.85	8.1	1.25	10	68.5	31	155
D	69	60.3	67.3	7	8.7	1.7	10	70	31	215
E	71.5	61.8	69.5	7.7	9.7	2	10	77	31	278
F	71	60.2	67.35	7.15	10.8	3.65	10	71.5	31	472
G	71	61.1	67.5	6.4	9.9	3.5	10	64	31	405

Phase	Water Elev (high) = H	Top of Chalk (ave)	Base of Interburden (Ave) = h	Mineral Thickness	Sat Thickness	Required head change	K	T	r	Q (m3/d)
C	70	61.9	68.75	6.85	8.1	1.25	20	137	31	310
D	69	60.3	67.3	7	8.7	1.7	20	140	31	431
E	71.5	61.8	69.5	7.7	9.7	2	20	154	31	558
F	71	60.2	67.35	7.15	10.8	3.65	20	143	31	945
G	71	61.1	67.5	6.4	9.9	3.5	20	128	31	811

Task 5a Recharge into UMH Lagoon

The Thiem equation has been used to calculate recharge for the UMH lagoon. The assumptions used in this calculation include:

- Transmissivity of the aquifer is K(hydraulic conductivity) x b (thickness) where b is take as the mineral thickness (3.5m) excluding overburden
- 2 values for K have been used, 4m/d and 8m/d
- Area of the LMH lagoon is 24,361m^2, equivalent to a circle with the radius of 88m
- Available +ve head change in the lagoon will be set by the bund height (elevation of 76mAOD) and spill point elevation (75.5mAOD) which will range between +2m and +2.7m above the static water level
- Ro = 200m

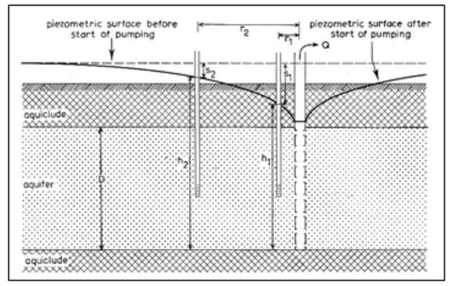
1) Thiem (Steady state confined)

$$Q = 2\Pi T \frac{(s_1 - s_2)}{2.3\log(\frac{r_2}{r_1})} = 2\Pi T \frac{(H - h_w)}{2.3\log(\frac{R_0}{r_w})}$$

Essential input
Optional input
Calculated

Steady state flow to a well in a confined aquifer

		expected		min	max	
Drawdown at observation well 1	s_1	2.7	m			m
Distance to observation well 1	r_1	88	m			
Drawdown at observation well 2	s_2	0	m	0.2	0.8	m
Distance of observation well 2	r_2	200	m			
Transmissivity of aquifer	T	28	m^2/d			m^2/d
Total discharge from well	Q	579.24	m^3/d	407.61	579.24	m^3/d



(Figure taken from Kruseman & de Ridder, 1994)

To find the drawdown at a given radius			
Discharge	Q	579.24	m^3/d
Radius of interest	r_2	100	m
Drawdown at radius r_2	s_2	2.3	m

$$s_2 = s_1 - \frac{2.3Q\log\left(\frac{r_2}{r_1}\right)}{2\pi T}$$

To find the radius of a specific drawdown			
Discharge	Q	579.24	m^3/d
Required drawdown	s_2	1	m
Radius of required drawdown	r_2	147.6	m

$$r_2 = r_1 10\wedge\left[\frac{2\pi T(s_1 - s_2)}{2.3Q}\right]$$

The following assumptions apply to this equation
- the aquifer is confined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore flow is horizontal
- the flow to the well is in a steady state

(from Kruseman & de Ridder, 1994)

Task 5b Recharge into LMH Lagoon

The Thiem equation has been used to calculate recharge for the LMH lagoon. The assumptions used in this calculation include:

- Transmissivity of the aquifer is K(hydraulic conductivity) x b (thickness) where b is take as the mineral thickness (6.8m)
- 2 values for K have been used, 10m/day and 20m/day
- Area of the LMH lagoon is 37,594m^2, equivalent to a circle with the radius of 109m
- Available +ve head change in the lagoon will be set by the bund height (elevation of 76mAOD) which will be approximately +6m above the LMH static water level
- Ro = 1000m

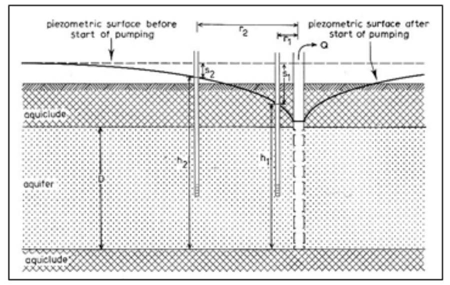
1) Thiem (Steady state confined)

$$Q = 2\Pi T \frac{(s_1 - s_2)}{2.3\log(\frac{r_2}{r_1})} = 2\Pi T \frac{(H - h_w)}{2.3\log(\frac{R_0}{r_w})}$$

Essential input
Optional input
Calculated

Steady state flow to a well in a confined aquifer

		expected		min	max	
Drawdown at observation well 1	s_1	-6	m			m
Distance to observation well 1	r_1	109	m			
Drawdown at observation well 2	s_2	0	m			m
Distance of observation well 2	r_2	1000	m			
Transmissivity of aquifer	T	136	m^2/d			m^2/d
Total discharge from well	Q	-2315.84	m^3/d	-2315.84	#######	m^3/d



(Figure taken from Kruseman & de Ridder, 1994)

To find the drawdown at a given radius			
Discharge	Q	-2315.84	m^3/d
Radius of interest	r_2	209	m
Drawdown at radius r_2	s_2	-4.2	m

$$s_2 = s_1 - \frac{2.3Q\log\left(\frac{r_2}{r_1}\right)}{2\pi T}$$

To find the radius of a specific drawdown			
Discharge	Q	-2315.84	m^3/d
Required drawdown	s_2	-3.2	m
Radius of required drawdown	r_2	306.6	m

$$r_2 = r_1 10\wedge\left[\frac{2\pi T(s_1 - s_2)}{2.3Q}\right]$$

The following assumptions apply to this equation
- the aquifer is confined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore flow is horizontal
- the flow to the well is in a steady state

(from Kruseman & de Ridder, 1994)

Task 7 Restoration Phase, Back Drain Flow (see Task 1d)

Task 8e Restoration Phase – Combined Lagoon Discharge Capacity

The Thiem equation has been used to calculate recharge for the combined UMH and LMH lagoon areas. The assumptions used in this calculation include:

