Modelling Group
WATER NEW ZEALAND

Modelling Symposium

Deriving PS Discharge Volume – A Case Study in Tauranga

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The New Zealand Water & Wastes Association Waiora Aotearoa

QUESTIONS

Who has derived PS Inflows using SCADA Data?

Was the process an efficient one? And how effectively can PS derived inflows be used for model calibration?

Photo credit: Field Services Ltd (FSL)

Presentation Overview

- Context: Wastewater Infrastructure Planning
- Model Calibration/Validation
- Flow Data Sources
- A Case Study in Tauranga
- Summary

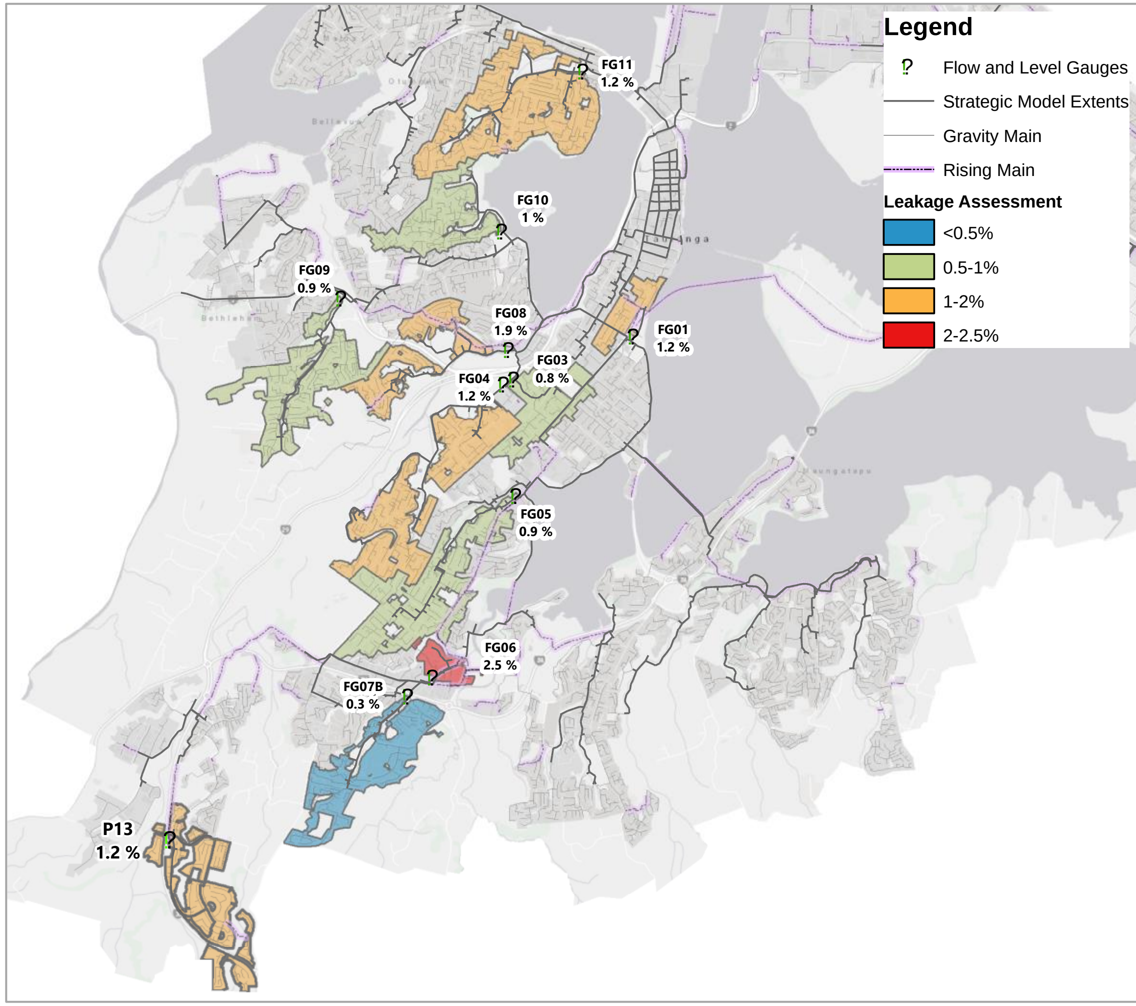
Papamoa Beach (Leonard (Len) Gall)

Context: Wastewater Network Infrastructure Planning

- Wastewater spills to the environment is not desirable.
    - hydraulic constraints i.e. upstream capacity > downstream capacity.
- Inflow and Infiltration (I/I), driven by rainfall is typically the main contributor.
- Development of hydrologic and hydraulic computational model for complex network and calibration is essential to forecast network capacity issues.
- Inform network investment programme to meet regulatory and growth requirements.

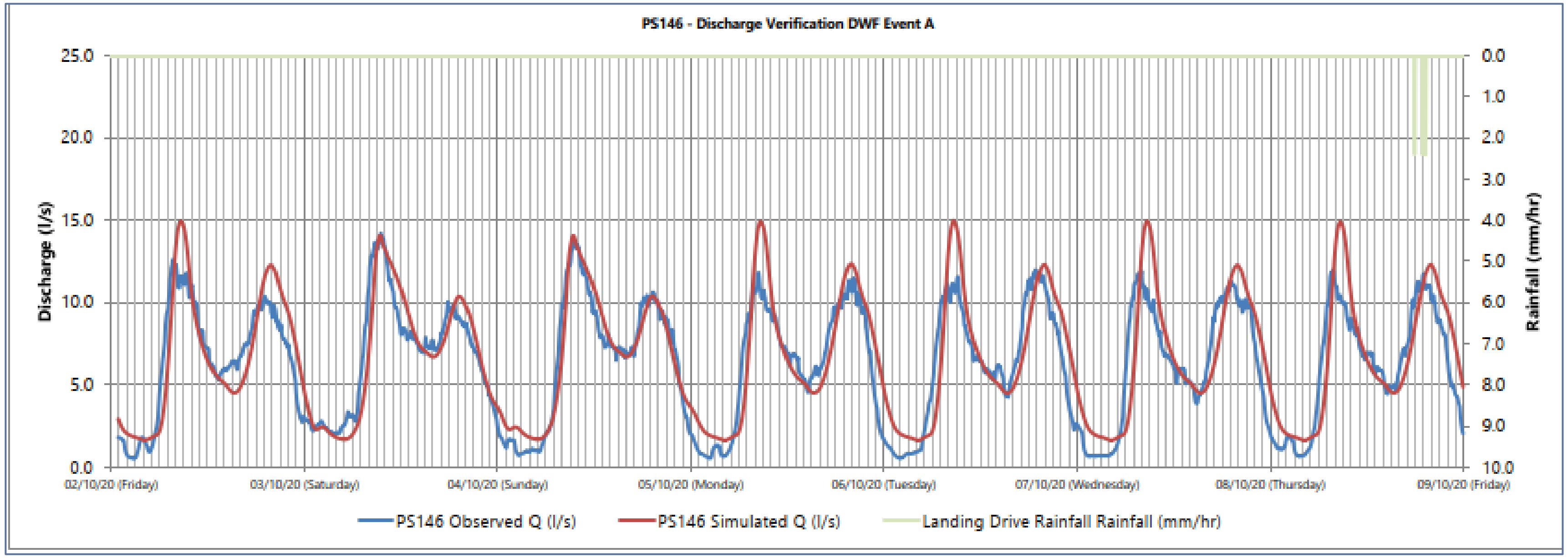
Quantifying I/I

- Not a desktop assessment as we don't know where I/I comes from.
- I/I can be quantified from flow data collection and model calibration/validation.
- Cost and technology limitations practically restrict the resolution I/I can be resolved at.



