Thames Water Modelling Tasks
Graven Hill Development
Modelling Report
Thames Water Utilities Limited

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Executive summary

Thames Water Developer Services (DS) have requested a modelling study to determine the impact of the proposed development at Graven Hill near the town of Bicester, in Thames Water's Ardley Flow Monitoring Zone (FMZ) network. The completion date and phasing information for the development has yet to be confirmed, therefore it has been assumed that the construction will be completed within 10 years.

The proposed Graven Hill Development site lies within District Metered Area (DMA) ZARDLY06, of the Ardley FMZ. The proposed development will consist of 1,900 residential properties that are located to the south of Bicester.

The demand that has been modelled for the Graven Hill Development consists of an average daily demand of 6.4l/s with a peak morning demand of 25.6l/s. In addition a combined fire flow demand of 25l/s is needed to supply the development from a single location on the distribution network in the need of fighting a fire.

The model results indicated that the proposed development will have a significant impact on pressures in the local area when it is added to the Year 2026 forecasted zonal demand. The pressures at the proposed Point of Connection (POC) will drop to zero as well as at other parts of the surrounding area within DMA06. The network will therefore need local reinforcement in order to meet the requirements of the Graven Hill Development without significantly impacting on pressures in the existing network.

The modelling results indicated that to resolve the pressure issues caused by the addition of the new development, an existing 850m of main along the A41 road should be reinforced with a 225mm (Internal Diameter, ID) main. This reinforcement will return pressures back to those simulated in the pre-development scenario.

A supply/demand mass balance for the Ardley Reservoir was calculated from the spreadsheet (N.OXF S-D Bal_fWRMP14_Graven Hill (Atkins)) provided by TWUL for the Year 2016 and the Year 2026 peak week demand scenarios (for a dry year critical period). The calculation indicates that with a maximum transfer rate of 15.1Ml/day between Angelinos WBS and Ardley SR, there will be no deficit in transfer capacity for the Year 2016 or for the Year 2026 planning period when the Graven Hill Development demand is completed.

The Reservoir Policy calculations show there is adequate capacity at Ardley in regard to the balancing storage requirement if the Graven Hill Development does proceed and maintaining the current maximum supply rate from Angelinos Booster Pumping Station (BPS). However the existing capacity at Ardley is insufficient to meet the future emergency storage requirement in Year 2026. There will be a 0.94 Ml deficit in regard to the emergency storage requirement when the development is not included in Year 2026 and this will become an increased deficit of 1.83 Ml in the Year 2026 once development is completed. An additional reservoir cell at Ardley site will therefore be required that increases the storage capacity by at least 1.83 Ml (assumed adjacent to the current reservoir site).

A Fire Flow was simulated by applying an additional flow of 25l/s on an existing single fire hydrant close to the proposed Graven Hill development POC. The model indicated that once the reinforcement main of 225mm (ID) is completed, the fire flow can be achieved.

1. Introduction

Thames Water Developer Services (DS) have requested a modelling study to determine the impact of the proposed development at Graven Hill near Bicester town, in Thames Water's Ardley Flow Monitoring Zone (FMZ) network. The completion date and phasing information for the development has yet to be confirmed, therefore it has been assumed that the construction will be completed within the next 10 years.

The proposed development is to consist of 1,900 residential properties and is to be located at the southern end of Bicester town. The proposed Graven Hill development site lies within District Metered Area (DMA) ZARDLY06, of the Ardley FMZ.

Two demand scenarios were considered for the Graven Hill development, consisting of:

- Peak demand Year 2026.
- Fire demand of 25l/s supplied from a single location on the distribution network.

The location of the proposed development site is shown in Figure 1.

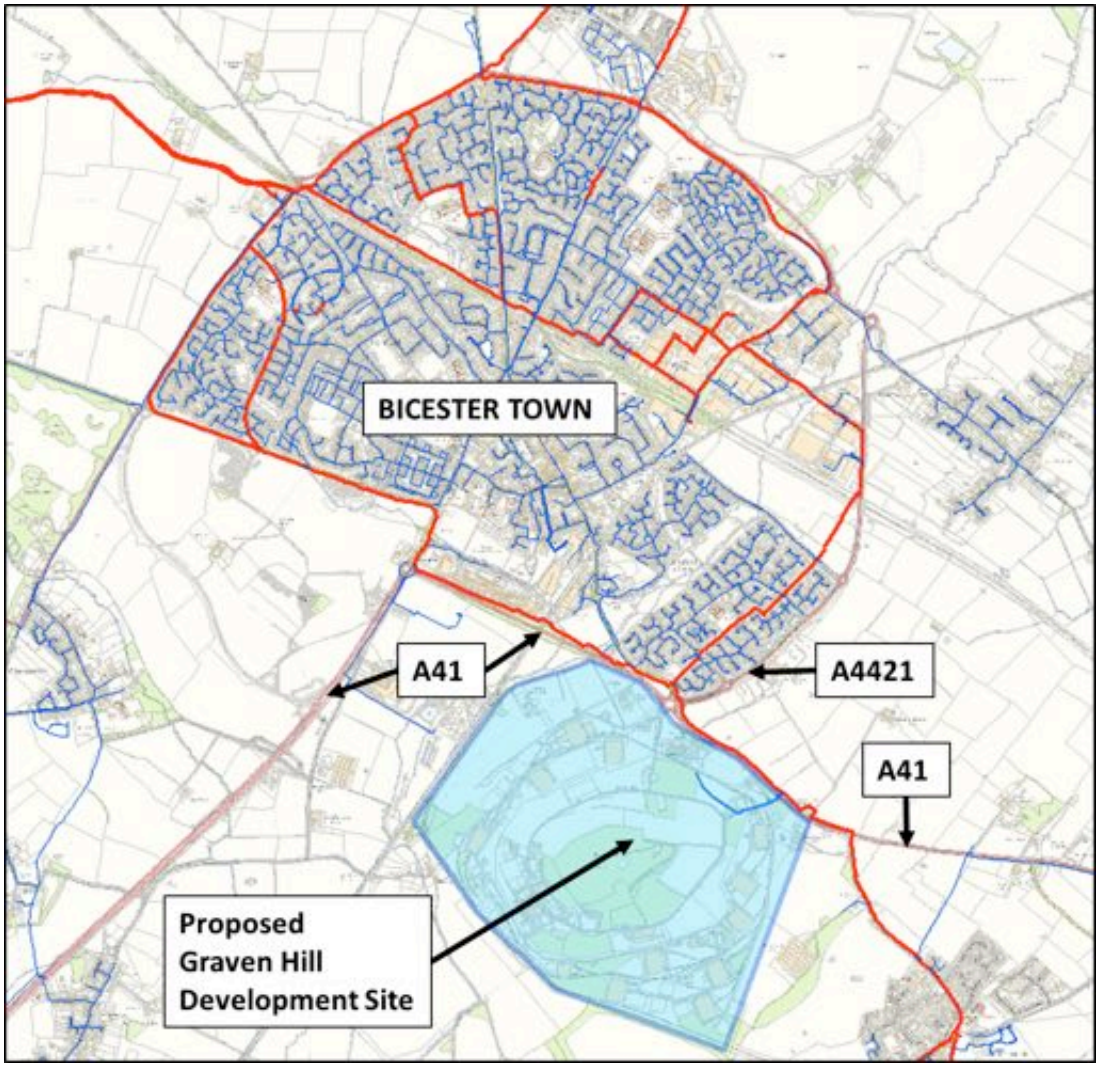


Figure 1 – Graven Hill Development Site

1.1 Ardley FMZ

The Ardley FMZ is located in north Oxfordshire and covers Bicester town and the rural areas to its south and west. There are approximately 22,000 properties in the zone with an average daily demand of approximately 10.43Ml/d, (obtained from TW telemetry for the 12 month period to June 2015).