- Transmissivity of the aquifer is K(hydraulic conductivity) x b (thickness) where b is take as the mineral thickness (3.5m) excluding overburden
- 2 values for K have been used, 4m/day and 8m/day
- Area of the LMH lagoon is 61,955m^2 (24,361+37,594) equivalent to a circle with the radius of 140m
- Available +ve head change in the lagoon will be set by the bund height (elevation of 76mAOD) and spill point elevation (75.5mAOD) which will range between +2m and +2.7m above the static water level
- Ro = 200m

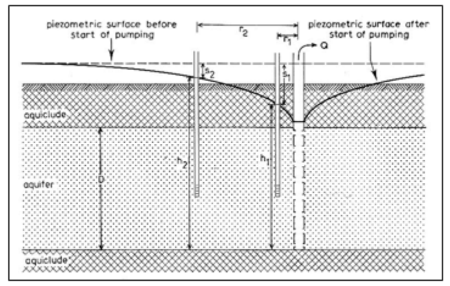
1) Thiem (Steady state confined)

$$Q = 2\Pi T \frac{(s_1 - s_2)}{2.3\log(\frac{r_2}{r_1})} = 2\Pi T \frac{(H - h_w)}{2.3\log(\frac{R_0}{r_w})}$$

Essential input
Optional input
Calculated

Steady state flow to a well in a confined aquifer

		expected		min	max	
Drawdown at observation well 1	s_1	2.7	m			m
Distance to observation well 1	r_1	140	m			
Drawdown at observation well 2	s_2	0	m	0.2	0.8	m
Distance of observation well 2	r_2	200	m			
Transmissivity of aquifer	T	28	m^2/d			m^2/d
Total discharge from well	Q	1333.27	m^3/d	938.22	1333.27	m^3/d



(Figure taken from Kruseman & de Ridder, 1994)

To find the drawdown at a given radius

Discharge	Q	1333.27	m^3/d
Radius of interest	r_2	100	m
Drawdown at radius r_2	s_2	5.2	m

$$s_2 = s_1 - \frac{2.3Q\log\left(\frac{r_2}{r_1}\right)}{2\pi T}$$

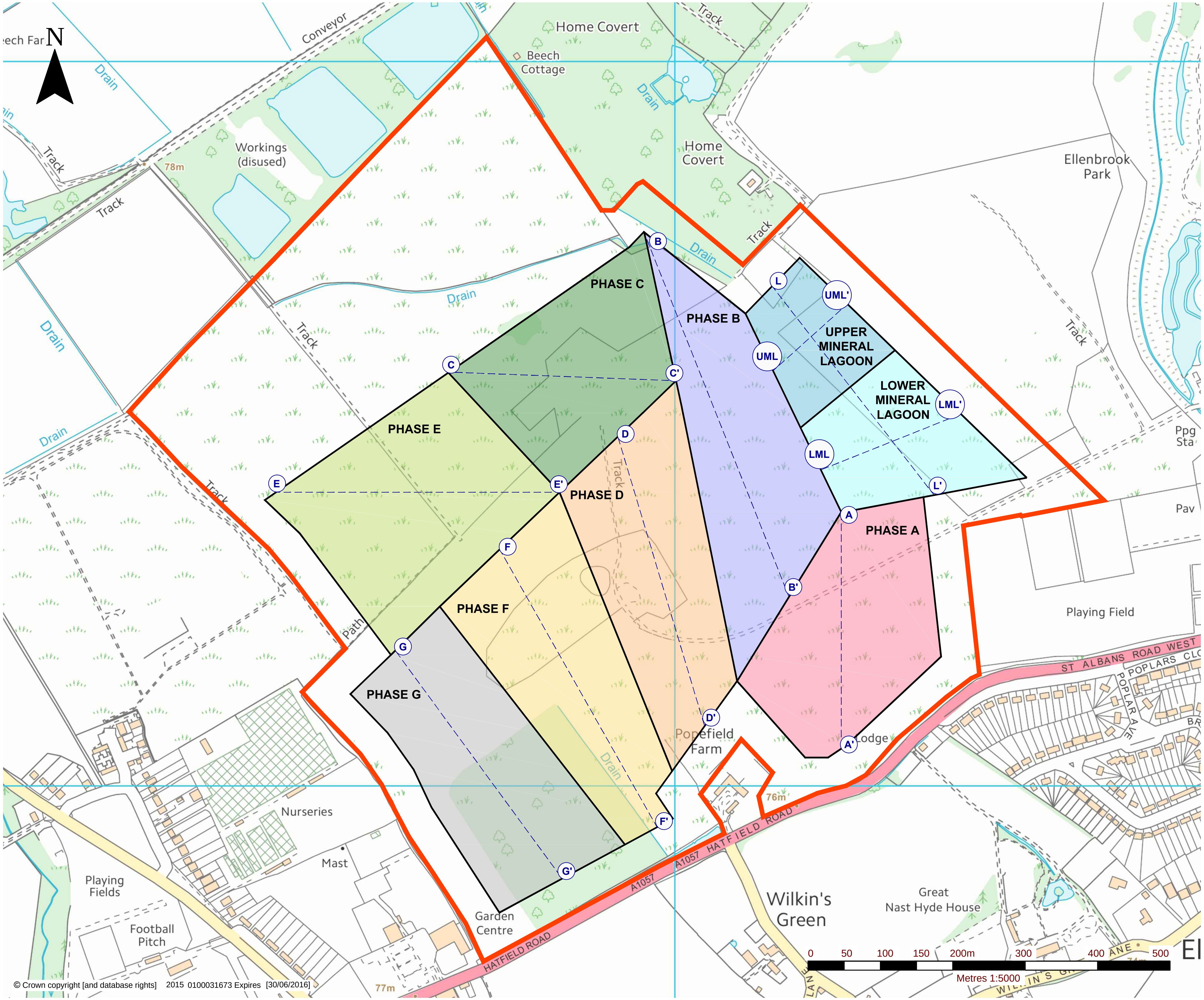
To find the radius of a specific drawdown

Discharge	Q	1333.27	m^3/d
Required drawdown	s_2	1	m
Radius of required drawdown	r_2	175.3	m

$$r_2 = r_1 10^\wedge\left[\frac{2\pi T(s_1 - s_2)}{2.3Q}\right]$$

The following assumptions apply to this equation
- the aquifer is confined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore flow is horizontal
- the flow to the well is in a steady state

(from Kruseman & de Ridder, 1994)



