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HOMERS FARM WATER DISCHARGE INFILTRATION STRUCTURE DESIGN

For

HARLEYFORD AGGREGATES

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HOMERS FARM WATER DISCHARGE INFILTRATION STRUCTURE DESIGN

1. INTRODUCTION

GWP Consultants LLP (GWP) has been commissioned by Harleyford Aggregates (Harleyford) to develop a design for an on-site water disposal structure on the Homers Farm site (see Drawing No. HAHOM1906A-1).

This report provides details of the estimation of likely water discharge rates from the site, ground investigations to evaluate the infiltration rates to the adjacent sand and gravel aquifer and an outline design for a groundwater recharge structure to enable on-site waters to be disposed to the surrounding aquifer.

This work has been undertaken to support an environmental permit application for a bespoke water discharge activity and groundwater (point source) activity, being prepared by another consultancy on behalf of Harleyford.

2. DEVELOPMENT ACTIVITIES

The Homers Farm site is an on-going sand and gravel extraction operation, being sequentially restored using imported waste materials back to existing ground level. The dry mineral above the groundwater table will be removed from approximately half the site before below water table excavation commences. Dry and wet benches will be used throughout the duration of the operation as far as possible to provide flexibility of working, both in terms of mineral extraction and waste placement.

Beneath the site at depth, a Thames Water water supply transmission main runs across the site from north to south. Previous discussions between Thames Water and the operator have agreed the site will not be de-watered due to concerns regarding reducing the load bearing pressures on the water main and possible pipeline buoyancy uplift risks. Consequently, the pre-development groundwater levels have to be maintained on the site.

The wider site area and the surrounding sand and gravel aquifer have historically been impacted in places by third party spillages of hydrocarbons. In order to prevent these hydrocarbons entering the current site, the excavation area perimeter has been cut-off from the wider aquifer using a clay cut-off. The current excavation area is therefore hydraulically separated from the surrounding aquifer.

The sand and gravel volume inside the perimeter cut-off (low permeability liner) is still partially saturated with groundwater, as there was no de-watering undertaken during the cut-off placement. The groundwater level within the site is therefore consistent with the pre-development baseline.

It has been recognised by the site operator and their consultants that in excavating the gravel and replacing it with a low permeability imported waste, the on-site groundwater will be displaced upwards within the cut-off. This increase in water level within the cut-off will need to be removed from the void and discharged back into the sand and gravel aquifer outside of the perimeter cut-off.

This report evaluates the volume and rate of water that will be displaced, as well as the capacity of the surrounding aquifer to receive this displaced groundwater.

3. SITE WATER BALANCE

The site water balance will include the groundwater currently existing within the site, plus direct rainfall falling within the area inside of the clay cut-off.

3.1 Groundwater Volume

The calculations for determining quantity of groundwater are based on the following assumptions:

The sand and gravel aquifer over the excavation area has a reported average thickness *c.* of 7.1m.

The average depth to the groundwater table is 3.1m, giving an average saturated thickness of gravel of 4.0m across the site.

The effective porosity of the sand and gravel is estimated at 20%.

The total area within the cut-off is 76,500m^2, of which only 50% will be worked at any one time.

The total volume of groundwater within the cut-off can therefore be estimated at 61,200m^3.

3.2 Direct Rainfall

The site area within the perimeter cut-off will receive direct rainfall throughout the year. The FEH Web Service estimates annual rainfall to average 608 mm/yr. Over the area within the perimeter cut-off this amounts to 46,512 m^3/yr (equating to 127m^3/d).

Given the site is stripped of vegetation and soils, it is reasonable to assume this rainfall will all directly enters the sand and gravel within the clay cut-off perimeter (ignoring any losses due to evaporation).

Assuming a 20% porosity, then without pumping this water out of the site this would result in a groundwater level rise within the cut-off of 3.04m per annum.

In reality, much of the site area will be an excavated void down to the groundwater table. Should groundwater rise into the void above the groundwater table, clearly the storage volume in this void will be 100%.

3.3 Groundwater Displacement by Imported Waste

The extracted sand and gravel is to be replaced sequentially by the importation of inert waste. A conservative assumption for the porosity of this waste is estimated at 5%.