The Ardley FMZ is supplied from Angelinos Water Booster Station (WBS) via zonal meter ZM00522. This water directly supplies the more rural region of the network as well as supplying the Ardley SR too. Downstream of the Ardley SR, the network supplies the more urban area of Bicester. The section between the Angelinos WBS and Ardley SR can be considered to be four separate areas:

A. Areas supplied from the trunk main around west side of the Bicester town

B. Bletchingdon area

C. Tackley area

D. Weston on the Green Area

There are two flow meters monitoring the inlets to Ardley SR from Angelinos WBS, both of which can backfeed into the rural area when the pumps are not operating. There is also a small inflow to the reservoir site from the Duns Tew FMZ.

The Ardley site comprises two separate reservoirs each with 2 cells. Both reservoirs supply via the outlet meter, ZM10346, to Bicester town which is split into eight DMA's (ZARDLY01 to 08).

The schematic of the Ardley FMZ is shown in Figure 2.

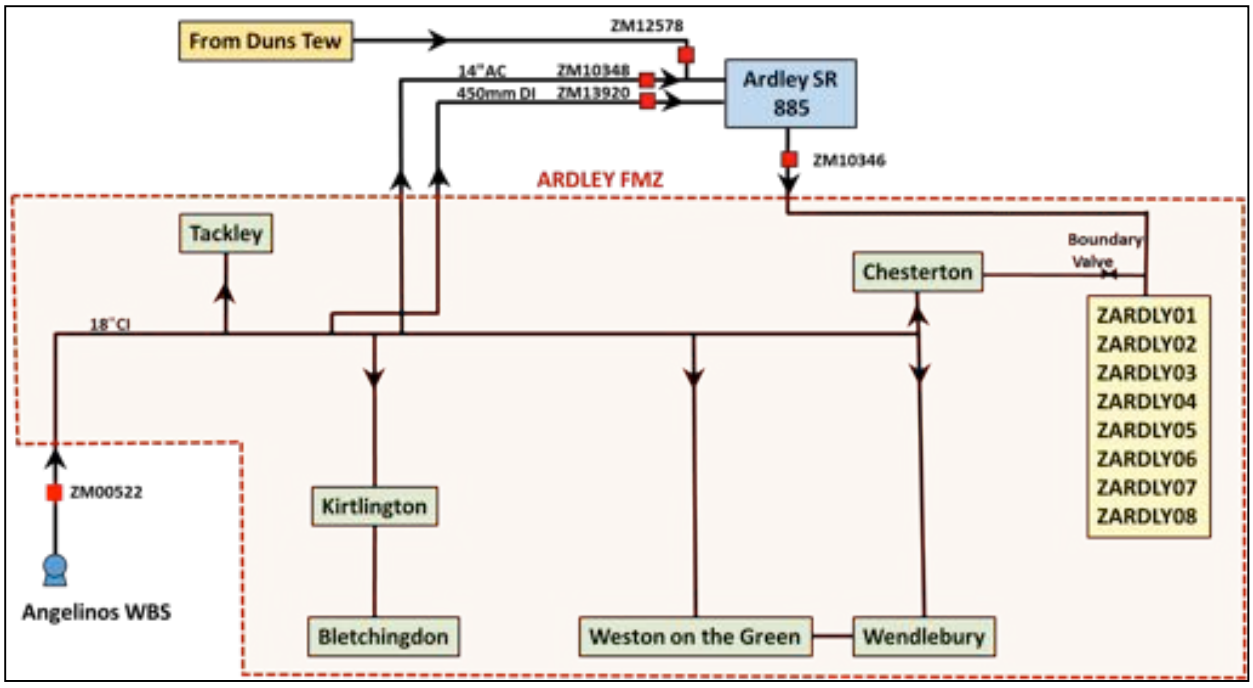


Figure 2 – Ardley FMZ Schematic

2. Scope of Work

This study is to determine the impact of the proposed development of the Graven Hill development on the Ardley FMZ network. The aims of the study are:

1. Review the Ardley FMZ calibrated model (built for this study) in order to assess the pre-development performance of the Ardley FMZ.

2. Produce Flow Balances for both the Year 2016 and the Year 2026 of the North Oxford strategic supply system, with and without the proposed development of Graven Hill.

3. Determine the emergency and balancing storage deficit/surplus at Ardley SR with and without the demand from the proposed Graven Hill development.

4. Modification of the model to include the future **Year 2026** zonal demands **without** the Graven Hill development – **Scenario A.**

5. Modification of the model to include the future **Year 2026** zonal demands **with** the Graven Hill development – **Scenario B.**

6. Identify the impact of the final phase of the Graven Hill development on the Ardley FMZ and thus whether network improvements are required.

7. If network improvements are required, propose potential solutions for supply to the final phase of the development, verified with modelling results.

8. Report on findings and make recommendations for appropriate solutions.

2.1 Fire Flow Requirement

Fire flow demands have been estimated based on the limited information available and the Water UK document ‘‘Water for fire fighting’‘ (Jan 2007 3rd edition) which contains guidelines regarding expected firefighting flow rates. Based on these guidelines the required firefighting flow has been taken as 25l/s for the development on the assumption that there may be multi-occupied development units of more than 2 floors. The WN05 standard states that for the instantaneous peak hour demand with the fire supply incorporated, the design shall take into account hydrant losses to ensure positive pressure at the fire hydrant, and minimum residual pressure in the mains of preferably 7.0m. For a fire flow of 25l/s this equates to approximately 15.2m.

3. Model Calibration and Field Test

No model existed of the Ardley Flow Monitoring Zone (ZARDLY), and hence a new all mains calibrated model was produced in order to model the proposed Graven Hill Development.

The model was built in InfoWater and is based on a recent (June 2015) GIS download. The modelling was carried out using InfoWater v11.5 and ArcGIS v10.

A field test was carried out between the 10th and 29th of June 2015. The objective of the field test was to provide sufficient pressure data to achieve calibration of the model within the specified tolerance across the zone. A total of 68 pressure locations were monitored during the field test, including the pump suction and delivery mains at Upper Arncott Booster.

Of these 68 locations, three pressure loggers were installed outside of the zone and one logger had data that could not be retrieved. Therefore, 64 logged data sets were available for use in calibrating the model. All data loggers used during the field test recorded data at 15 minute intervals. Telemetry flow, pressure and storage level data was also used where available for the calibration day.

The overview of the logging locations used are shown in Figure 3.