01109.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

LEGEND

- SITE BOUNDARY
- PHASE BOUNDARY
- SECTION LINE

PHASES

- PHASE A
- PHASE B
- PHASE C
- PHASE D
- PHASE E
- PHASE F
- PHASE G
- PHASE UPPER MINERAL LAGOON
- PHASE LOWER MINERAL LAGOON

built on relationships

SLR global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

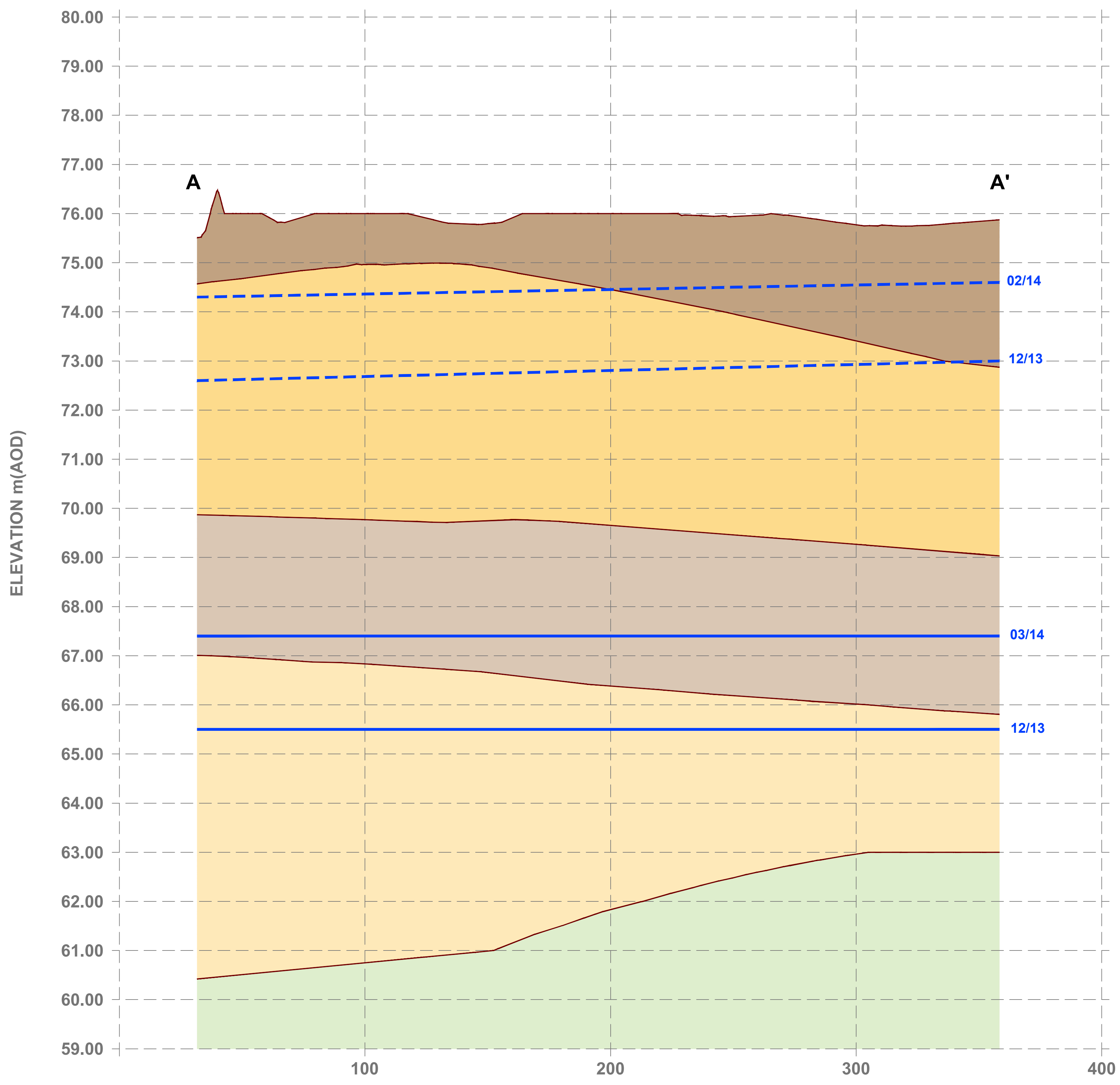
ENVIRONMENTAL STATEMENT

PHASING PLAN AND LINES OF SECTION

DRAWING A

Scale	Date
1:5000 @ A3	NOVEMBER 2015

PHASE A
SECTION A - A'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

UMA PIEZOMETRIC SURFACE

LMA PIEZOMETRIC SURFACE

OVERBURDEN

UM HORIZON

INTERBURDEN

LM HORIZON

CHALK

built on relationships

global environmental solutions

TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

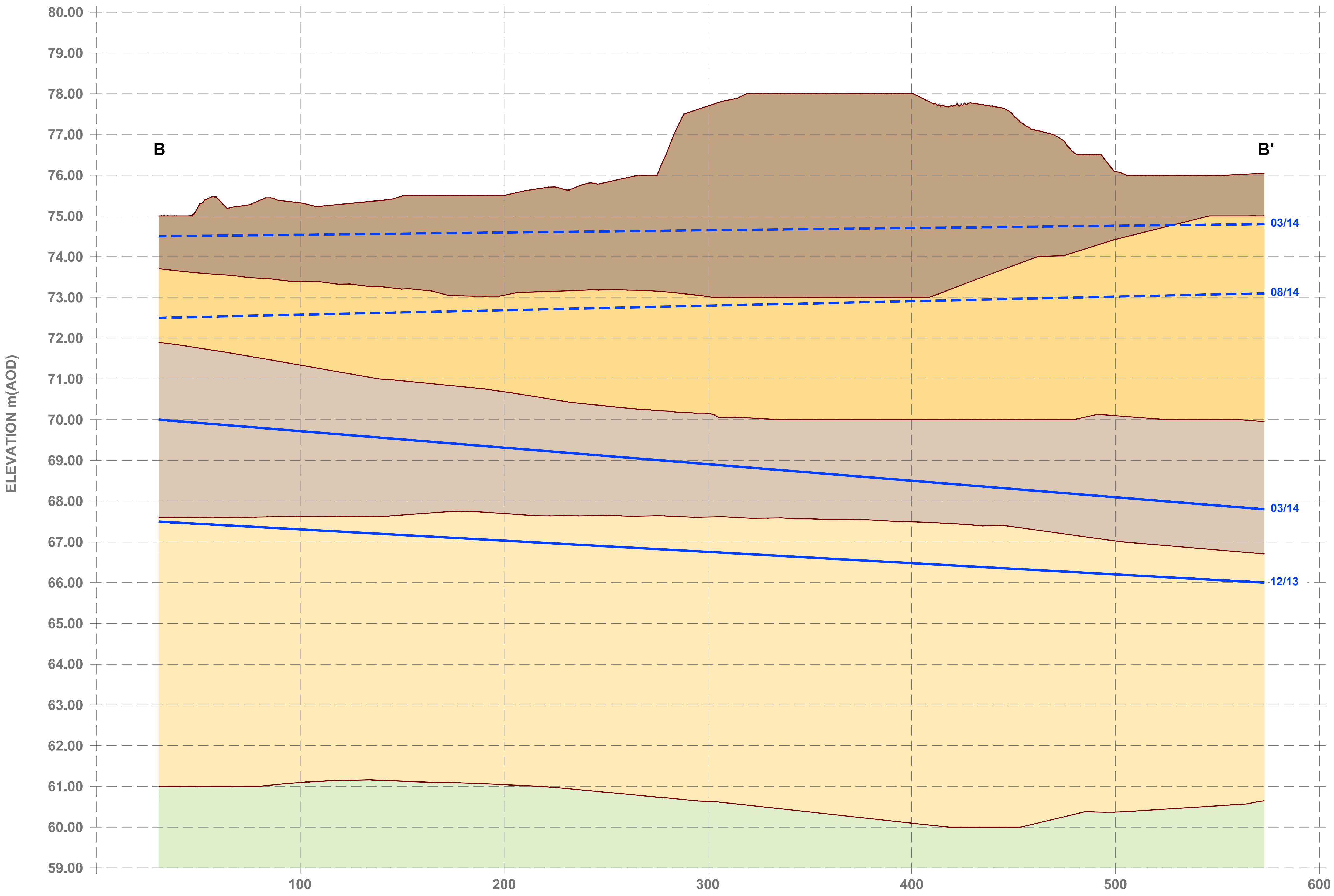
SECTION A - A'