Model Calibration/Validation

- <u>Model Calibration</u> – Development of model parameters based on measured flow and depth data. Typically against *high quality* measured data.
- <u>Model Validation</u> – To assess the model's representation of network performance at key locations. Can be against *lower quality* measured data, but less justification for model parameter adjustment.



Flow Data Sources

- Flow data can be collected through gauging of the wastewater flows in the network.

- There are two types of gauging:
  - Temporary (HVQs, weirs)
  - Permanent (Magflow meter, PS logger, Level sensor)

- PS sites (with magflow meter) – outflows are measured directly

- PS sites (without magflow meter) – SCADA data collected can be post processed to derive:
  - Inflow – flows entering the PS wetwell
  - Outflow – flows that are pumped out

A Case Study in Tauranga

Key objectives:

- Determine the suitability of SCADA data derived PS inflows (using different methodologies) for use in model calibration/validation.

- Inform future gauging strategy (In-sewer gauging/magflow versus Qouts)

View from the top of Mt. Maunganui (Czech the World, Adriana Halouskova)

Case Study Approach

PS146 Case Study Approach

- Identify the available data sources
- Identify suitable Dry Weather Flow (DWF) and Wet Weather Flow (WWF) Periods
- Data processing to derive inflows via different methodologies
- Error quantification – hourly volumes were derived from the different outputs above for the identified DWF and WWF periods and were compared against the hourly volumes as derived from the independent flow volume source (HVQ).

Available Data Sources

- TCC Supplied SCADA Measured/Calculated Data
    i. Water level (depth from Wetwell floor), m
    ii. Pump run times (sec) and pump stop time steps

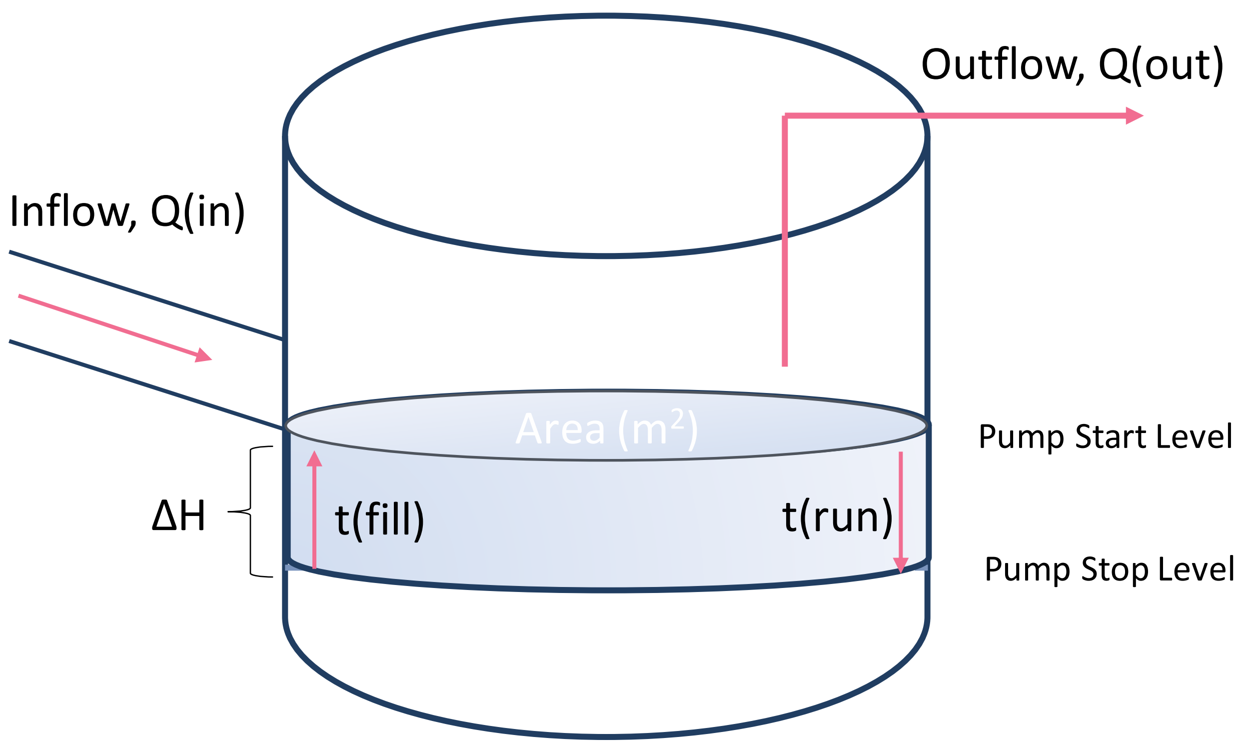
- Independent Flow Volume Source (HVQ)
    i. Flow (l/s) and depth (m) data collected upstream of PS146

PS Inflow Derivation Methodologies

$$Q\ (fill) = \Delta H * \frac{Area}{t(P2\ on - P1\ off)}$$

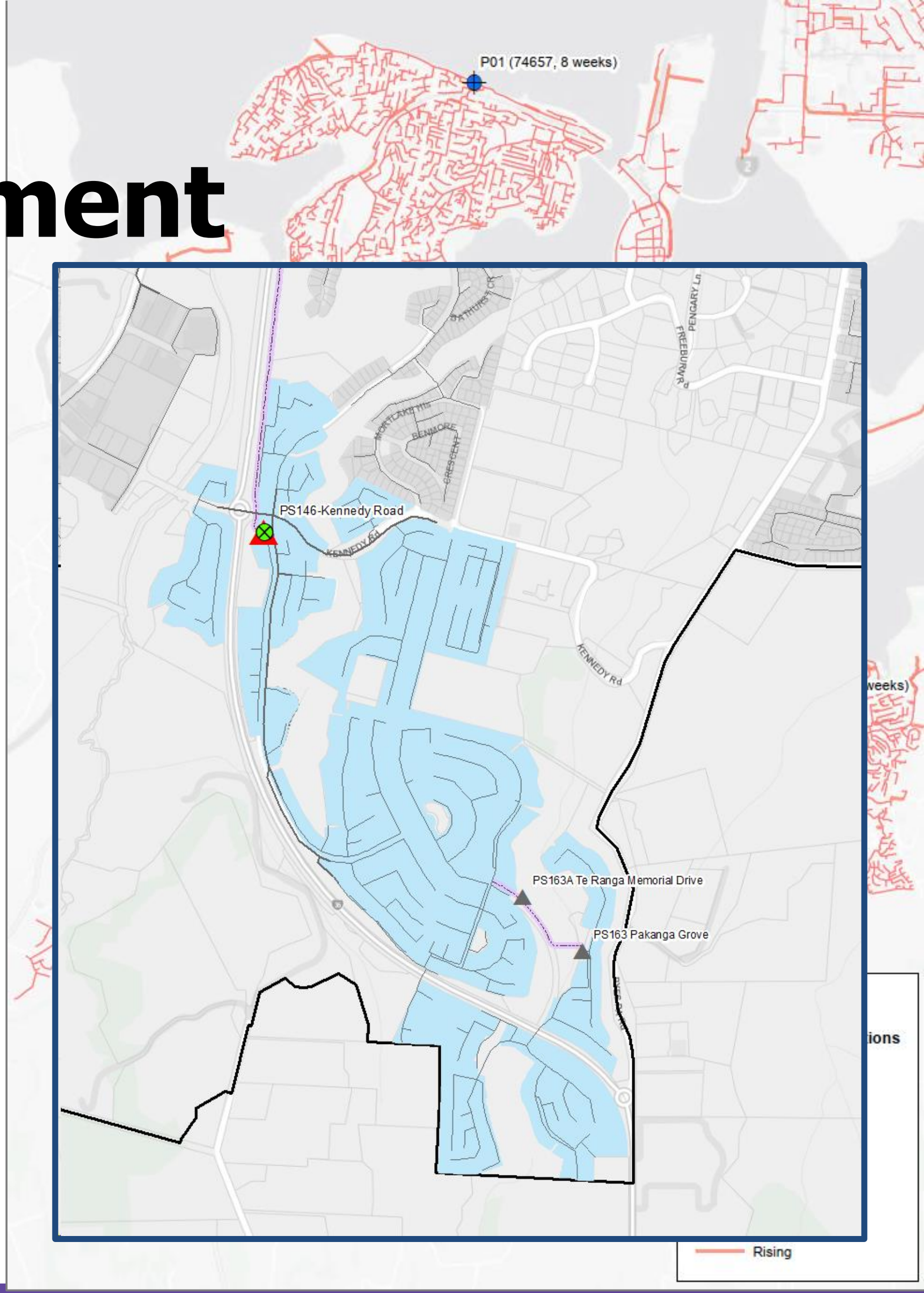
$$Q\ (run) = Qp * \frac{t_{run}}{t(P2\ off\ - P1\ off)}$$