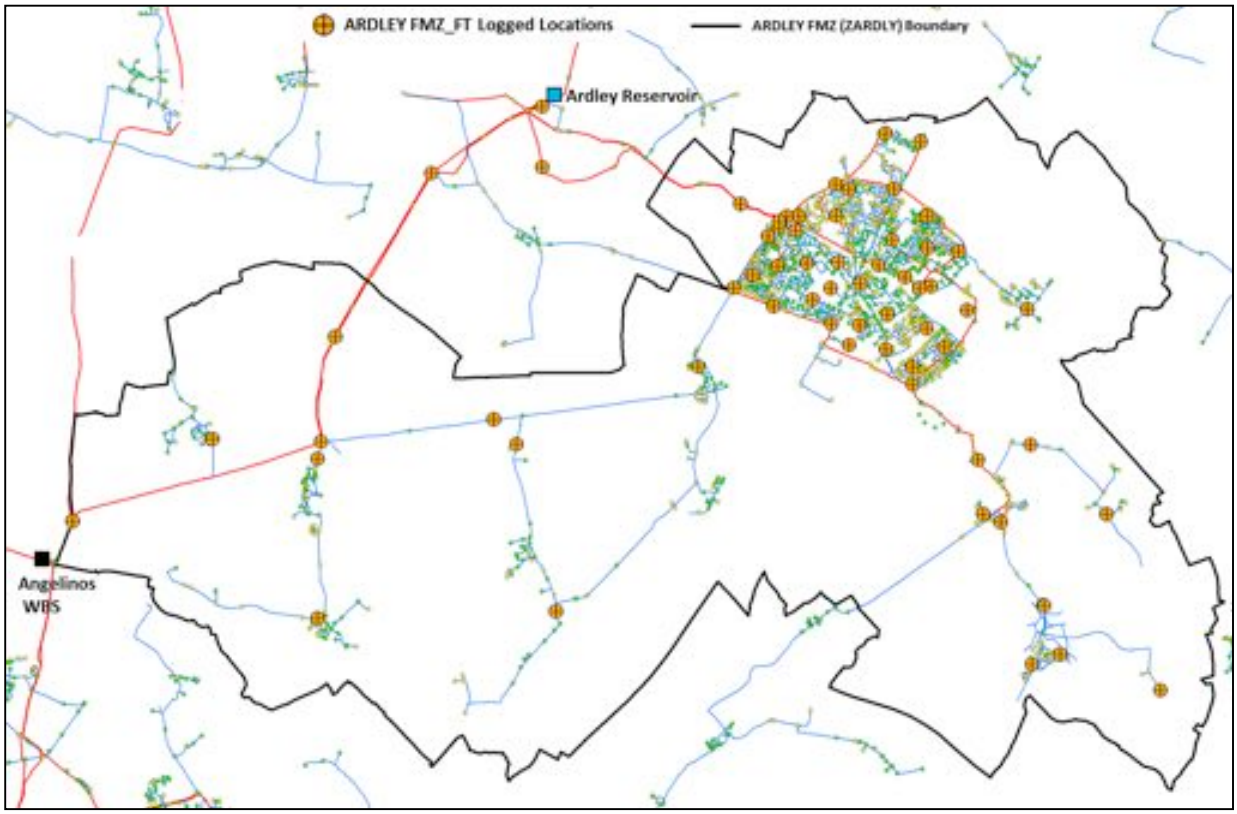


Figure 3 - Field Test Logger Locations Overview

To simulate the operation of the "Calibration Day" (16th June 2015), demand profiles (Type1 to Type9) were created using the generic Thames Water Demand Analysis spreadsheet and from this, the calibration model was produced, labelled as **"ZARDLY_CAL_JUNE2015_V1"**.

This will be referred to as the "**Calibration Day Model**" for the purpose of this report. For further details of the calibrated model, refer to Ardley Model Calibration Report _v1.0. It should be noted that boundary valve between the pumped and gravity systems is open on the calibration day model.

4. Strategic Supply and Demand

4.1 Strategic Supply/Demand Mass Balance Calculations

It has been assumed that the Graven Hill Development will start in 2016 and will be completed by the Year 2026. Supply/demand mass balances for the Angelinos to Ardley Reservoir system (see Appendix A) were calculated from the spreadsheet (N.OXF S-D Bal_fWRMP14_Graven Hill (Atkins)) provided by TWUL for the Year 2016 and 2026 peak week demand scenarios (for a dry year critical period). The mass balance calculations indicate that with a maximum supply rate of 15.1Ml/day from Angelinos WBS to Ardley SR, there will be no deficit in transfer capacity for the Year 2016 or for the Year 2026 when the Graven Hill development is completed.

4.2 Reservoir Policy Calculations

Reservoir Policy Calculations were also carried out for Ardley Reservoir (see Appendix C) to understand how it would be impacted by the Graven Hill Development.

The Reservoir Policy calculations show there is adequate capacity at Ardley in regard to the balancing storage requirement if the Graven Hill Development does proceed. However the existing capacity at Ardley is insufficient to meet the future emergency storage requirement in Year 2026. There will be a 0.94 Ml deficit in regard to the emergency storage requirement without the development in 2026 and this will become an increased deficit of 1.83 Ml once the development is completed.

An additional reservoir cell at Ardley site will therefore be required that increases the storage capacity by at least 1.83 Ml (assumed adjacent to the current reservoir site).

5. Hydraulic Network Modelling

5.1 Description of Modelling Scenarios

The hydraulic analysis to assess the impact of the proposed Graven Hill development was carried out modifying the "Calibration Day Model'' to create a 2015 DYCP PD+HR model. The model created for 2015 DYCP PD+HR is representative of the peaking factor (1.60) identified in the Confidence Grade Model.

The 2015 DYCP PD+HR model (model total daily demand 13.04Ml/d) is created by factoring up the calibration day demand (11.07Ml/d) profiles to meet the additional demand (0.67Ml/d) plus MOD site (Park Rise/Merton Road MOD site) demand (0.3Ml/d) during the morning peak. The MOD site (Park Rise/Merton Road MOD site) demand was applied during the morning peak period on the model (Node ID 7503586) on average 27.5l/s as this demand which is occasional in nature, was not present on the calibration day.

The 2015 DYCP PD+HR Model was then modified to create the 2026 DYCP PD+HR model (Scenario A - Base Model) by factoring up the demand profiles to meet the total FMZ forecast demand for the 2026 planning period (13.34Ml/d).

Scenario B was then created by adding the Graven Hill development demand to the Scenario A model.

Three separate hydraulic analyses have been carried out for the Graven Hill Development as listed in Table 1. The impact of the Graven Hill Development on the Ardley FMZ network was assessed by comparing the Scenario B results with those from Scenario A. Scenario C was then created to improve the network issues that were highlighted by Scenario B.

Scenario	Demand	Model's Description
A	2026 DYCP PD+HR	Base model created using 2015 DYCP PD+HR model factored up using the total FMZ demand for the 2026 planning period
B	2026 DYCP PD+HR + Graven Hill Development Demand	Proposed demand for Graven Hill Development is added to Scenario A
C	2026 DYCP PD+HR + Graven Hill Development Demand	Reinforcement: Scenario B model with solution added

Table 1 – Scenarios modelled

The calibration day model indicates that the Peak Instantaneous Demand (PID) normally occurs at 07:00 am in the morning. The results for each scenario have therefore been compared at this time of the day.

5.1 Modelled Daily Demand

Table 2 shows the daily demands that were used in creating the Ardley models. The 2026 DYCP PD+HR demand was taken from the demand forecast 'Demand Forecast ZARDLY'. It can be seen that the forecast demand is 10.5% higher than the Calibration Day demand.

Demand	Daily Demand (Mld)
"Calibration Day" 16th June 2015	12.07
2026 DYCP PD+HR	13.34

Table 2 - Model demands

6. Supply and Demand Data

6.1 Development Demand Data

Table 3 provides a summary of the demand for the proposed Graven Hill Development, based on 1,900 residential units:

	Average Daily Demand, ADD (l/s)	Morning Peak Demand, PID (l/s)
Graven Hill Development Demand	6.4	25.6

Table 3 – Graven Hill Development Demand

Table 4 shows the model demands for Scenario A and Scenario B under the 2026 DYCP PD +HR demand scenario. It shows that the demand in the Ardley FMZ will increase by 4.1% due to the Graven Hill Development.

Model Demand under 2026 DYCP PD+HR (Ml/d)		
Scenarios	**Scenario A**	**Scenario B**
Ardley FMZ	13.34	13.34
Graven Hill Development	0.00	0.67
Total (Ml/d)	13.34	14.01

Table 4 - Model Demand for Ardley FMZ

7. Development Site

7.1 Site Supply

The development site is located to the south part of the township of Bicester and will be fed through the 355mm HPPE (PE100) main, which runs along the A41 road in DMA ZARDLY06. This main is fed off the 350mm DI Bicester ring shown in Figure 4.