In order to maintain the groundwater level within the clay cut-off at 3.10mbgl (needed to ensure loading and stability above the Thames Water tunnel running below the site), the volume of groundwater held within the 15% reduction in porosity between the sand and gravel and the imported waste will need to be pumped out of the site. This volume of groundwater can be estimated at:

Volume Displaced Groundwater (m^3) = Reduction in Porosity (%) x Area (m^2) x Saturated Thickness (m)

Volume Displaced Groundwater = 20% - 5% x 76,500m^2 x 4m = 45,900 m^3

Harleyford advises the placement of waste will take approximately 3 years and will be at a continuous import rate. The displaced groundwater to be removed per day (due to the reduction in porosity) can therefore be calculated as 42 m^3/d (*i.e.* 45,900 m^3 divided by 3 years divided by 365 days).

3.4 Required Discharge Rate

The required average daily pumping rate from the excavated void to remove the displaced groundwater due to gravel replacement with low porosity waste plus the direct rainfall entering the gravel so as to maintain the groundwater level within the perimeter cut-off at exactly 3.1mbgl is therefore 127m^3/d + 42m^3/d = 169m^3/d.

This calculation does not take into account the temporary increase in water storage volume available in the excavated void after gravel has been removed and before waste material has placed. If pumping rates are entirely controlled by not lowering groundwater levels deeper than 3.1mbgl, then pumping rates will be lower than 169m^3/d.

This pumping rate also does not allow for water leaving the site in the sand and gravel mineral product. Specific retention could be as much as 10% by volume, although the extent to which this volume leaves the area within the cut-off depends where stockpiles are stored, how the product is processed and washed and whether additional waters are used for washing. As these parameters are not known, no allowance has been made for water removal in the product mineral.

In reality direct rainfall will vary throughout the year and the daily discharge rate will reduce during the drier summer months and increase during the wetter winter months if the groundwater level is to be maintained exactly at 3.1mbgl.

Alternatively, during the wetter months, pumping can be maintained at the average discharge rate and groundwater (and open void water) levels can be allowed to rise. During drier periods the average pumping rate will then eventually bring the groundwater levels back down to the deepest acceptable groundwater level in the site of 3.1mbgl.

4. STORM WATER ANALYSIS

It has already been identified in the section above that rainfall does not fall uniformly throughout the year and that accordingly pumping rates could vary throughout the year. Clearly during the three years of the site operation, it is possible for the site to experience extreme storm rainfall events.

Using a very conservative scenario of the 1 in 10 Year (+40% for climate change) Storm Event, the maximum rainfall that could fall on the site within such an event is calculated to be 108mm.

If this were to enter the sand and gravel with 20% porosity, then groundwater levels would rise by 0.54m, whereas groundwater levels within a low porosity (5%) waste material would rise by 2.16m. Neither of these is an issue for the site.

Assuming however a 100% run-off from the gravel/waste, this would generate a storm water volume of 8,262m^3. Allowing for the 3.1m unsaturated zone that will be maintained on the site, this would require an open void area of 2,665m^2 (*i.e.* 53m x 50m) in order to hold the water, prior to its seepage into the mineral and waste surrounding the excavated void.

Assuming the pumping would be initiated after the storm event at 169m^3/d, then this would take 49 days to remove the storm water volume.

5. INFILTRATION FACILITY DESIGN

It is proposed the rainwater (including storm event water) and the displaced groundwater will be pumped from the excavated void and discharged back into the surrounding sand and gravel aquifer at a location outside of the clay cut-off but within the wider site perimeter (see Drawing No. HAHOM1906A-1).

5.1 Infiltration Tests

Two infiltration tests have been undertaken on the site during May 2019. The test pit locations are shown on Drawing No. HAHOM1906A-1, with photographs of the excavated trial pits in Appendix 1 and the soakaway analysis provided in Appendix 2.

The trial pits were excavated such that the underlying sand and gravel were exposed and being tested.

The calculated infiltration results were 1.1 x 10^{-5}m/s and 3.0 x 10^{-5}m/s. These infiltration values are perhaps surprisingly low, even representing as they do vertical and not horizontal permeabilities, but therefore are considered to provide a conservative estimate of infiltration.

Using the minimum infiltration rate value of 1.1 x 10^{-5}m/s (*i.e.* 0.95 m/d), and assuming a uniform pumped inflow rate of 169m^3/d, an infiltration structure area of 178m^2 (10m x 18m) is required to enable the infiltration of the maximum anticipated runoff.