DRAWING B

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE B
SECTION B - B'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

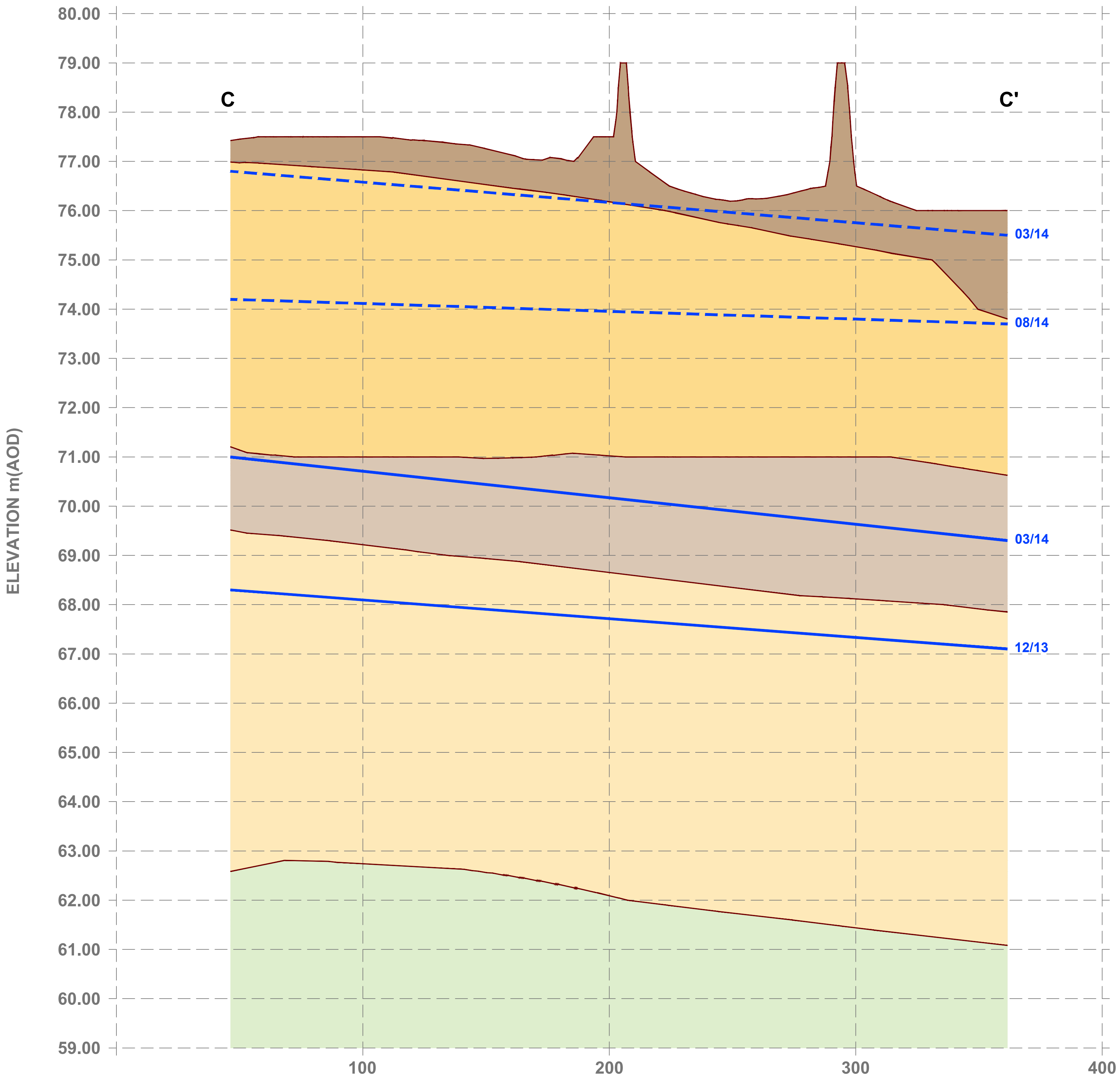
SLR
global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME
ENVIRONMENTAL STATEMENT
SECTION B - B'
DRAWING C

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE C
SECTION C - C'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR
global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