Volume In = Volume Out



Independent Flow Measurement

- TCC Stage 2 Flow Monitoring was undertaken at 12 locations over various durations.
- An HVQ was installed upstream of PS146 Kennedy Road, in the 300mm sewer.
- Data captured at this site includes flow and depth.
- According to the GIS there are two PSs contributing into PS146.

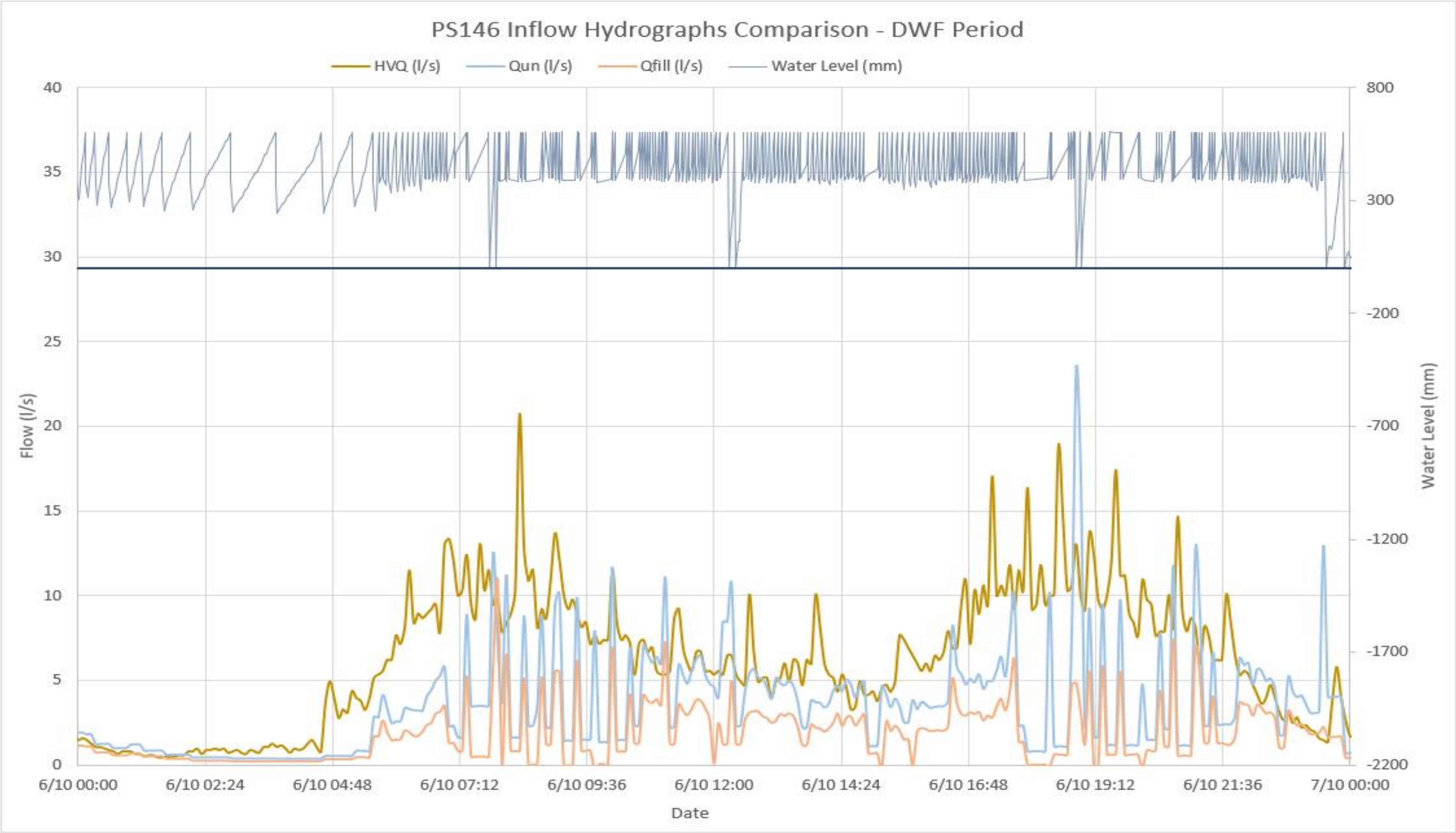


Inflows Comparative Analysis

PS146 Inflow Comparative Analysis

$$Q\ (fill) = \Delta H * \frac{Area}{t(P2\,on - P1\,off)}$$

$$Q\ (run) = Qp * \frac{t_{run}}{t(P2\,off\ - P1\,off)}$$



Pump Station Fun Facts:

- Measured PS Capacity = 96 l/s
- Average pump run time ~20sec.
- Average wetwell filling time ~10 minutes.

Relative Error % (against HVQ)	
Qfill	Qrun
-70	-40

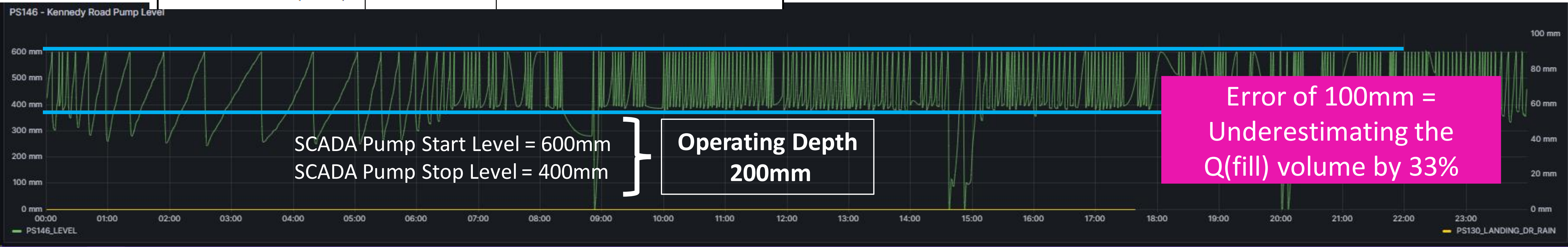
PS146 Level Sensor Scaling Error

Pump Details		
Number of Pumps	2	
Brand	Flyght	Look for pump plate on site. Take photo if found.
Model Number/Serial No.	Unknown	
Rated Power:	Unknown	
Depth* to Top of Pump Body	6260mm	• Measure to pump body, not hook. • If pumps are at materially different heights, document height of each pump.
Depth* to Duty Pump Start - Measured in Well	6000mm	
Depth* to Duty Pump Stop - Measured in Well	6300mm	
Pump Set Points - Read off pump controller		• Read off pump controller on-site if possible.
Duty Start Setpoint	400mm	
Duty Stop Setpoint	200mm	
Assist Pump Start Setpoint	800mm	