5.2 Infiltration Structure Design

An area has been provisionally set aside for the infiltration structure of 30m x 40m (1,200m^2).

It is proposed the structure will be an open excavation, consisting of a 2.0m deep excavation with 1 in 3 slopes. The excavation will remove any fine overburden materials including residual sub-soils and local Brickearths, exposing the underlying sand and gravel aquifer.

A 2.0m deep infiltration structure ensures 1.0m of unsaturated zone remain beneath the floor of the structure.

It is proposed 2 No. 10m x 20m infiltration basins are constructed, although only one will be in use at any one time. This will allow for the second basin to be cleaned of any residual silts that may accumulate over time.

A basin of 10m x 20m (200m^2) has a Factor of Safety of 1.12 over the calculated required infiltration size of 178m^2 (using the minimum infiltration test value).

The pumped inflow rate may vary throughout the year, as previously discussed, but will nominally be 169m^3/d.

Each infiltration basin will clearly have a storage volume within it of 400m^3, allowing more rapid pumping if this was required on site for operational reasons.

6. CONCLUSIONS AND RECOMMENDATIONS

An area of sand and gravel aquifer on Homer's Farm are to be excavated within a clay cut-off along the site boundary.

The existence of a Thames Water water supply transmission main requires groundwater levels to not reduce below the pre-development level, throughout the mineral excavation and waste backfilling operations.

Placement of imported waste with a low porosity below the groundwater table will result in increasing groundwater levels unless groundwater is pumped out.

Similarly rain falling on the sand and gravel aquifer and waste inside of the cut-off will also result in rising groundwater levels, unless pumping from the void takes place.

The required average daily discharge pumping rate has been estimated at $169m^3/d$ (2 l/s).

Analysis of extreme storm event rainfall determines that up to $8,262m^3$ of rainwater (equivalent to a depth of 11cm) could fall into the site within a single event. This would result in groundwater levels rises of between 0.5 and 2.0m.

Pumping out of this storm water event could take almost 50 days. By using above water table and below water table benches – both for sand and gravel extraction and waste placement - such storm events will not present a problem for the site.

Infiltration testing of the underlying sand and gravel aquifer has demonstrated infiltration rates of 1-3 x $10^{-5}m/s$.

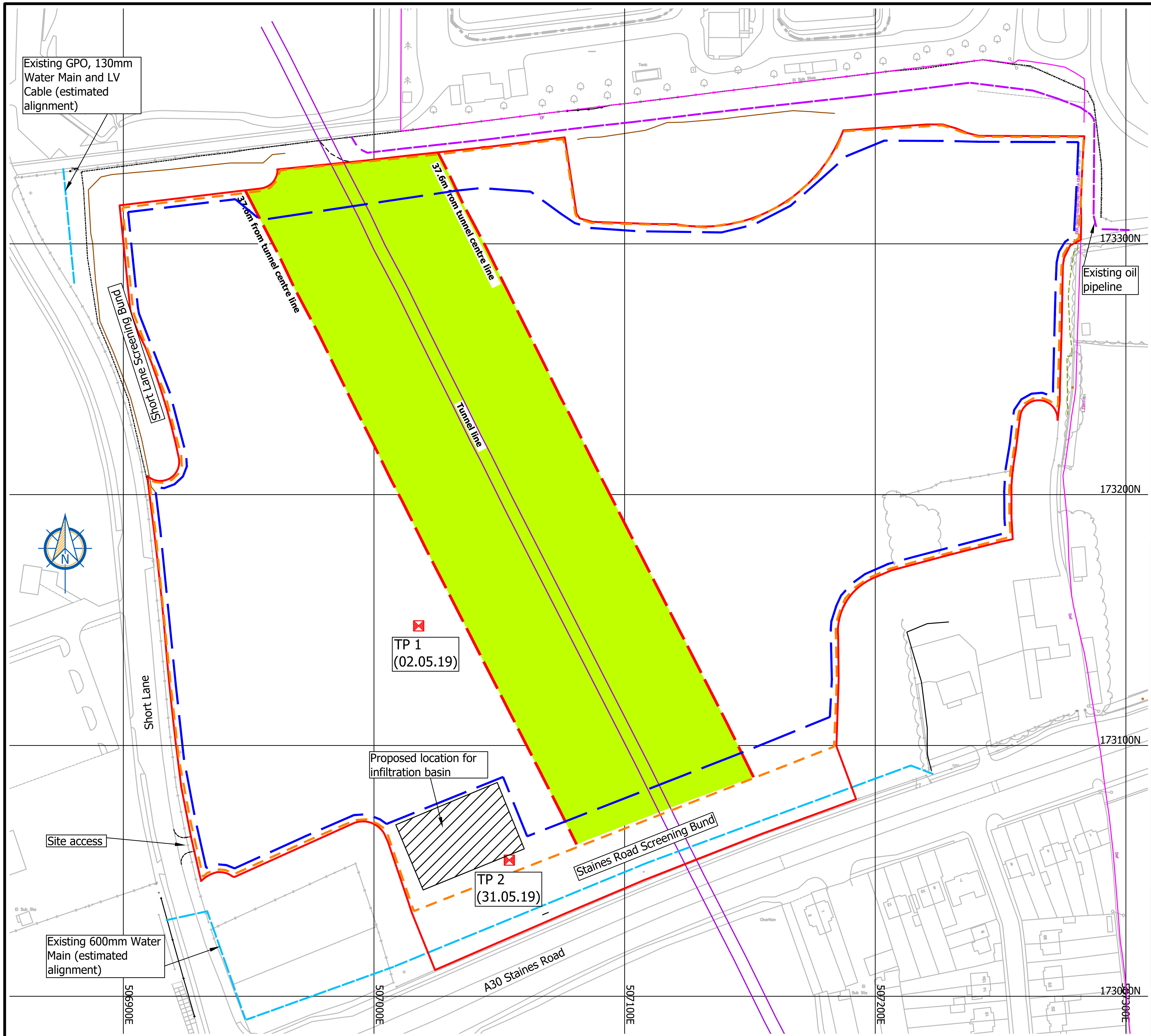
Using the minimum infiltration rate and the identified pumping discharge rate, an infiltration area of $178m^2$ is required to dispose of the discharge water.