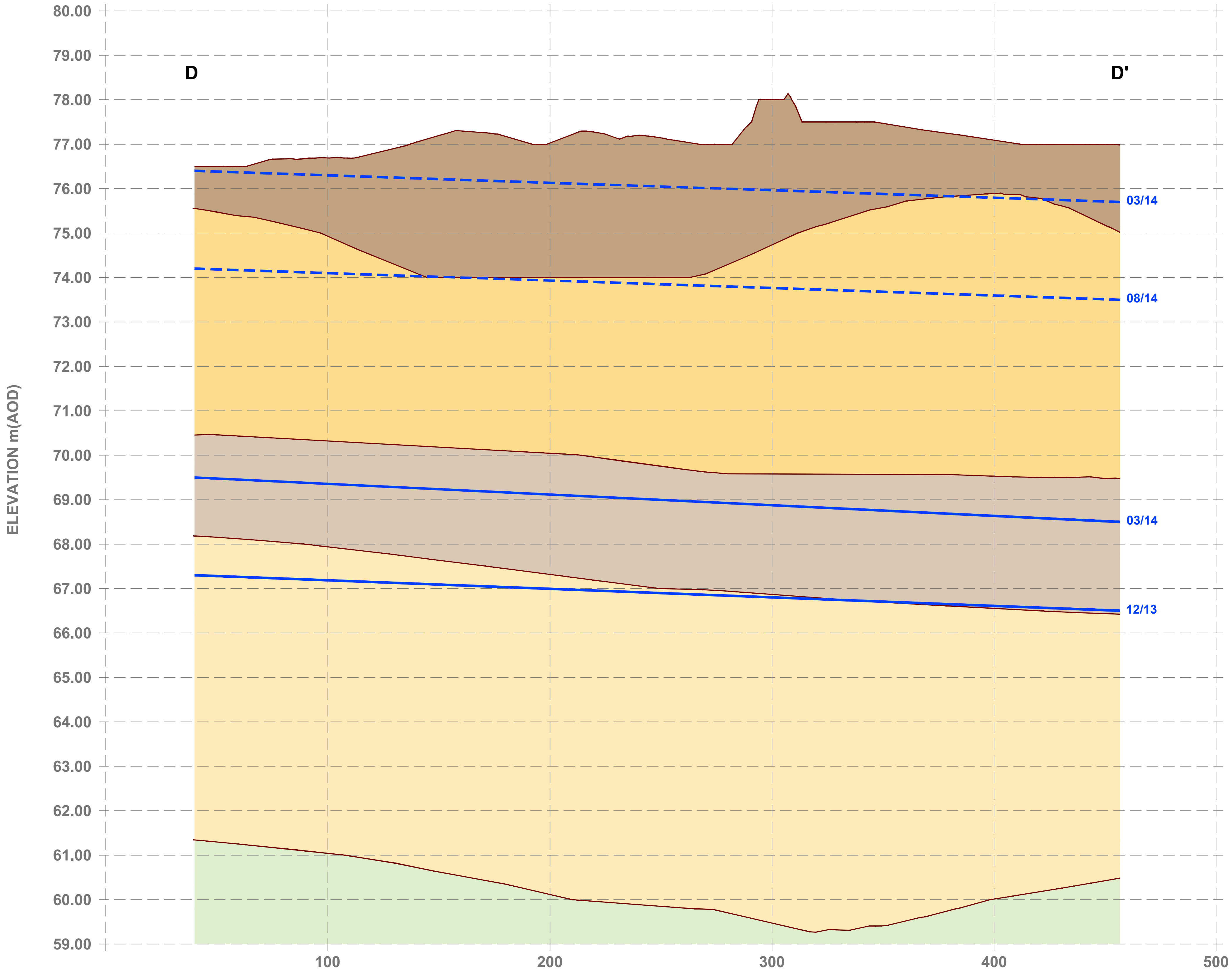
HATFIELD AERODROME
ENVIRONMENTAL STATEMENT
SECTION C - C'

DRAWING D

Scale: SEE DRAWING (A3)
Date: NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE D
SECTION D - D'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR
global environmental solutions

TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

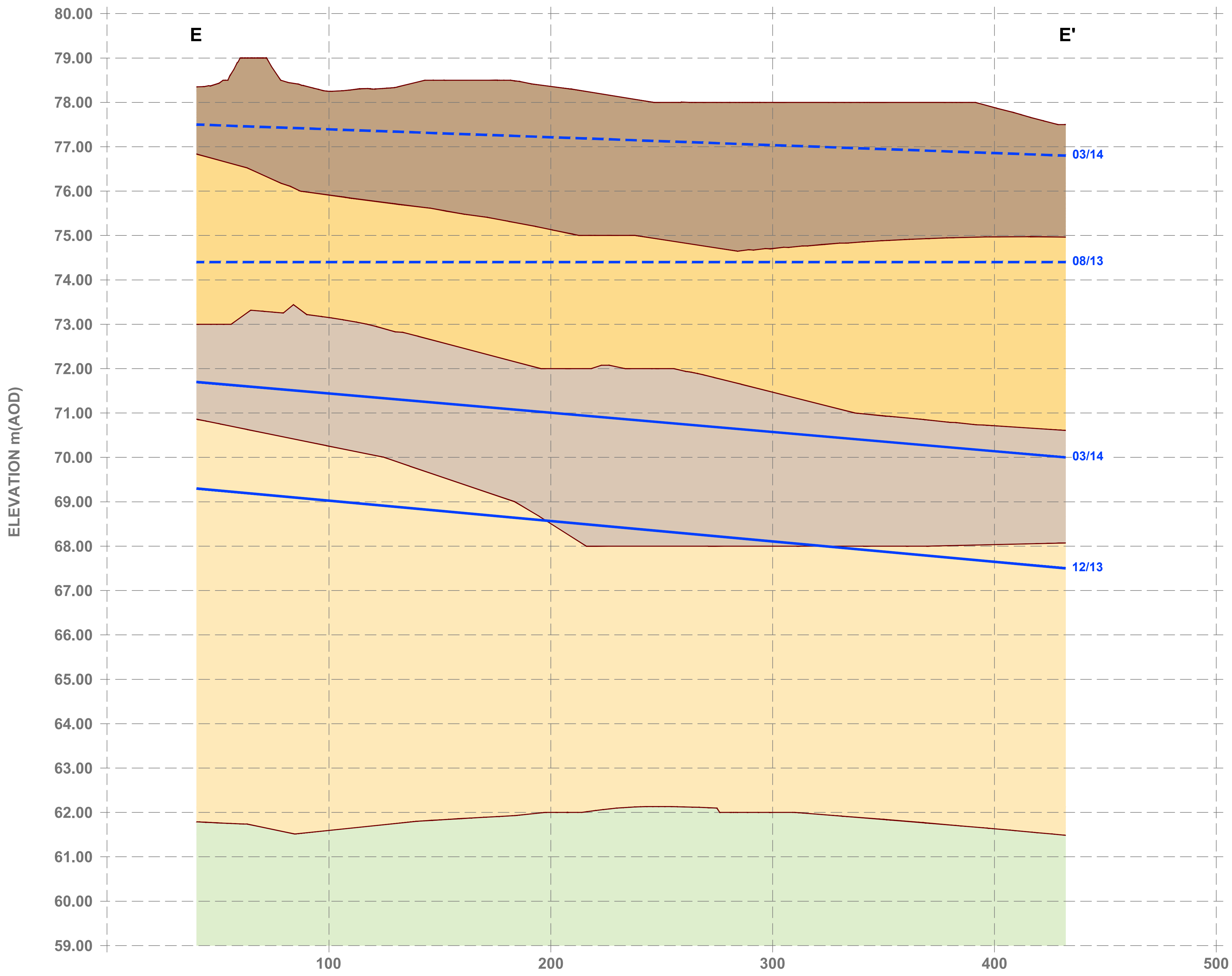
SECTION D - D'

DRAWING E

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE E
SECTION E - E'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