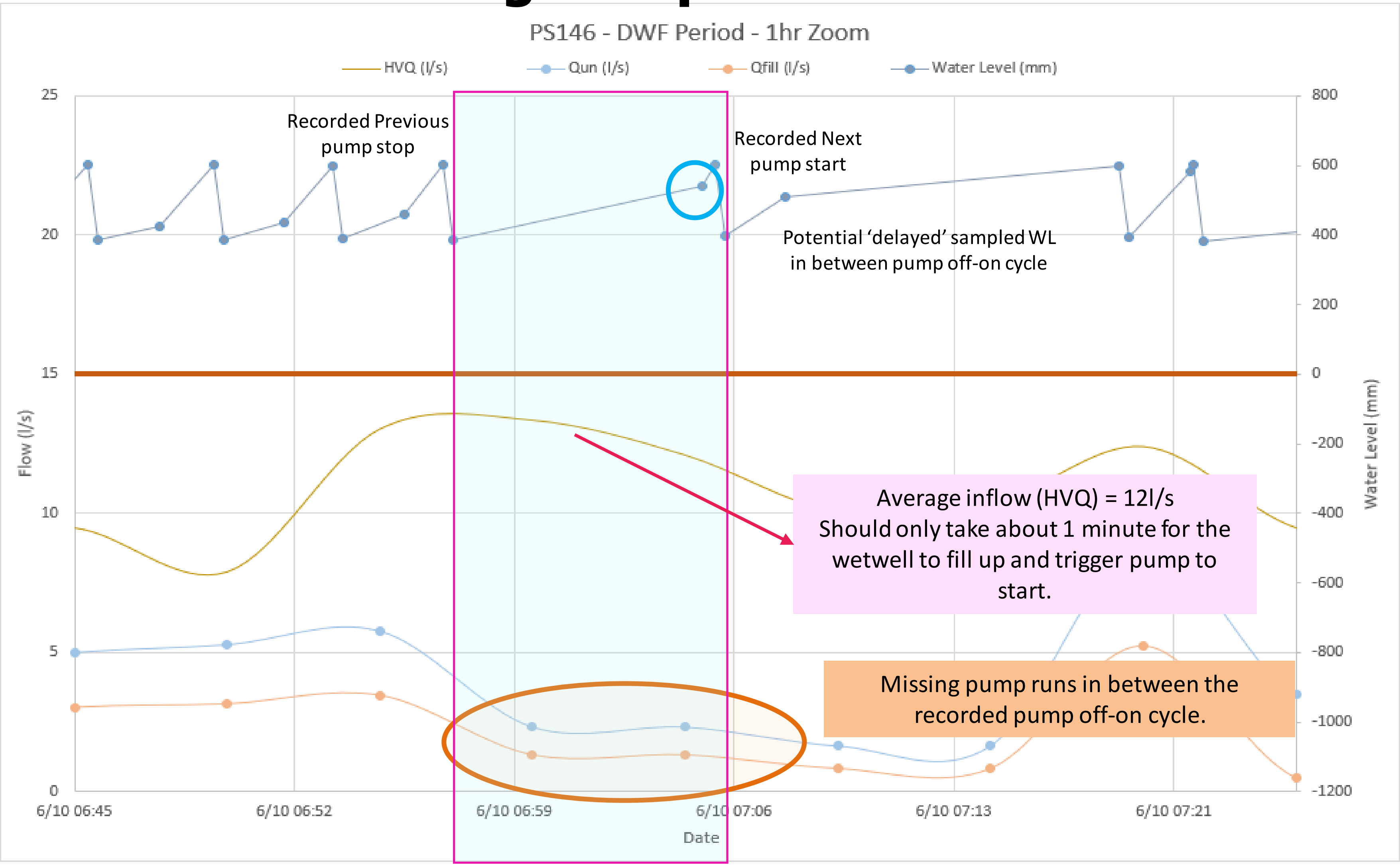
$$Q\,(fill) = \Delta H * \frac{Area}{t(P2\,on - P1\,off)}$$

Measured Pump Start Level = 850mm
Measured Pump Stop Level = 550mm
Operating Depth 300mm

Pump Start Set Point = 400mm
Pump Stop Set Point = 200mm
Operating Depth 200mm



PS146 Missing Pump Runs



$$Q\,(fill) = \Delta H * \frac{Area}{t(P2\ on - P1\ off)}$$

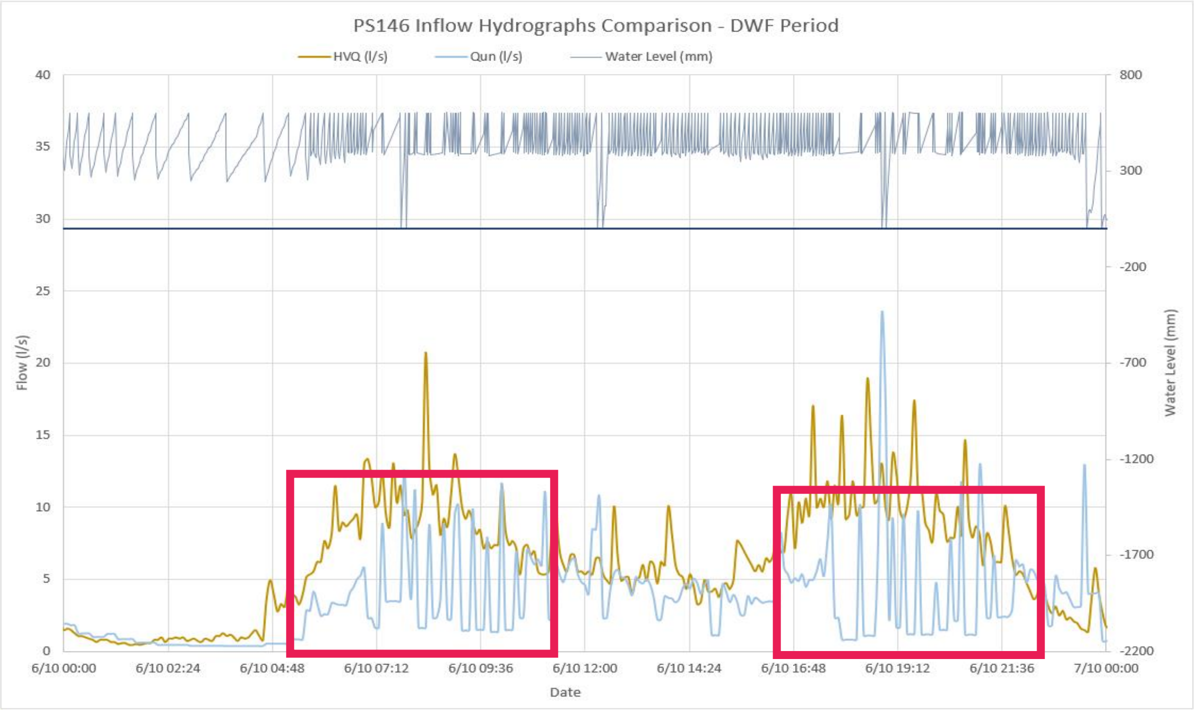
- The sampling of the water level data coincides with change of pump status and occurs in between pump off-on cycle, ie. filling of wetwell.
- However, the water level sampling frequency was inconsistent.
- Potential data transmission/signal failures resulting in:
  - Missing pump runs
  - Delayed sampled water level data
  - Lower inflows.