The proposed point of connection (POC) for the Graven Hill Development site is on the existing 355mm HPPE main at the location shown in Figure 4.

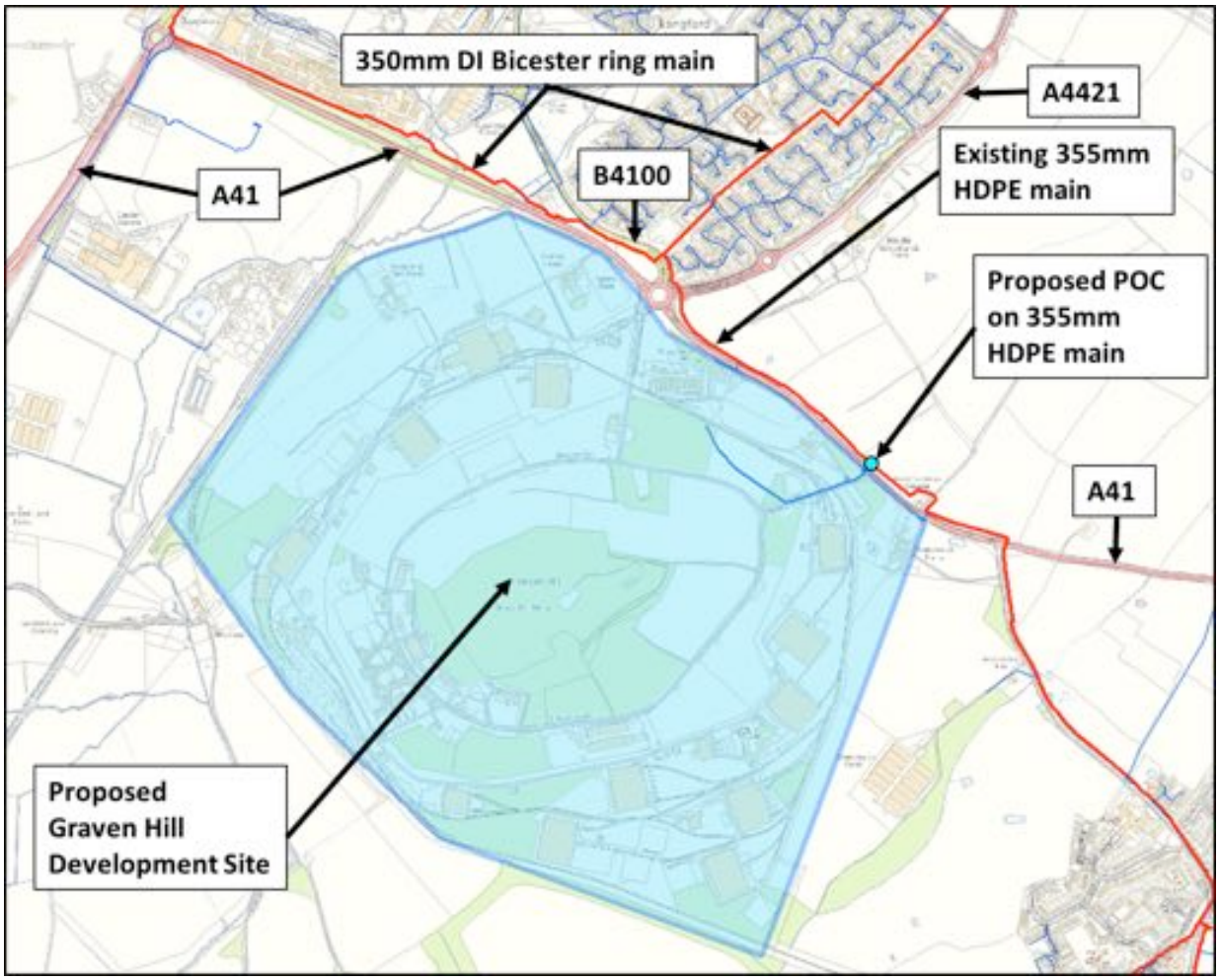


Figure 4 – Graven Hill Development Proposed Point of Connection

8. Modelling Results

8.1 Summary of Modelling Results

The Scenario A model was run in order to assess the predicted performance of the network in the Year 2026 if the Graven Hill Development did not proceed. It showed that the PID pressure at the POC will be 12.9m and 23.7m at DMA06's CPP as listed in Table 5.

The modelling results for Scenario B (with the development demand) indicated that the proposed development will have a significant impact on pressures in the local area. Table 5 shows that for Scenario B, pressures at the proposed POC will drop to zero as well as in other parts of the surrounding network. This indicates that the network will need local mains reinforcement in order to meet the requirements of the Graven Hill Development without significantly impacting on pressures in the existing network.

To achieve similar levels of service to those simulated in Scenario A, Scenario C was created. Scenario C looked at reinforcing 850m of high headloss main in order to return pressures back to those levels simulated in Scenario A.

The modelling results for Scenario C indicated that reinforcing the existing 850m of high headloss main along the A41 with 225mm (ID) main would return pressures back to those simulated in Scenario A. Figure 5 shows the location of the mains reinforcement. Figure 5 also shows the location of the pressure comparison points for each of the scenarios.

Table 5 shows that with these improvement works, the pressure at peak time at the POC, the suction side of Upper Arncott WBS and also at the CPP point in DMA06 will return to similar levels to those simulated in the Base Model (Scenario A).

Model Node Reference	Location	Peak Demand Pressure (m) @ 07.00 am		
		Scenario A Base Model	Scenario B With Graven Hill	Scenario C Solution: Reinforcement
8084970	POC to Graven Hill development	12.9	0.0	13.5
7487735	Suction side of Upper Arncott WBS	14.9	0.0	15.6
1556217	CPP8704 in DMA06	23.7	0.0	23.7

Table 5 - Pressure results for Scenario A, Scenario B and Scenario C at 07:00 am

Charts showing the pressure comparison at the POC, the suction side of upper Arncott WBS and at the CPP point in DMA ZARDLY06 for Scenarios A, B and C are shown respectively in Figures 6, 7 and 8.