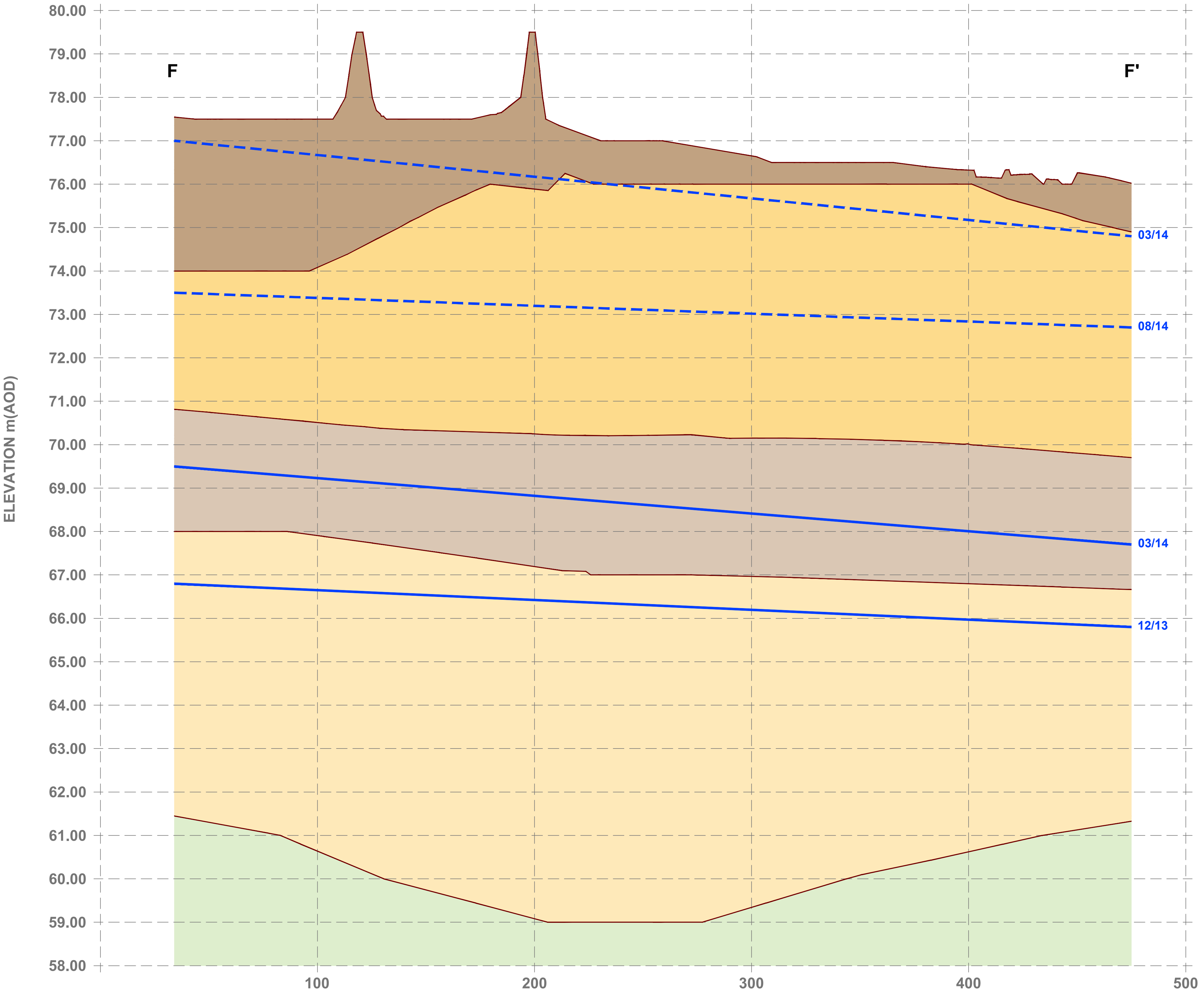
SECTION E - E'

DRAWING F

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE F
SECTION F - F'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR
global environmental solutions

TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

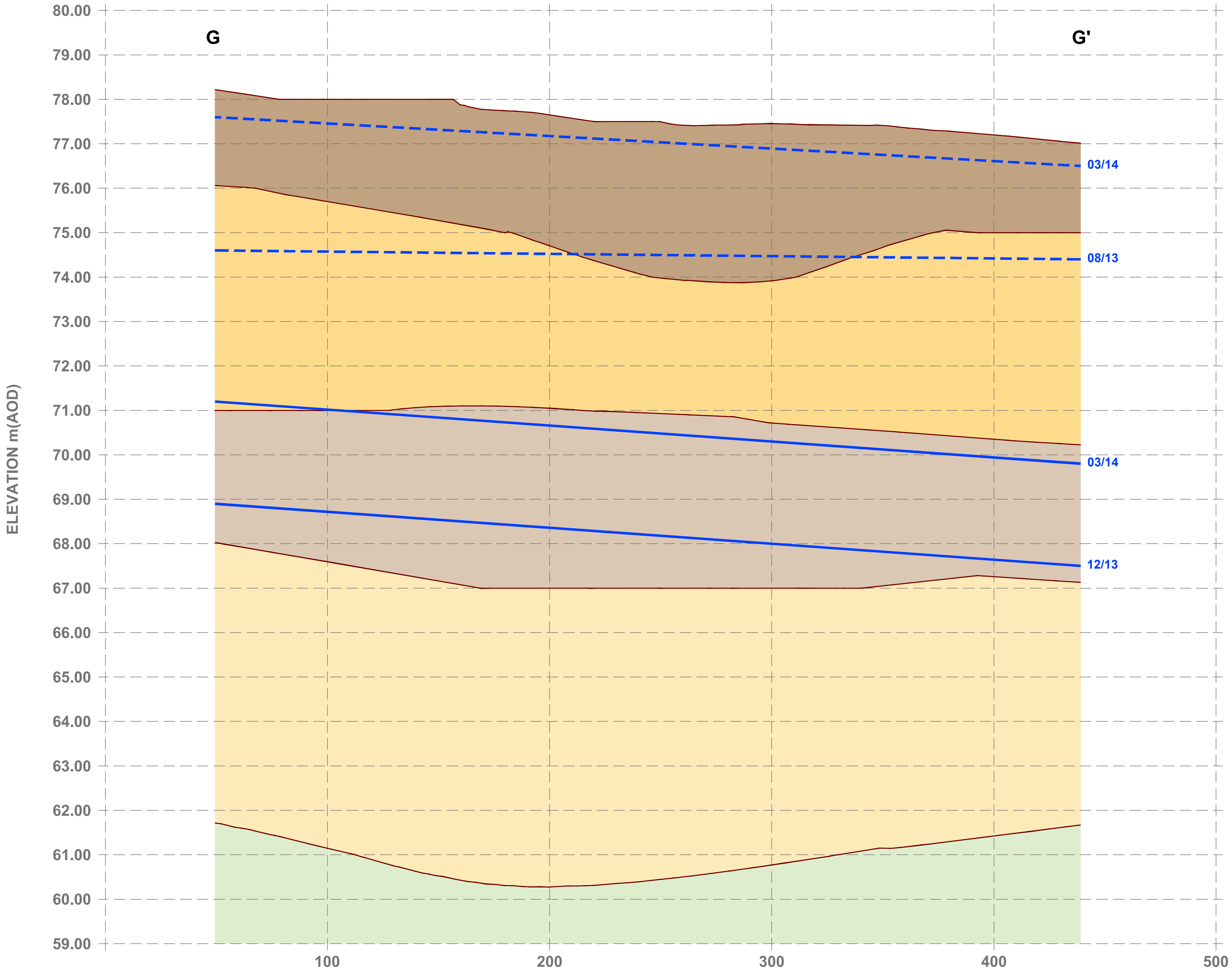
HATFIELD AERODROME
ENVIRONMENTAL STATEMENT
SECTION F - F'