PS146 ‘Siphon’ Effect

- Detailed review of the pump run times and water level has shown that, in some instances, the flow continues to move through the rising main after the pump has turned off, ie. ‘siphon’ effect.

$$Q\ (run) = Q_r * \frac{t_{run}}{t(P2\ off\ - 1\ off)}$$

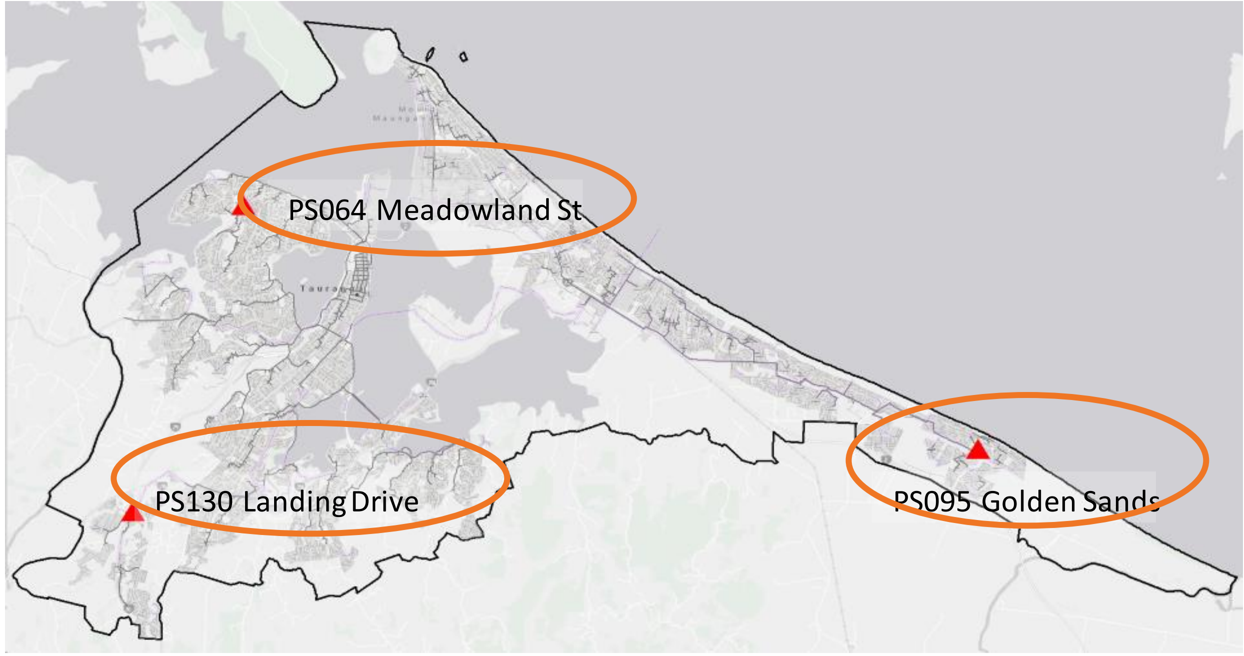
- Q(run) inflows underestimated due to ‘missing’ volumes.



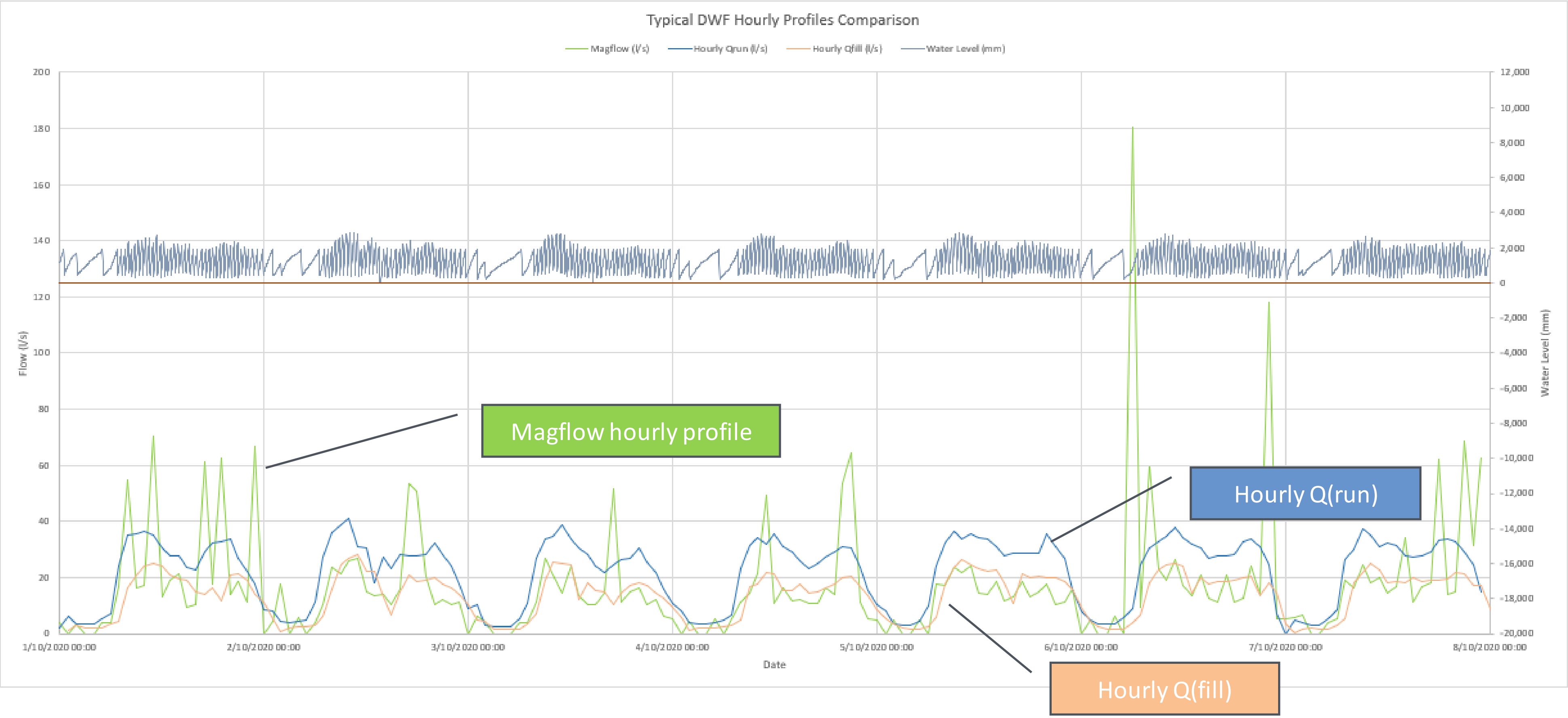
Increasing Sample Size

Other Pump Station Sites

- Same approach was adopted for an additional 3 PS sites of varying size and operating behaviour:
  1. PS130 Landing Drive
  2. PS095 Golden Sands
  3. PS064 Meadowland Street
- Council's Magflow meter was used as the independent flow volume source to quantify the relative errors.