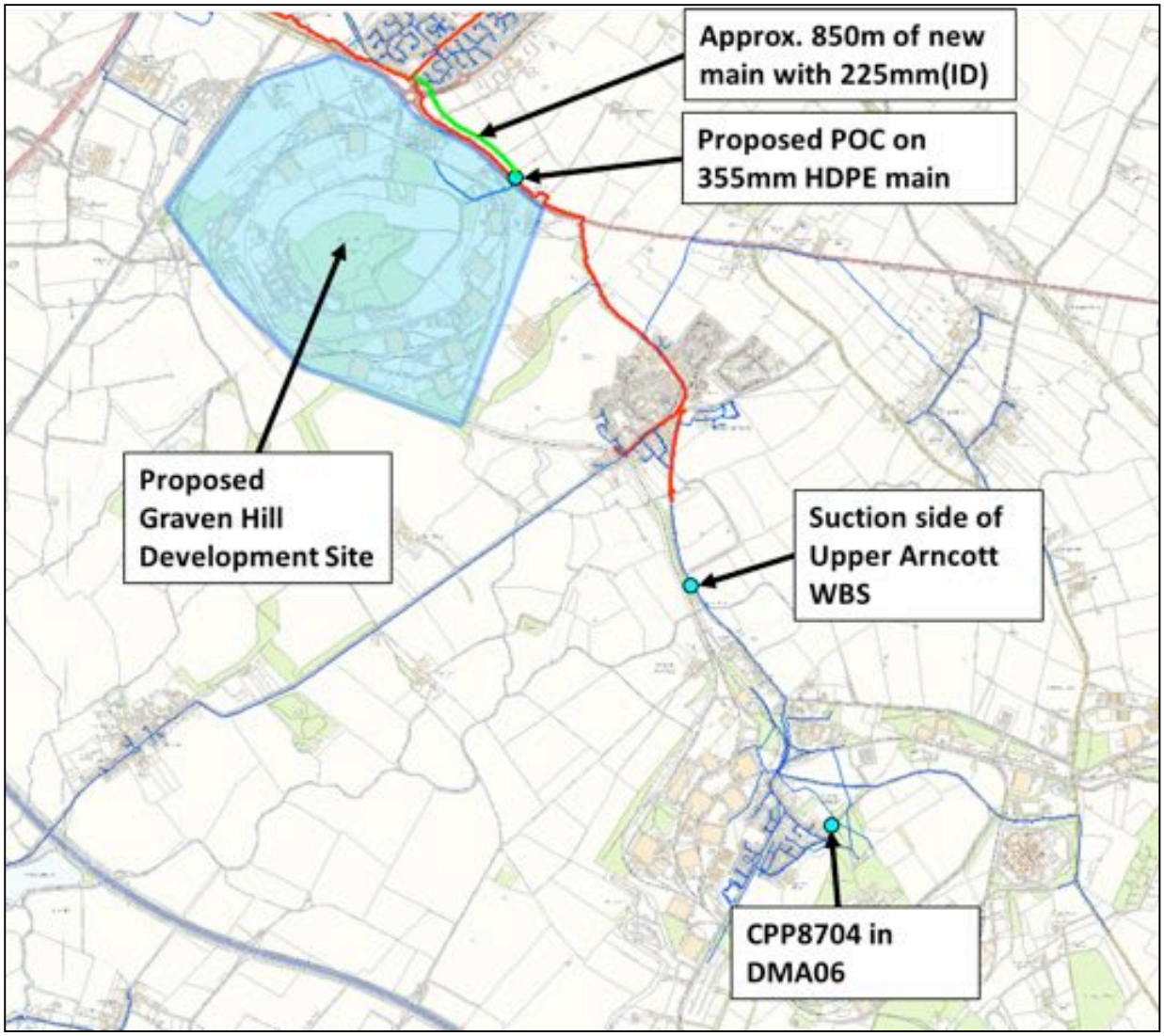


Figure 5 – Pressure comparison points within DMA ZARDLY06

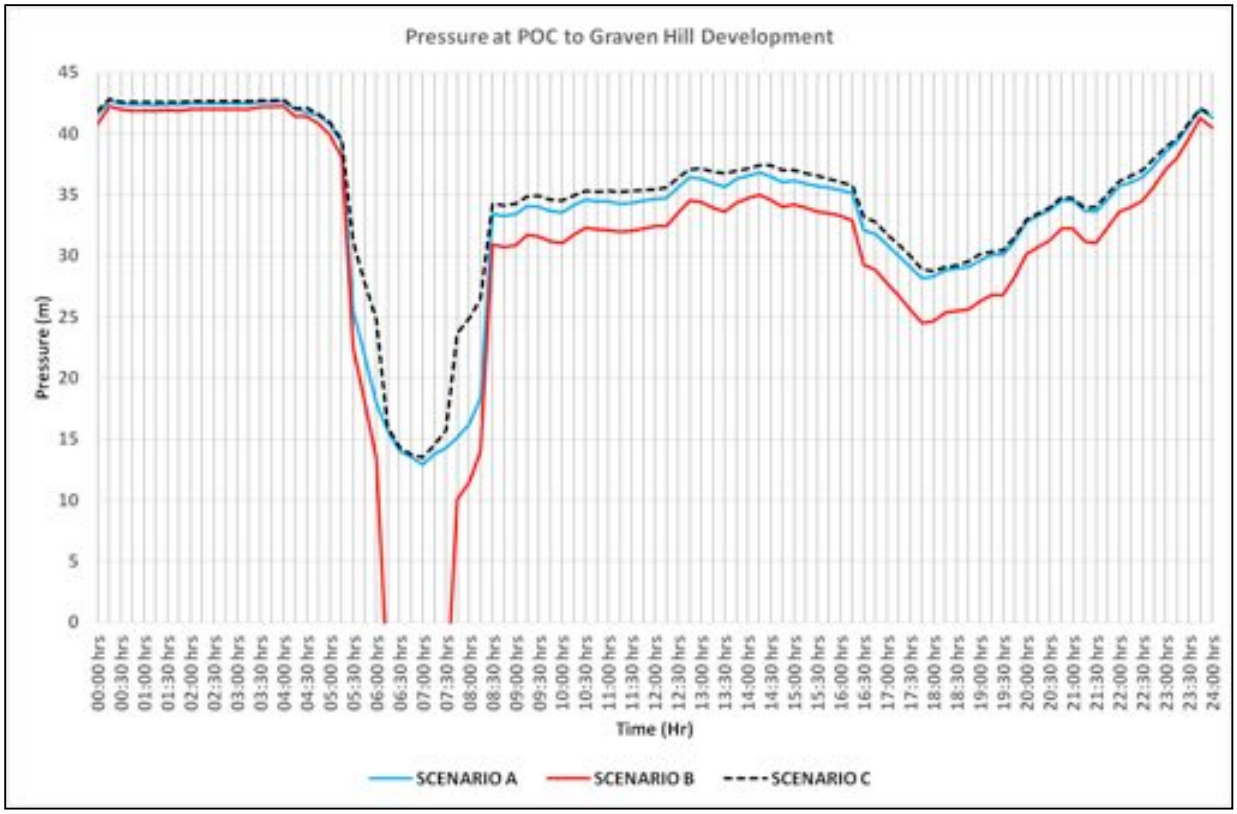


Figure 6 - Pressure Comparison at POC for Scenarios A, B & C

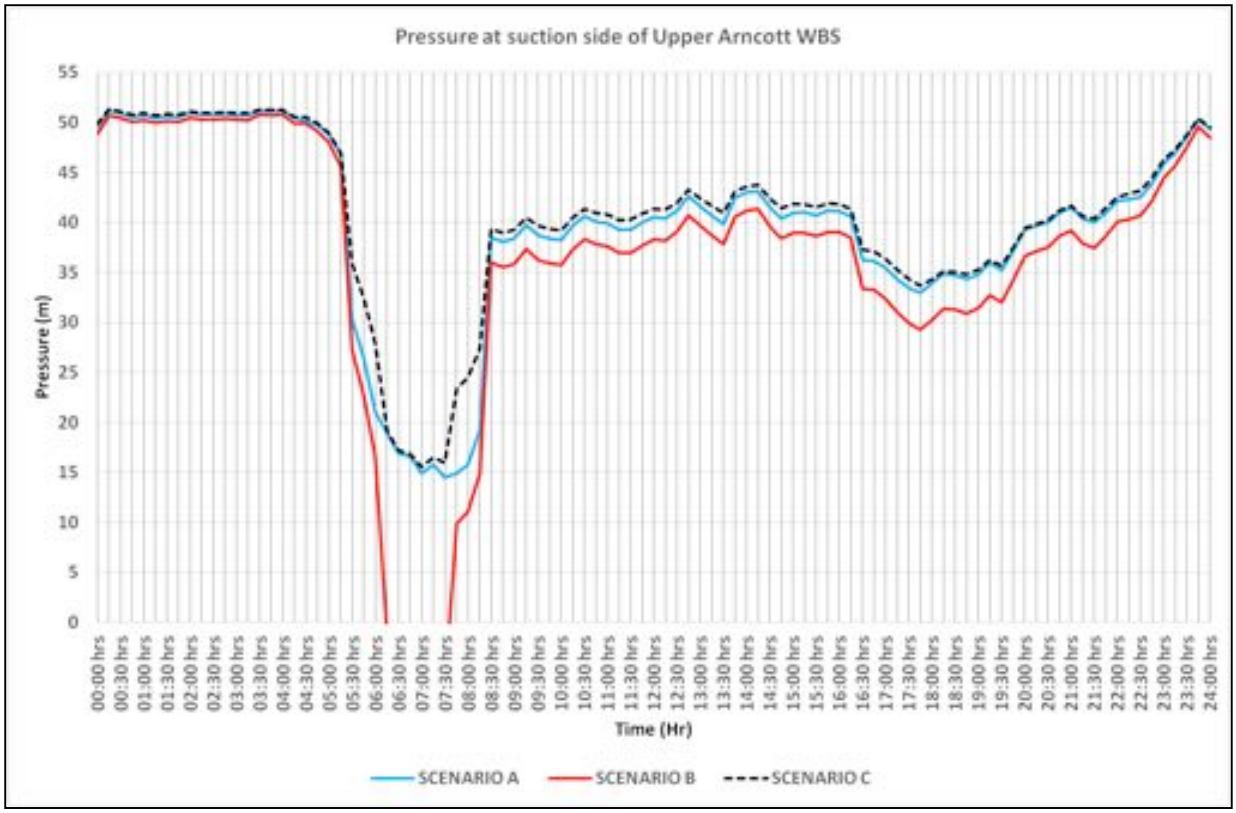


Figure 7- Pressure Comparison at suction side of upper Arncott WBS for Scenarios A, B & C

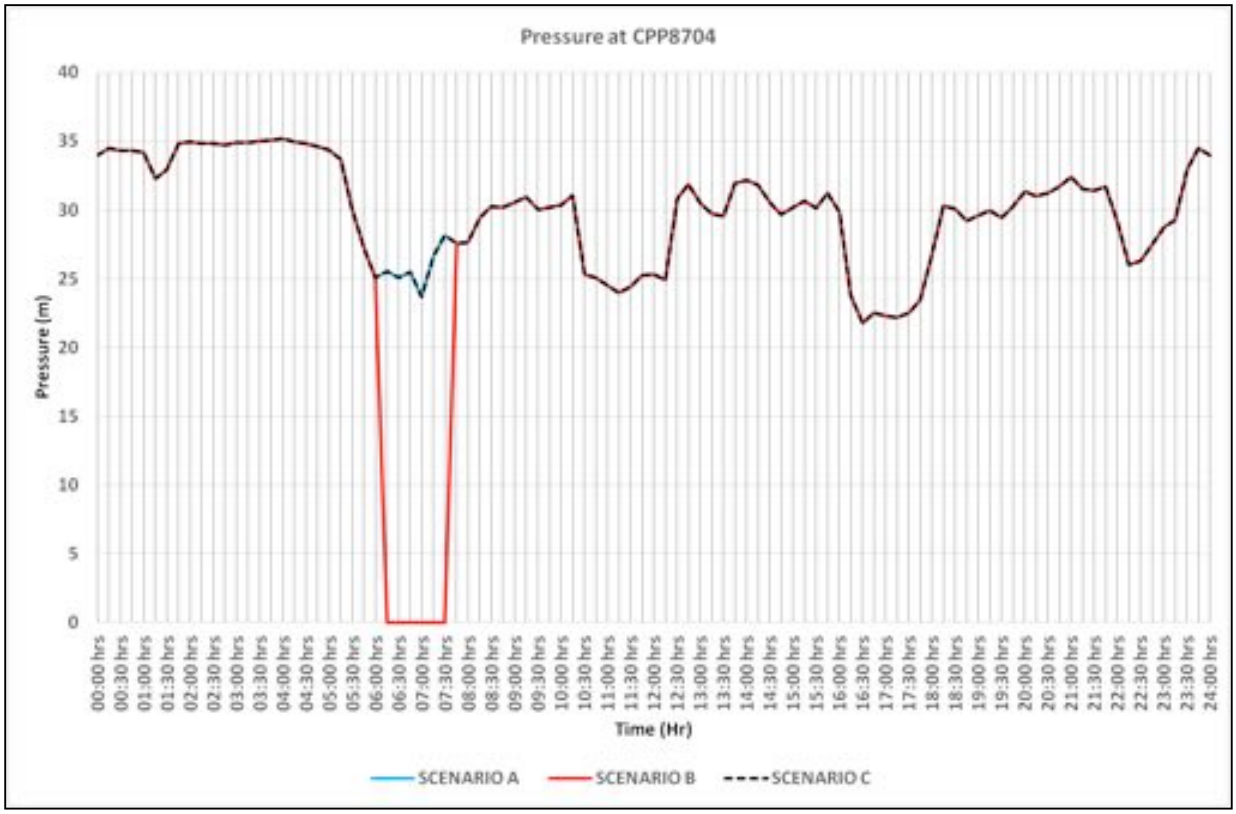


Figure 8 - Pressure Comparison at the CPP8704 in DMA ZARDLY06 for Scenarios A, B & C

8.2 Modelling Results with boundary valve closed

The boundary valve between the pumped and gravity system is closed in the model to assess the impact on simulated scenarios. Table 6 compares the modelled results with the boundary valve open scenario.

Model Node Ref	Location	Peak Demand Pressure (m) @ 07.00 am					
		Boundary Valve Open			Boundary Valve Closed		
		Scenario A Base Model	Scenario B With Graven Hill	Scenario C Solution	Scenario A Base Model	Scenario B With Graven Hill	Scenario C Solution
8084970	POC to Graven Hill development	12.9	0	13.5	12.2	0	12.6
7487735	Suction side of Upper Arncott WBS	14.9	0	15.6	14.2	0	14.6
1556217	CPP8704 in DMA06	23.7	0	23.7	23.7	0	23.7

Table 6- Pressure results for boundary valve closed for Scenario A, Scenario B and Scenario C at 07:00

9. Fire Flows

A fire flow of 25l/s was modelled based on the DYAA + HR model (Scenario D) that was created specifically for the Fire Flow assessment. The model included the 225mm reinforcement main. The hydrant that was simulated is fed from the same 355mm HDPE main as the POC and is shown in Figure 9.