It is proposed to construct 2 No. 10m x 20m infiltration basins, each 2m deep – to enable one to be operational and the other unused so it can be cleaned of any residual silt deposition.

A single basin has an over design floor area with a Factor Safety of 1.12, using the minimum infiltration rate and not accounting for the second basin.

The site operator has provisionally set aside an area of $1,200m^2$ (3 times that required) for these basins and related works.

GWP CONSULTANTS
JUNE 2019



LEGEND

- Environmental Permit boundary
- Excavation limit
- Low permeability seal position
- Infiltration test location (and date of test)
- Tunnel alignment
- Required off-set from tunnel requiring additional loading

NOTES

- Tunnel position taken from Haswell Consulting Engineers dated August 1993, forwarded by Thames Water.

Version	Revision and compilation notes	Date
A	Issued with report	24.06.2019

Client
Harleyford Aggregates Limited

Project
Homers Farm Quarry - Infiltration Structure Design

Site setting, location of infiltration tests and proposed location of infiltration trench

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20.06.2019	DJ/EMB	CC	1:1500 at A3

Drawing Ref	Drawing No	Version
HAHOM1906A	1	A

APPENDIX 1

Photographs of infiltration tests

Photograph No. 1: Trial Pit 1 (2nd May 2019) - filling trial pit with water. Pit dug by loading shovel.

Photograph No. 2: Trial Pit 1 (2nd May 2019) - trail pit at end of test.

Photograph No. 3: Trial Pit 2 (31st May 2019) – filling trial pit with water. Pit dug by backhoe.

Photograph No. 4: Trial Pit 2 (31st May 2019) – trail pit at end of test.

APPENDIX 2

Soak away analysis

Appendix 2 - Soak away analysis

	TP1	GEOMETRY
Top (as dug)	L (m)	4.60
	W (m)	3.58
	D (m)	0.67
Top (after test)	L_top (m)	4.60
	W1_top (m)	3.58
	W2_top (m)	3.58
Base (after test)	L_base (m)	1.12
	W_base (m)	3.23
Ddepth (after test)	D (m)	0.67
Top area (as dug)	A (m2)	16.47
Volume (as dug)	V (m3)	11.03
Base area (after test)	A_base (m2)	3.62
Top area (after test)	A_top (m2)	16.47
Volume (after test)	V_c (m3)	11.03