PS130 Hourly Volumes Error Quantification - DWF

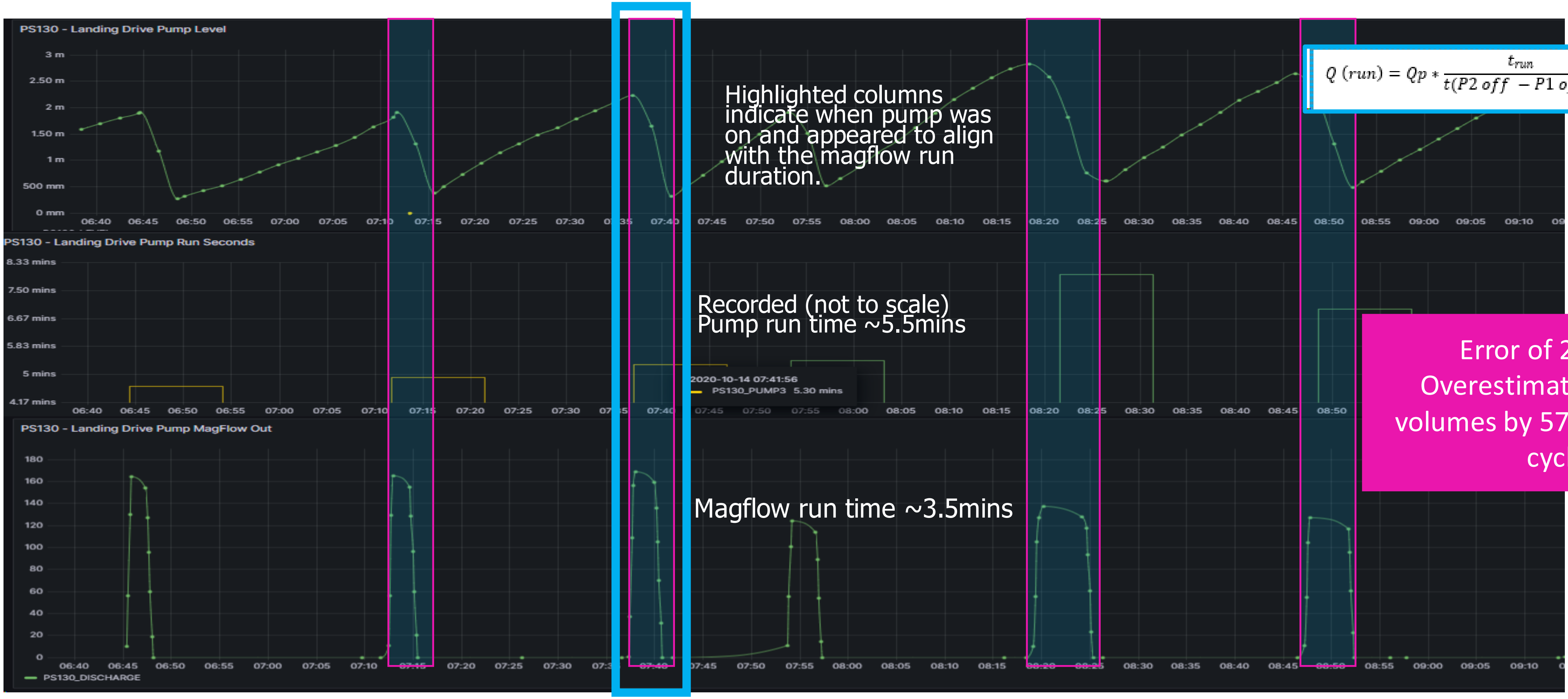


PS130 Fun Facts

- Measured PS capacity 125 l/s-160 l/s
- Average pump run time ~5mins
- Average wetwell filling time ~30mins