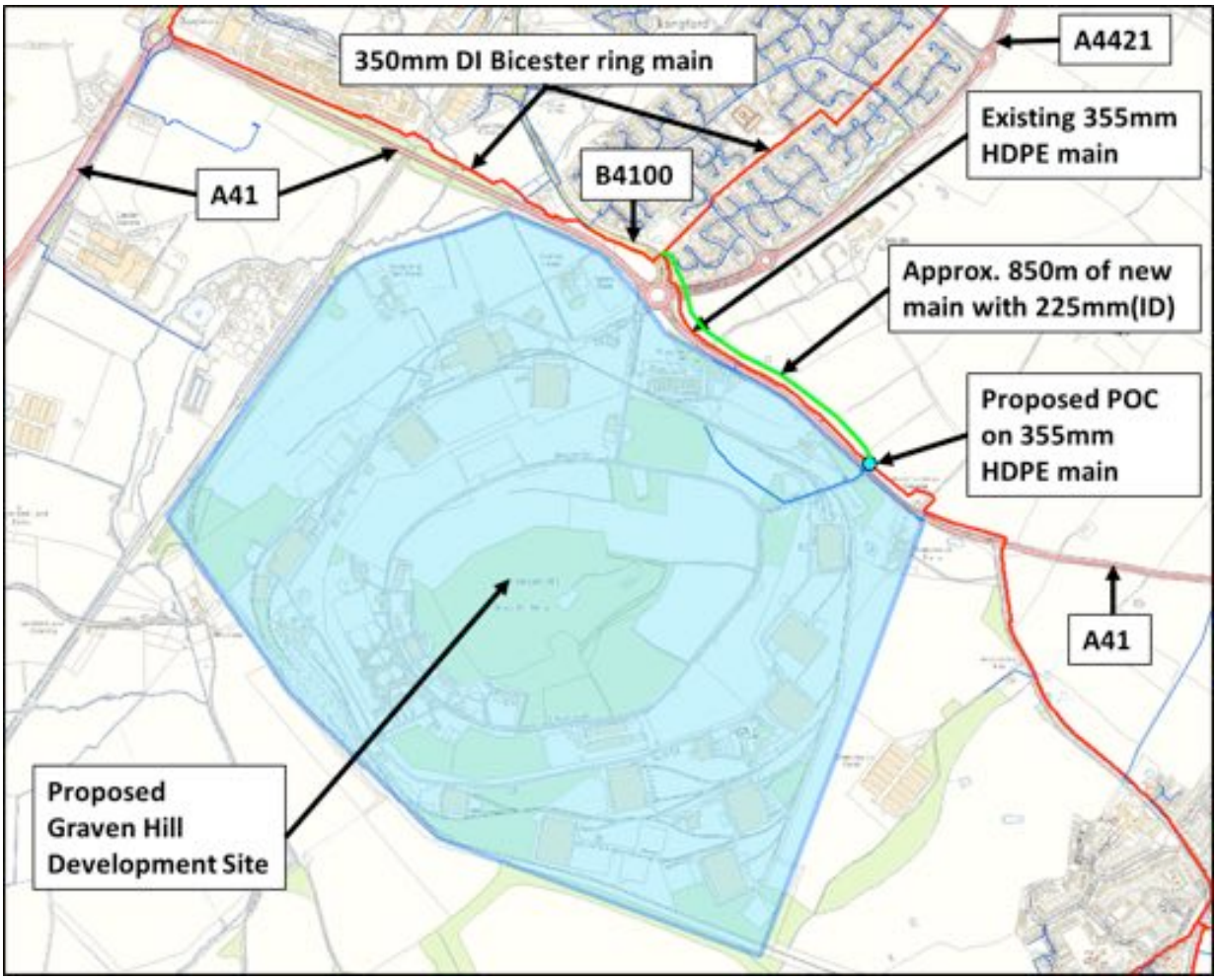


Figure 9 - Fire Hydrant test location

Table 6 shows the modelling results for the Fire Flow analysis. It indicates that the pressures at the hydrant will be greater than the required fire flow residual pressure of 15.2m when a fire flow of 25l/s was applied (in addition to the development demand) and hence the simulation passes.

Scenario	Location	Model Node Ref	Fire Flow Required (l/s)	Residual Pressure Required (m)	Residual Pressure Available (m)	Comments
D (2026 DYAA +HR)	Existing Fire Hydrant near to POC	8003465	25	15.2	22.7	Pass

Table 6 - Fire Flow Results

10. Conclusion

The model results indicated that the proposed development will have a significant impact on pressures in the local area when it is added to the Year 2026 forecasted zonal demand. Scenario B showed that pressures at the proposed POC will drop to zero as well the pressures in some parts of the surrounding area too within DMA ZARDLY06. The network will therefore need local reinforcement in order to meet the requirements of the Graven Hill Development.

The modelling results indicate that to resolve the pressure issues caused by the addition of the new development, an existing 850m of main along A41 road should be reinforced with a 225mm (ID) main. This reinforcement would return pressures back to a level that is similar to those simulated in the pre-development scenario.

A supply/demand mass balance for Ardley Reservoir was calculated from the spreadsheet (N.OXF S-D Bal_fWRMP14_Graven Hill (Atkins)) provided by TWUL for the Year 2016 and the Year 2026 peak week demand scenarios (for a dry year critical period). The calculation indicates that with a maximum transfer rate of 15.1Ml/day between Angelinos WBS and Ardley SR, there will be no deficit in transfer capacity for the Year 2016 or for the Year 2026 planning period when the Graven Hill Development demand is completed.

The Reservoir Policy calculations show there is adequate capacity at Ardley in regard to the balancing storage requirement if the Graven Hill Development does proceed and maintaining the current maximum supply rate from Angelinos BPS. However the existing capacity at Ardley is insufficient to meet the future emergency storage requirement in Year 2026,. There will be a 0.94 Ml deficit in regard to the emergency storage requirement when the development is not included in Year 2026 and this will become an increased deficit of 1.83 Ml in the Year 2026 once development is completed.

An additional reservoir cell at Ardley site will therefore be required that increases the storage capacity by at least 1.83 Ml (assumed adjacent to the current reservoir site).

A Fire Flow was simulated by applying an additional flow of 25l/s on an existing single fire hydrant close to the proposed Graven Hill development POC. The model indicated that once the reinforcement main of 225mm (ID) is completed, the fire flow can be achieved