Appendix 2 - Soak away analysis

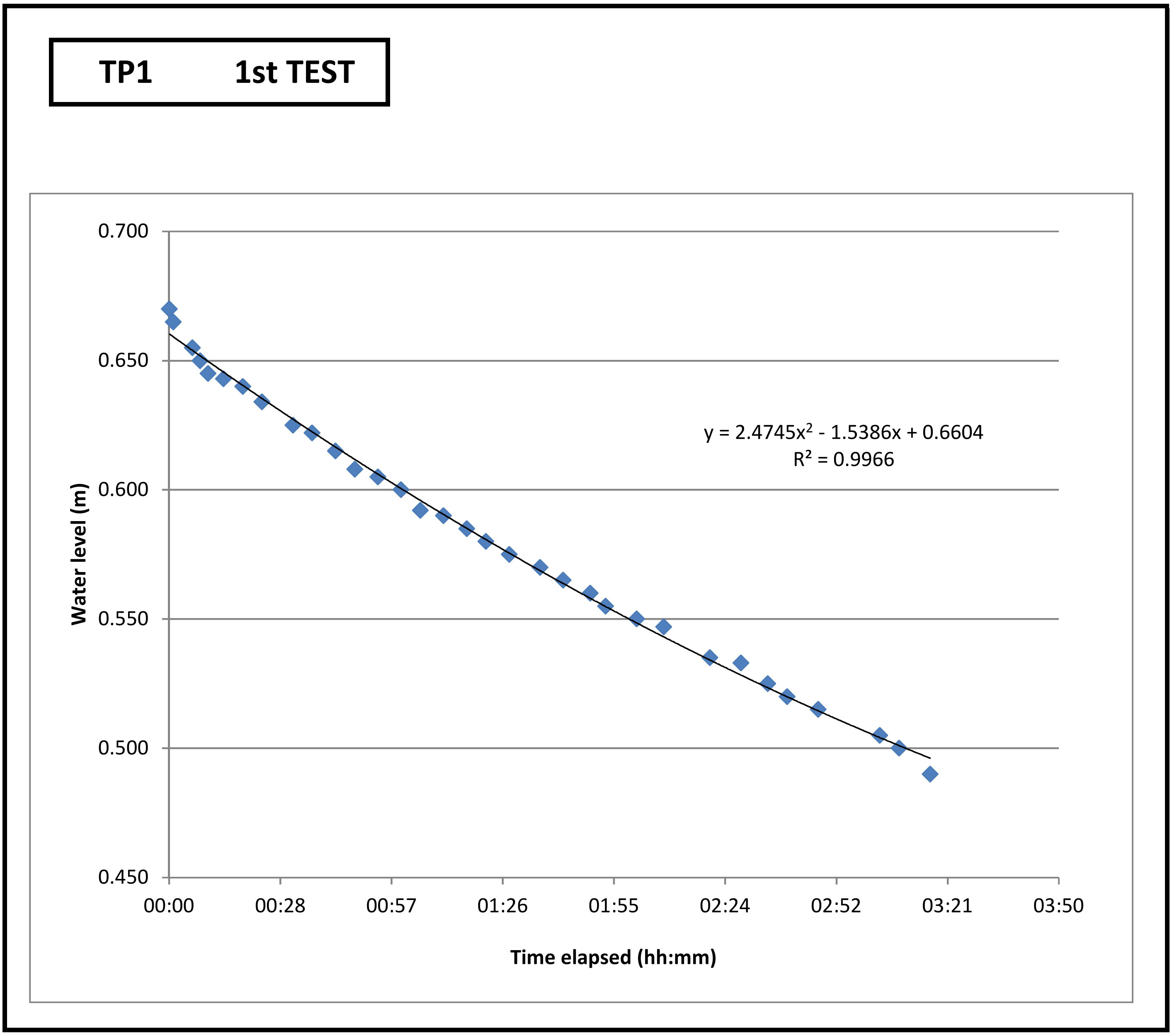
TP1	1st TEST

Date:	02/05/2019

f	1.08E-05
t_25	00:34
t_75	02:18
Equation	ax2+bx+c-y=0
a	2.4745
b	-1.5386
c	0.6604
y 25 (m)	0.625
y 75 (m)	0.535
A 25 (m2)	15.89
A 75 (m2)	14.73
A 50 (m2)	15.31
A_inf 50 (m2)	20.36
V 75-25 (m3)	1.38
t 75-25 (s)	6266.96
f (m/s)	0.0000108
f (m/s)	1.08E-05