Relative Error % (against Magflow Meter)	
Qfill	Qrun
-5	-55

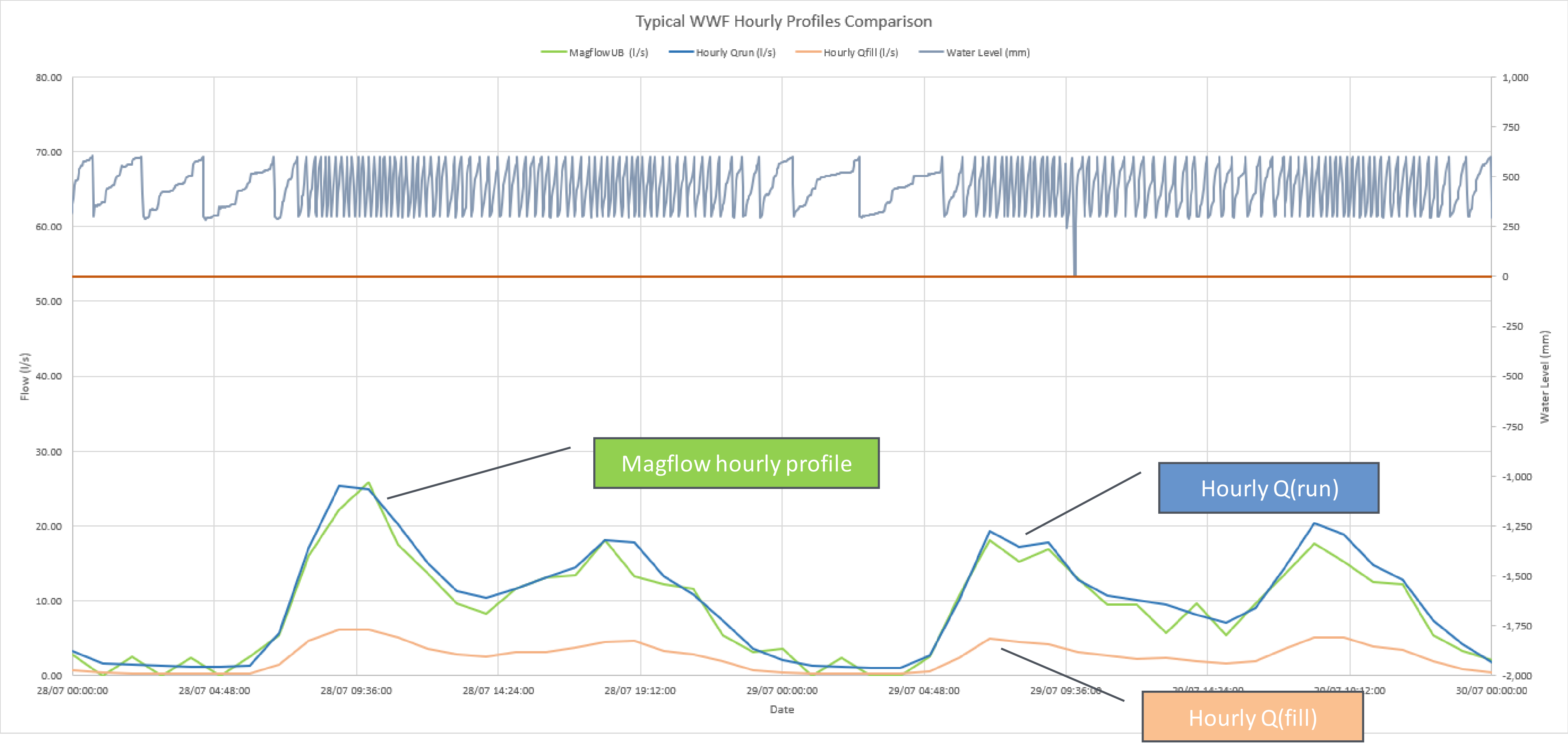
PS130 Potential Source of Error



$$Q\ (run) = Qp * \frac{t_{run}}{t(P2\ off\ - P1\ off)}$$

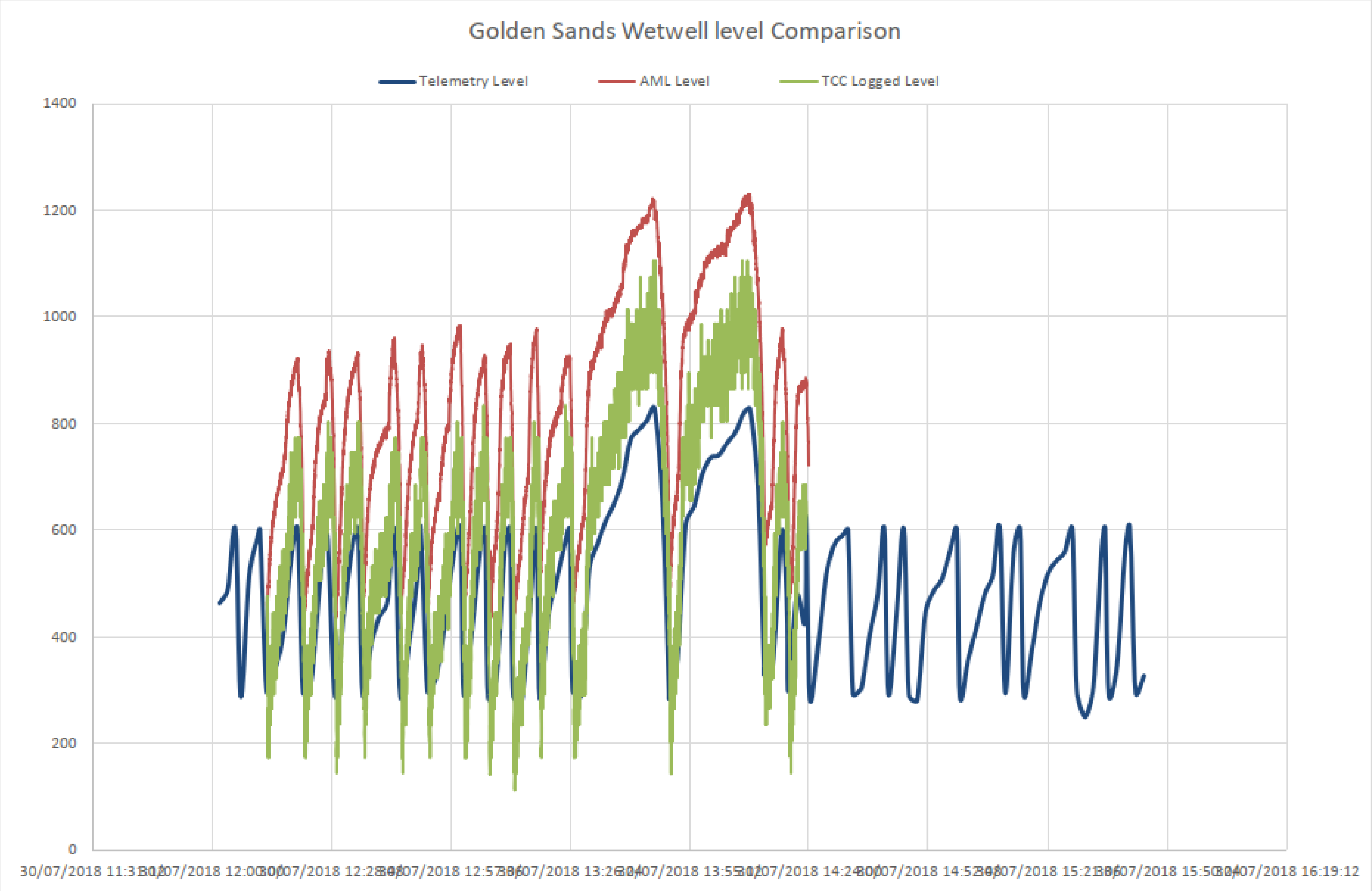
Error of 2mins = Overestimating Q(run) volumes by 57% per pump cycle

PS095 Hourly Volumes Error Quantification - WWF



Relative Error % (against Magflow Meter)	
Qfill	Qrun
-80	-10

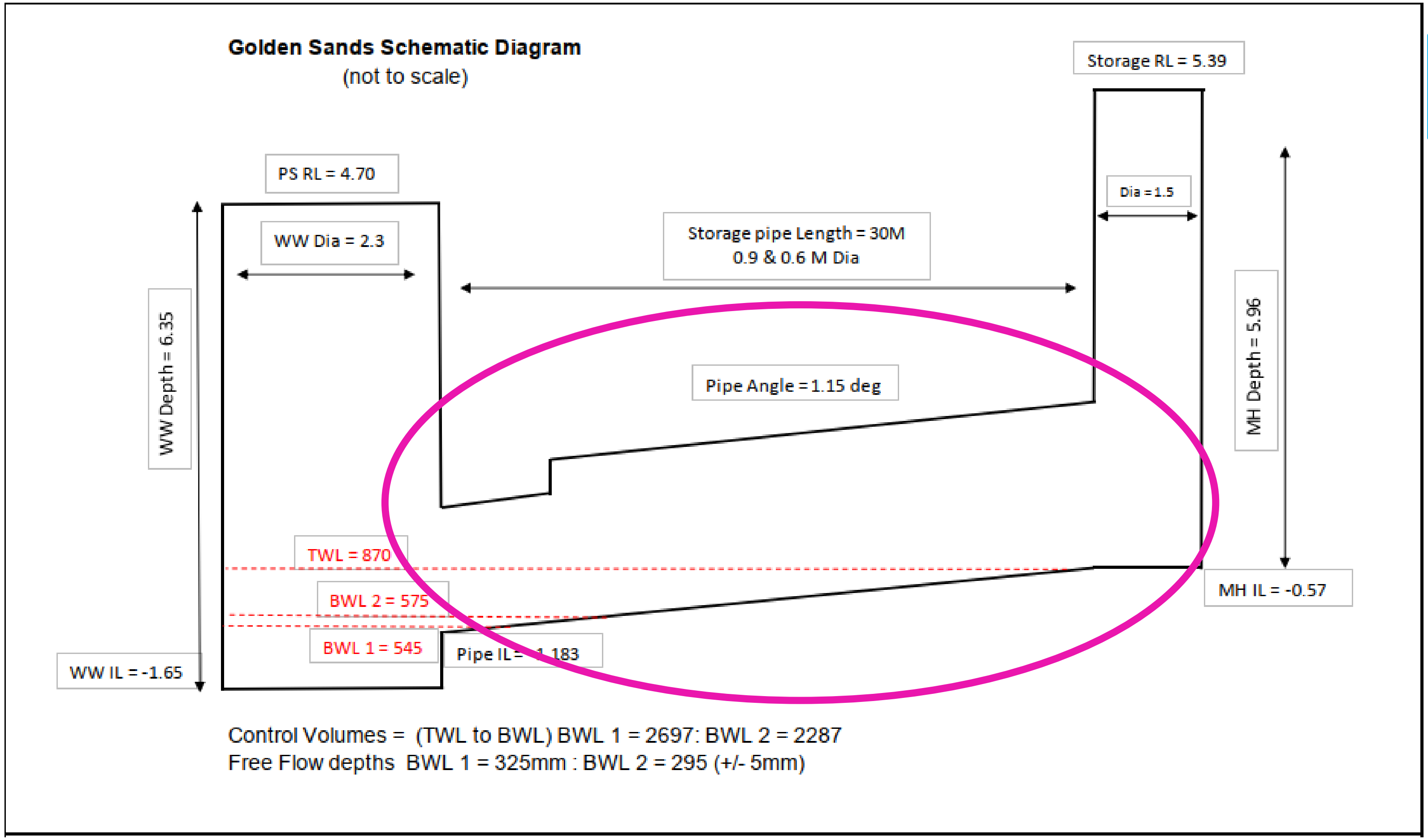
PS095 Potential Sources of Error



$$Q\,(fill) = \Delta H * \frac{Area}{t(P2\,on - P1\,off)}$$

Level sensor scaling error – both level sensor offsets and operating spans are different to that from SCADA.

PS095 Potential Sources of Error



$$Q\ (fill) = \Delta H * \frac{Area}{t(P2\ on - P1\ off)}$$

Submerged inline storage pipe – additional volumes unaccounted for in the Q(fill) inflows.