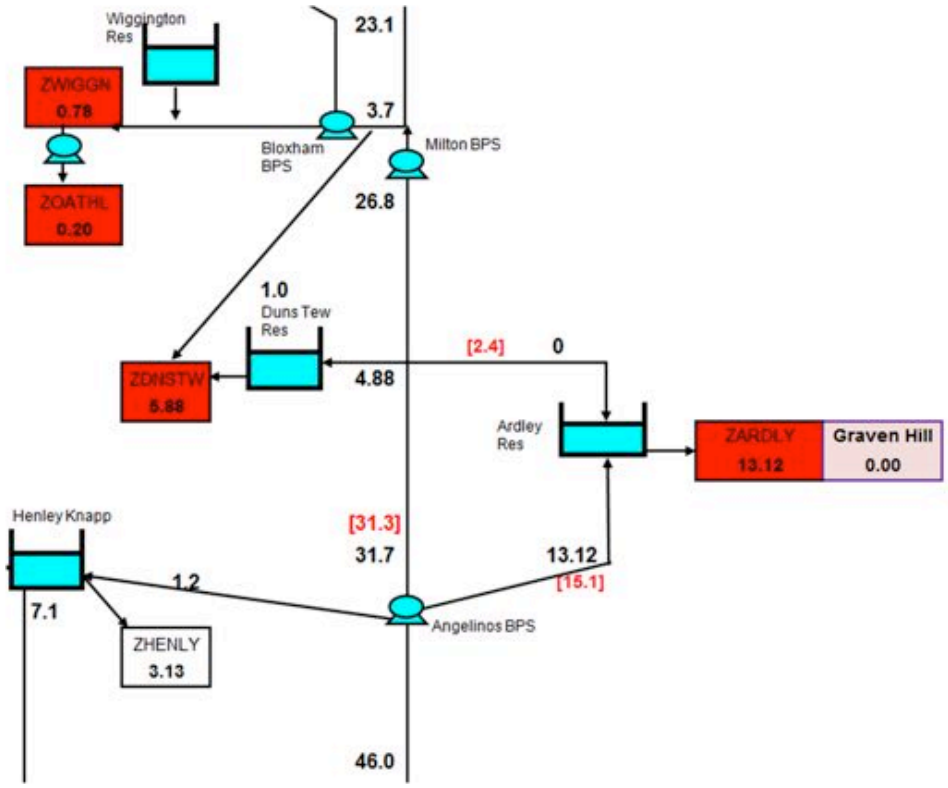
Appendices

Appendix A Glossary of Terms

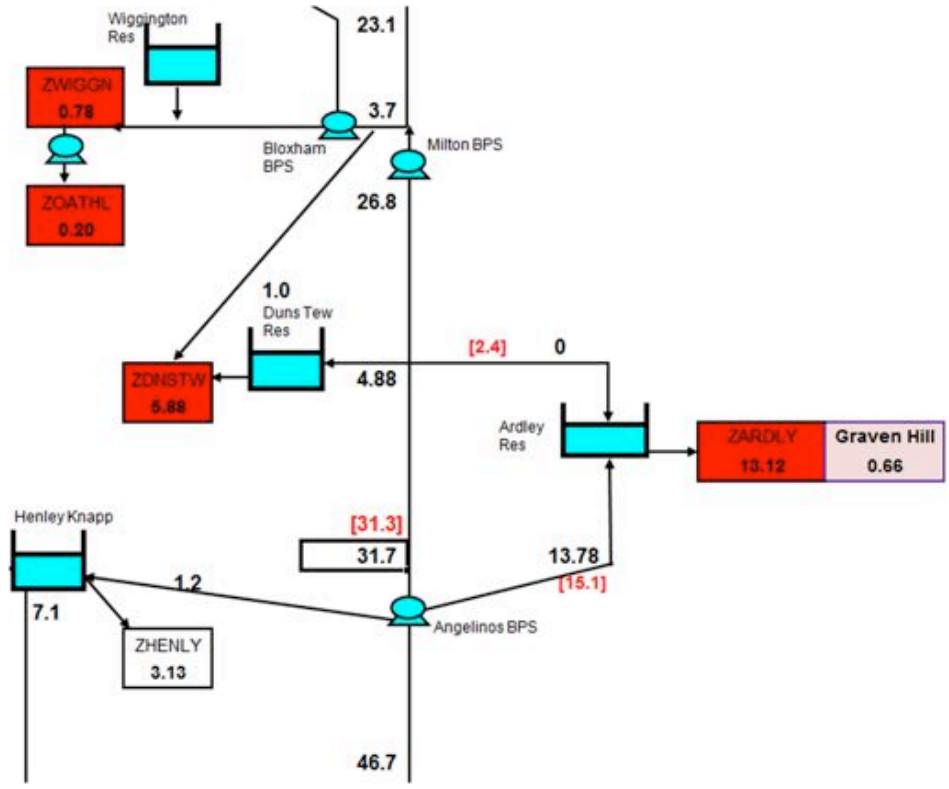
ADD	Average Day Demand, based on annual consumption figure
ADPW	Average Day Peak Weak
DI	Ductile Iron
DM	District Meter
DMA	District Metered Area
DYAA	Dry Year Annual Average
DYCP	Dry Year Critical Period
DYCP PD + HR	Dry Year Critical Period Peak Day plus Headroom
GIS	Geographical Information System
HPPE	High Pressure Polyethylene Pipe
ID	Internal Diameter
l/s	Litres per second
M	Metres
m/km	Meters per kilometre
m/s	Metres per second
m3	Cubic metres
mAOD	Metres Above Ordnance Datum
Mld	Mega Litres per day
PID	Peak Instantaneous Demand
POC	Point Of Connection
PRV	Pressure Reducing Valve
TW	Thames Water
FMZ	Flow Monitoring Zone
WBS	Water Booster Station
ZM	Zonal Meter

Appendix B Ardley Reservoir Supply/Demand Mass Balance

B.1 Ardley Reservoir Supply/Demand Mass Balance (Excluding Graven Hill Development) –2026 DYCP PW +HR



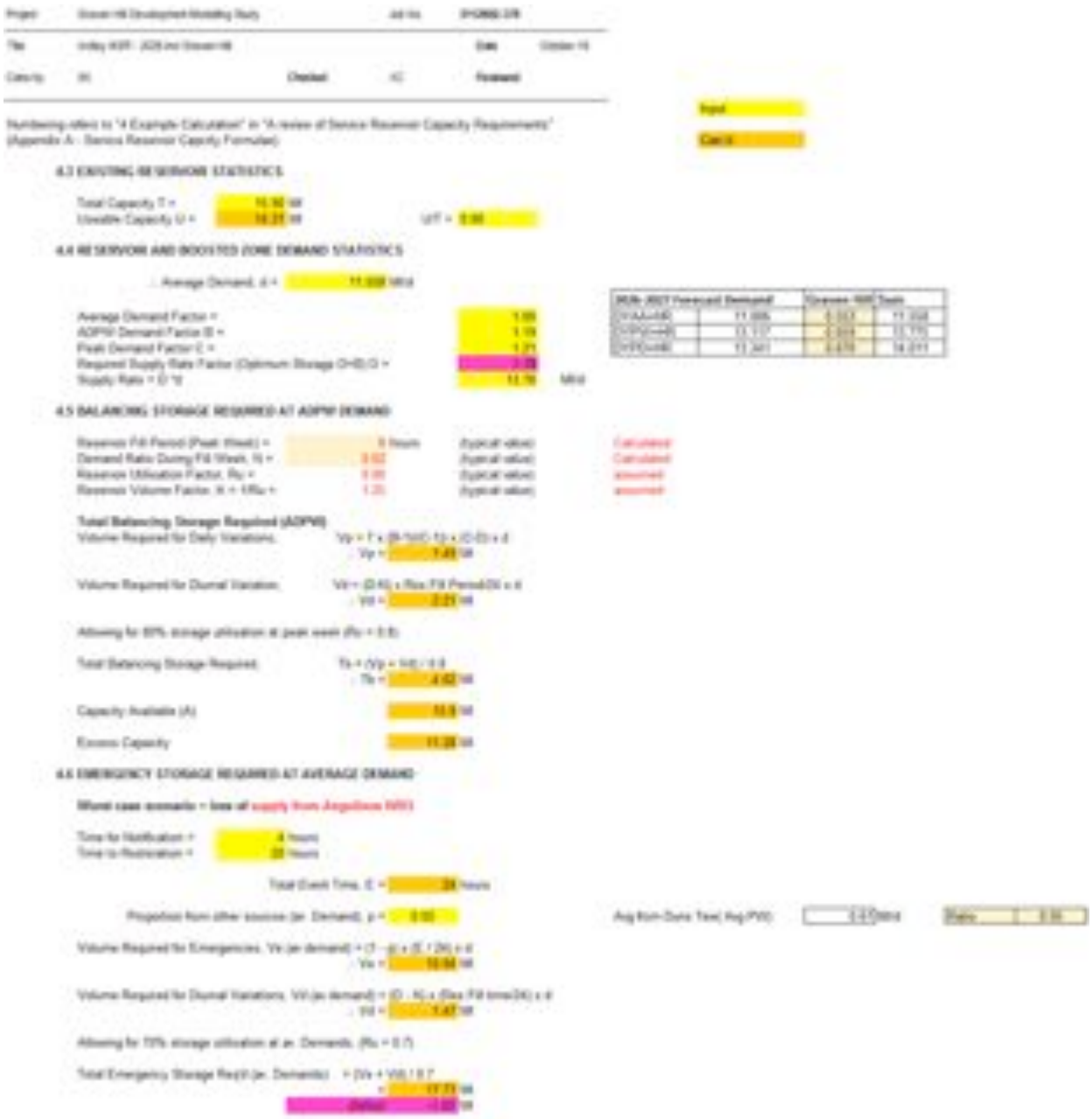
B.2 Ardley Reservoir Supply/Demand Mass Balance (Including Graven Hill Development) –2026 DYCP PW +HR



Appendix C Ardley Reservoir Policy Calculations

C.1 Ardley Reservoir Policy Calculation (Excluding Graven Hill Development) – 2026

C.1 Ardley Reservoir Policy Calculation (Including Graven Hill Development) – 2026



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