DRAWING G

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

PHASE G
SECTION G - G'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR global environmental solutions

TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

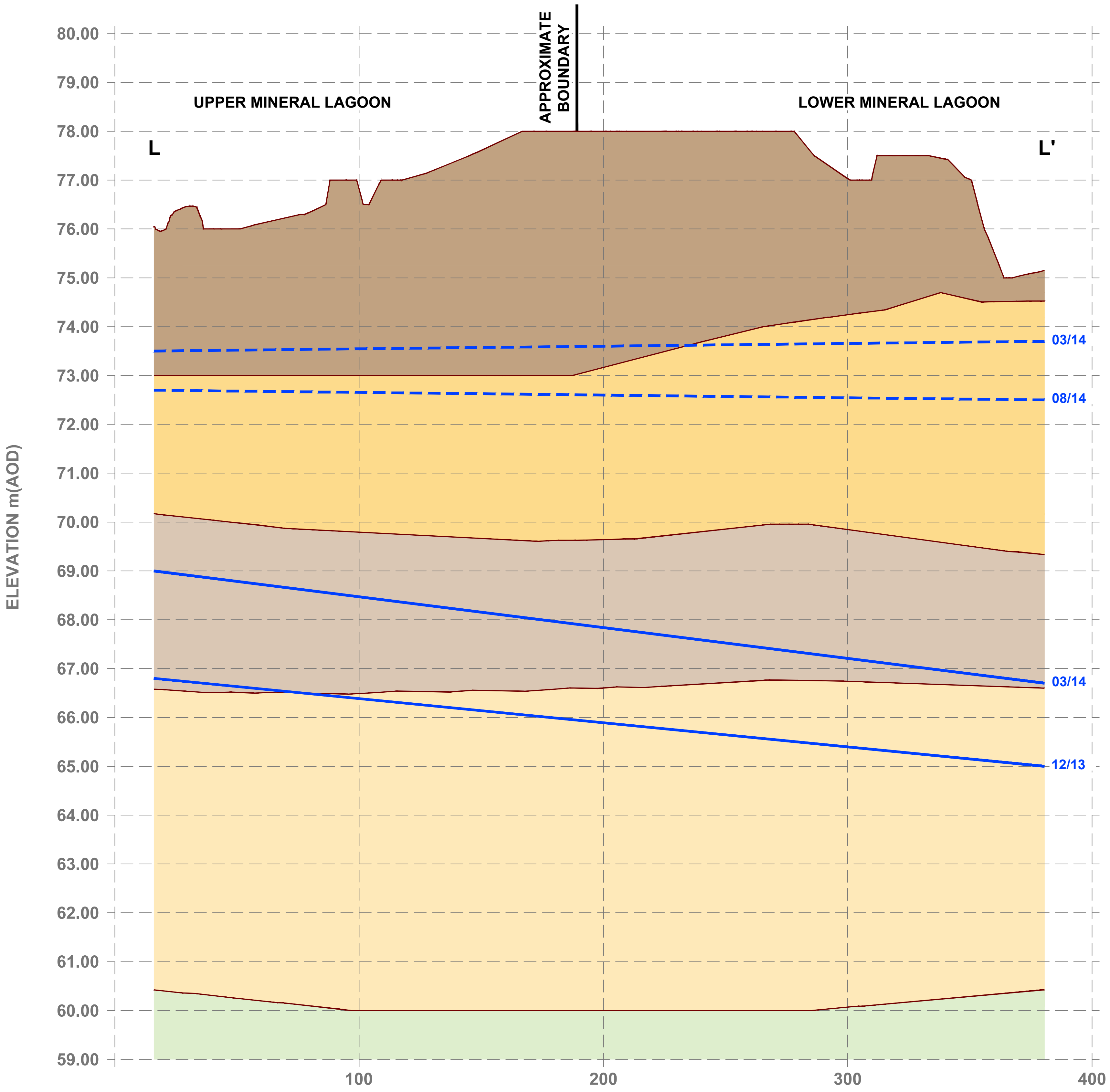
SECTION G - G'

DRAWING H

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

UPPER AND LOWER MINERAL LAGOONS
SECTION L - L'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

SECTION L - L'