Time	Time from start	Distance (m)	Water level (m)
08:22	00:00	0.000	0.670
08:23	00:01	0.005	0.665
08:28	00:06	0.015	0.655
08:30	00:08	0.020	0.650
08:32	00:10	0.025	0.645
08:36	00:14	0.027	0.643
08:41	00:19	0.030	0.640
08:46	00:24	0.036	0.634
08:54	00:32	0.045	0.625
08:59	00:37	0.048	0.622
09:05	00:43	0.055	0.615
09:10	00:48	0.062	0.608
09:16	00:54	0.065	0.605
09:22	01:00	0.070	0.600
09:27	01:05	0.078	0.592
09:33	01:11	0.080	0.590
09:39	01:17	0.085	0.585
09:44	01:22	0.090	0.580
09:50	01:28	0.095	0.575
09:58	01:36	0.100	0.570
10:04	01:42	0.105	0.565
10:11	01:49	0.110	0.560
10:15	01:53	0.115	0.555
10:23	02:01	0.120	0.550
10:30	02:08	0.123	0.547
10:42	02:20	0.135	0.535
10:50	02:28	0.137	0.533
10:57	02:35	0.145	0.525
11:02	02:40	0.150	0.520
11:10	02:48	0.155	0.515
11:26	03:04	0.165	0.505
11:31	03:09	0.170	0.500
11:39	03:17	0.180	0.490

Appendix 2 - Soak away analysis



Appendix 2 - Soak away analysis

	TP2	GEOMETRY
Top (as dug)	L (m)	3.93
	W (m)	2.12
	D (m)	0.86
Top (after test)	L_top (m)	3.93
	W1_top (m)	2.12
	W2_top (m)	2.12
Base (after test)	L_base (m)	2.72
	W_base (m)	1.40
Ddepth (after test)	D (m)	0.86
Top area (as dug)	A (m2)	8.33
Volume (as dug)	V (m3)	7.16
Base area (after test)	A_base (m2)	3.81
Top area (after test)	A_top (m2)	8.33
Volume (after test)	V_c (m3)	7.16

Appendix 2 - Soak away analysis

TP2 1st TEST | **Date: 31/05/2019**

f	3.02E-05
t_25	00:28
t_75	01:25
Equation	ax2+bx+c-y=0
a	-10.9694
b	-3.6923
c	0.8454
y 25 (m)	0.769
y 75 (m)	0.589
A 25 (m2)	7.93
A 75 (m2)	7.11
A 50 (m2)	7.52
A_inf 50 (m2)	13.12
V 75-25 (m3)	1.35
t 75-25 (s)	3414.38
f (m/s)	0.0000302
f (m/s)	3.02E-05

Time	Time from start	Distance (m)	Water level (m)
12:12	00:00	0.000	0.859
12:15	00:03	0.015	0.844
12:17	00:05	0.025	0.834
12:19	00:07	0.030	0.829
12:21	00:09	0.035	0.824
12:23	00:11	0.045	0.814
12:25	00:13	0.050	0.809
12:27	00:15	0.055	0.804
12:29	00:17	0.065	0.794
12:31	00:19	0.070	0.789
12:33	00:21	0.075	0.784
12:35	00:23	0.080	0.779
12:37	00:25	0.085	0.774
12:39	00:27	0.090	0.769
12:41	00:29	0.095	0.764
12:43	00:31	0.100	0.759
12:45	00:33	0.105	0.754
12:47	00:35	0.115	0.744
12:49	00:37	0.117	0.742
12:51	00:39	0.120	0.739
12:53	00:41	0.130	0.729
12:55	00:43	0.135	0.724
12:57	00:45	0.140	0.719
12:59	00:47	0.144	0.715
13:01	00:49	0.150	0.709
13:03	00:51	0.155	0.704
13:05	00:53	0.165	0.694
13:07	00:55	0.167	0.692
13:09	00:57	0.175	0.684
13:11	00:59	0.182	0.677
13:13	01:01	0.190	0.669
13:15	01:03	0.190	0.669
13:20	01:08	0.205	0.654
13:25	01:13	0.230	0.629
13:30	01:18	0.236	0.623
13:35	01:23	0.256	0.603
13:41	01:29	0.295	0.564
13:52	01:40	0.320	0.539
13:55	01:43	0.335	0.524
14:00	01:48	0.360	0.499

Appendix 2 - Soak away analysis

TP1 1st TEST