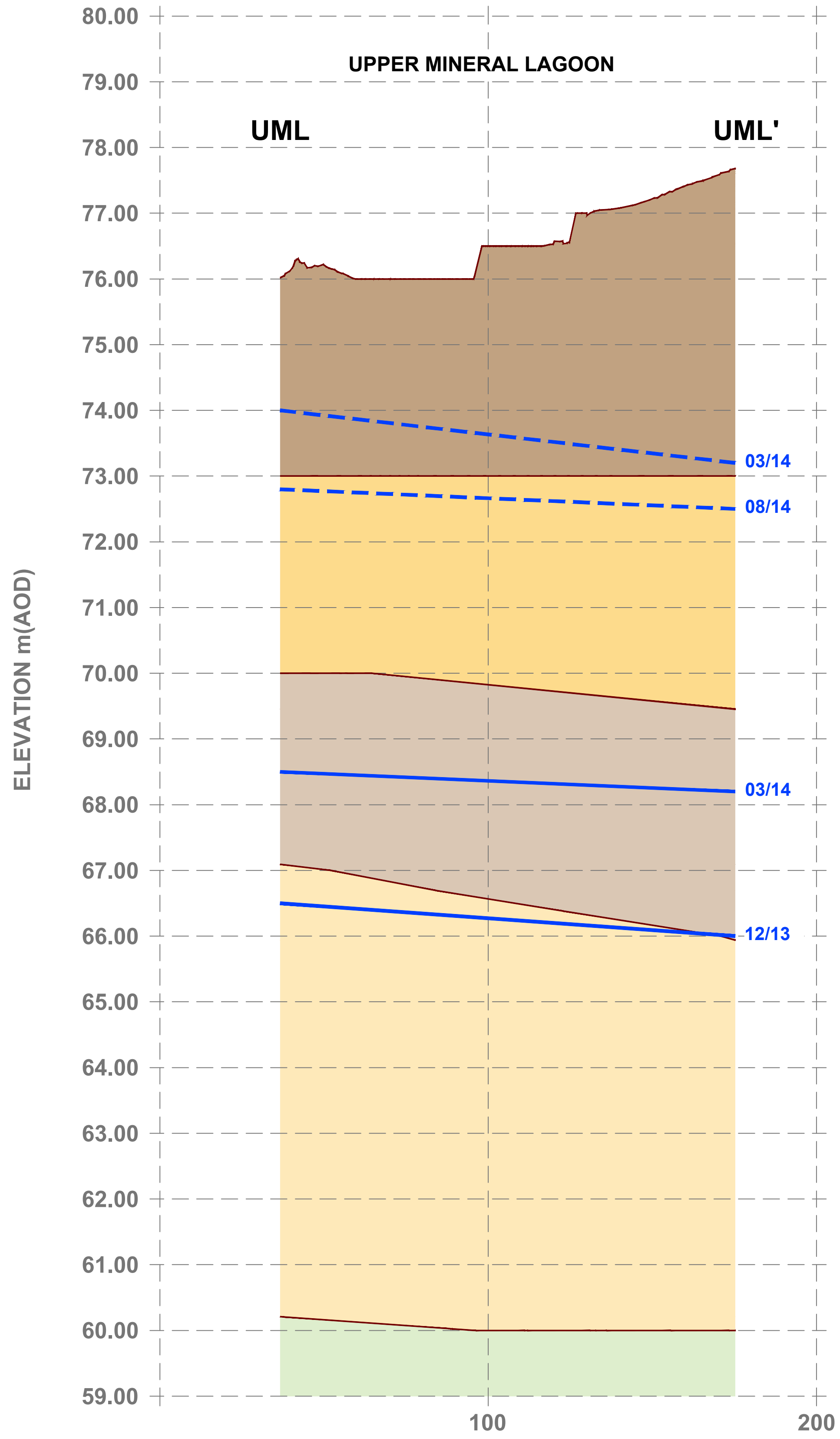
DRAWING I

Scale SEE DRAWING (A3)

Date NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

UPPER AND LOWER MINERAL LAGOONS
SECTION UML - UML'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

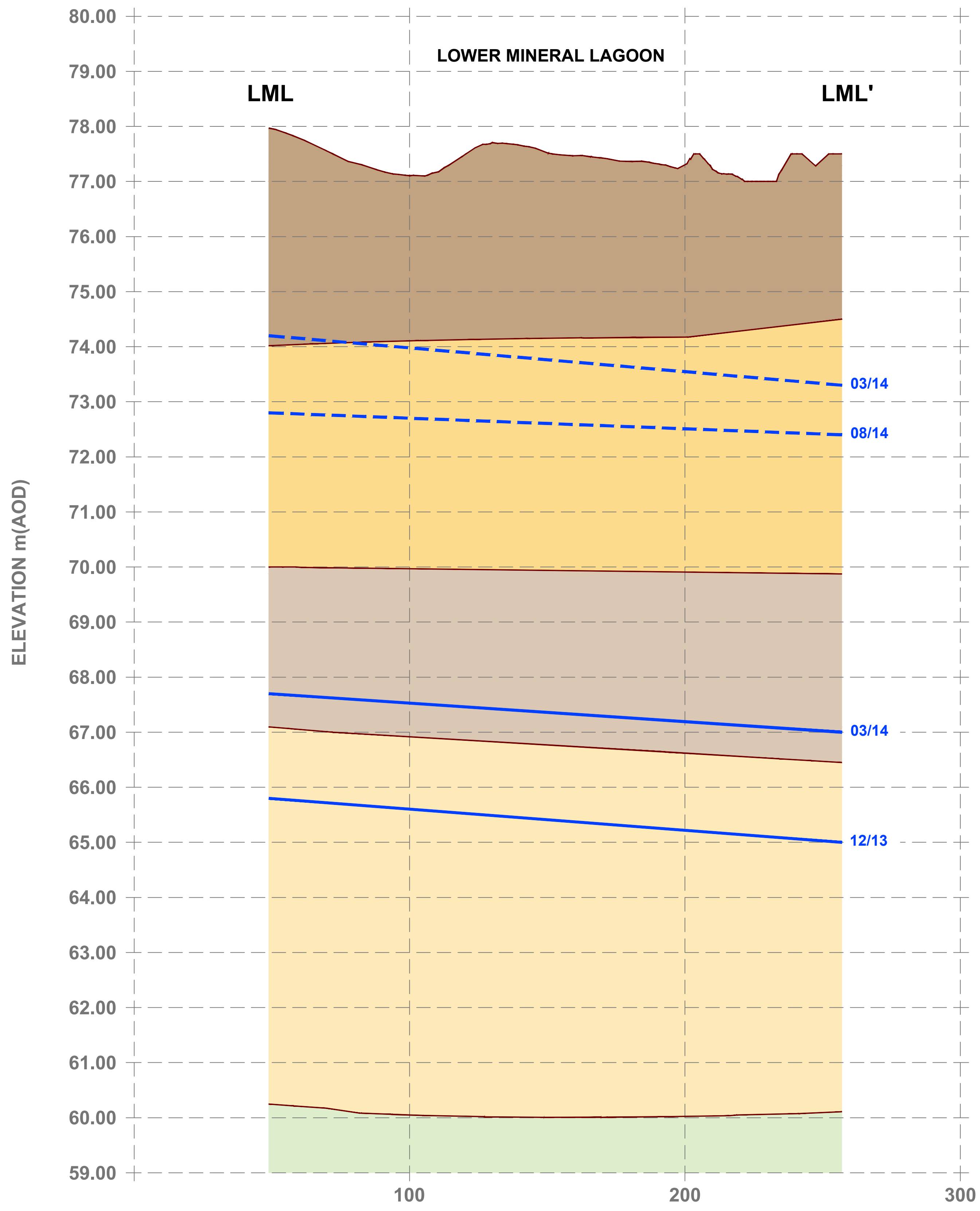
SLR global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME
ENVIRONMENTAL STATEMENT
SECTION UML - UML'
DRAWING J

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg

UPPER AND LOWER MINERAL LAGOONS
SECTION LML - LML'



VERTICAL SCALE 1:100, HORIZONTAL SCALE 1:2000

LEGEND

- UMA PIEZOMETRIC SURFACE
- LMA PIEZOMETRIC SURFACE
- OVERBURDEN
- UM HORIZON
- INTERBURDEN
- LM HORIZON
- CHALK

built on relationships

SLR global environmental solutions
TREENWOOD HOUSE
ROWDEN LANE
BRADFORD-ON-AVON
WILTS. BA15 2AU
T: 01225 309400
F: 01225 309401
www.slrconsulting.com

HATFIELD AERODROME

ENVIRONMENTAL STATEMENT

SECTION LML - LML'

DRAWING K

Scale	Date
SEE DRAWING (A3)	NOVEMBER 2015

01009.00132.18.DWG-A-K.0_PHASING PLAN&SECTIONS.dwg