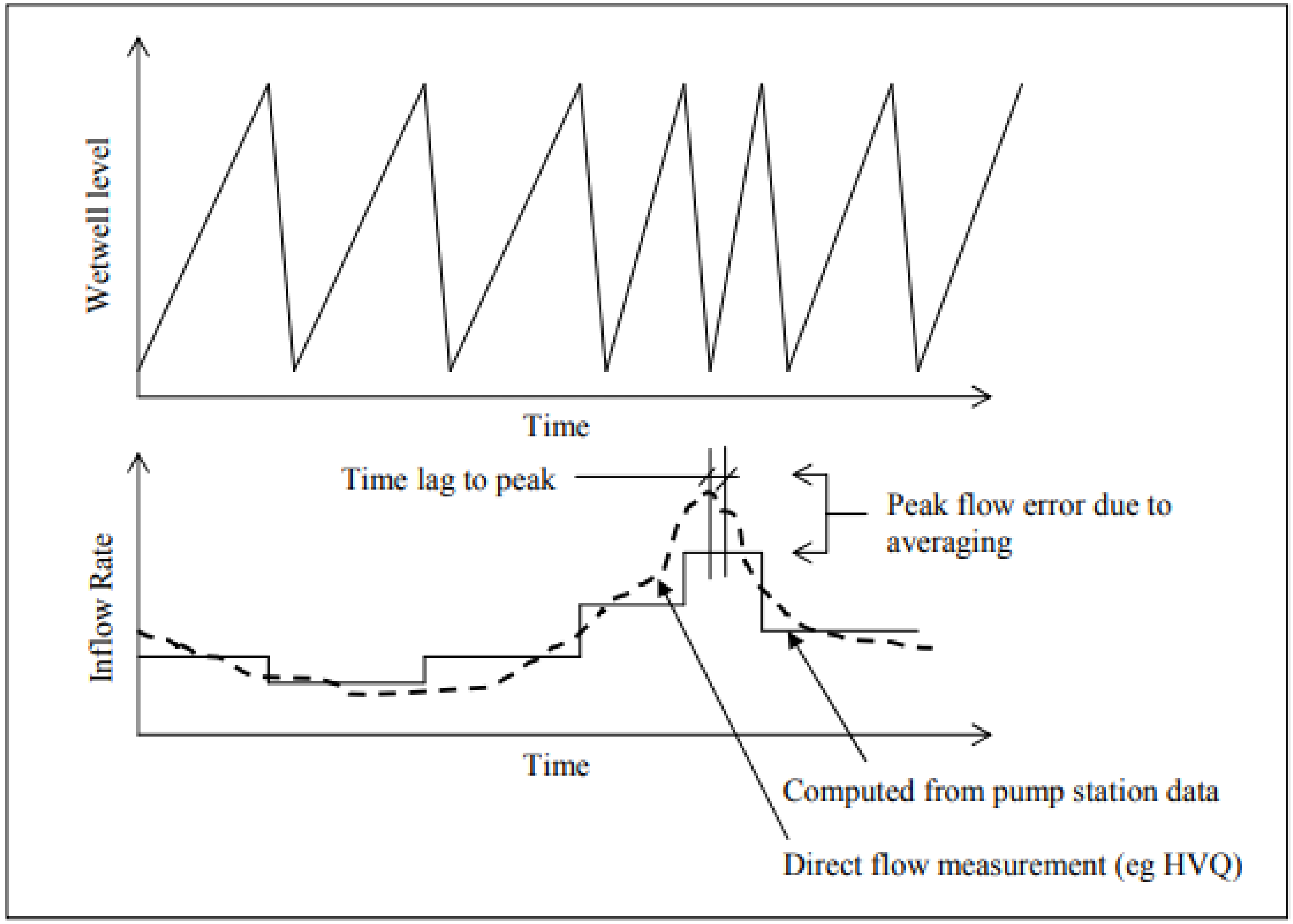
Error % Summary Table

PS Name	PS Capacity (l/s)	Period	Independent Source - Flow Volume (m3)	Error (%)	
				Q(fill)	Q(run)
PS146 Kennedy Road	96	DWF	3,800	**-70**	**-45**
		WWF	1,200	**-75**	**-45**
PS130 Landing Drive	P2 = 125 P3 = 160	DWF	11,200	**-5**	**55**
		WWF	8,100	**-50**	**-30**
PS095 Golden Sands	P1 = 56 P2 = 85	DWF	5,300	**-70**	**10**
		WWF	2,300	**-70**	**10**
PS064 Meadowland Street	80	DWF	7,200	**-5**	**-5**
		WWF	1,800	**-5**	**-5**

What now…

IS PS SCA
INFLOWS SU
CA

MORE APPR
VA



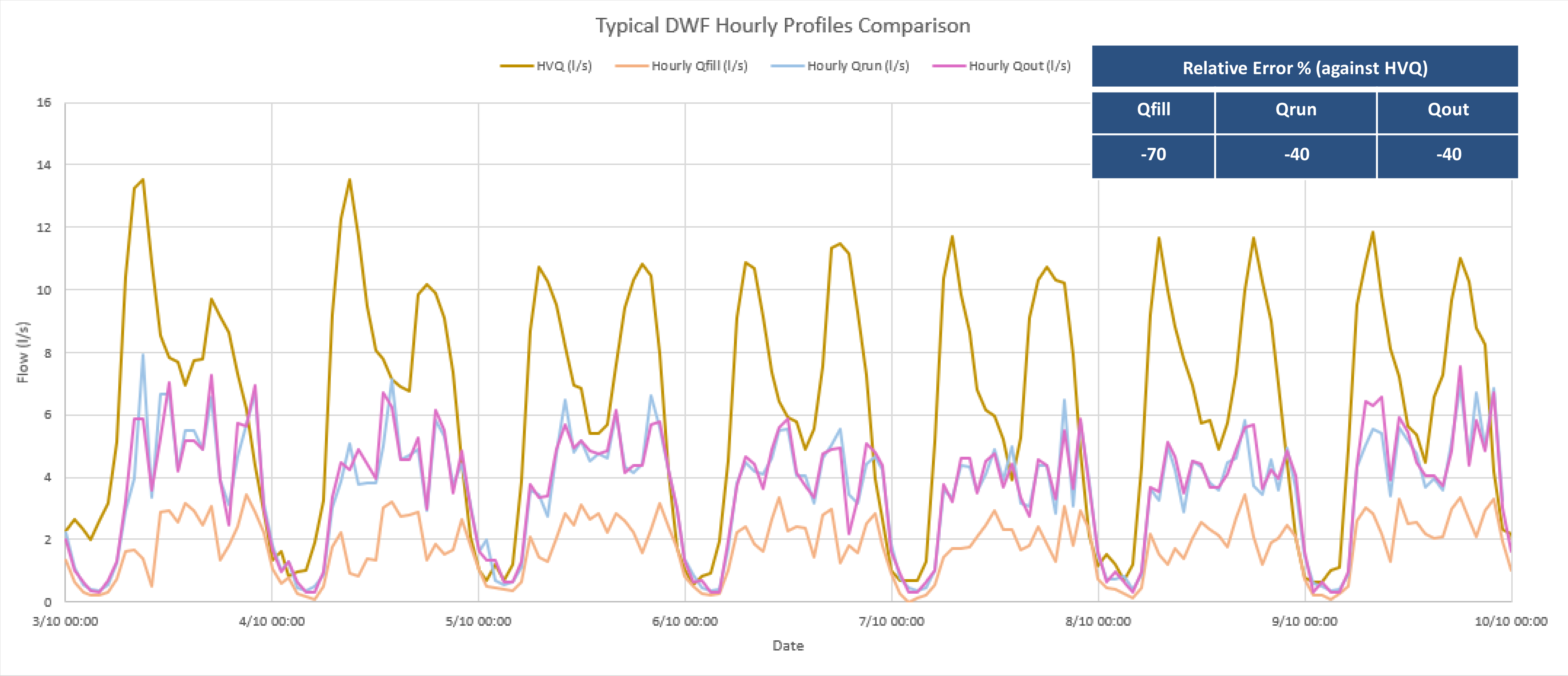
Introducing Hourly Q(out)

Total Pump Run Duration (hour)

$$Hourly\ Q\ (out) = Qp * \frac{\Sigma\ trun}{3600s}$$

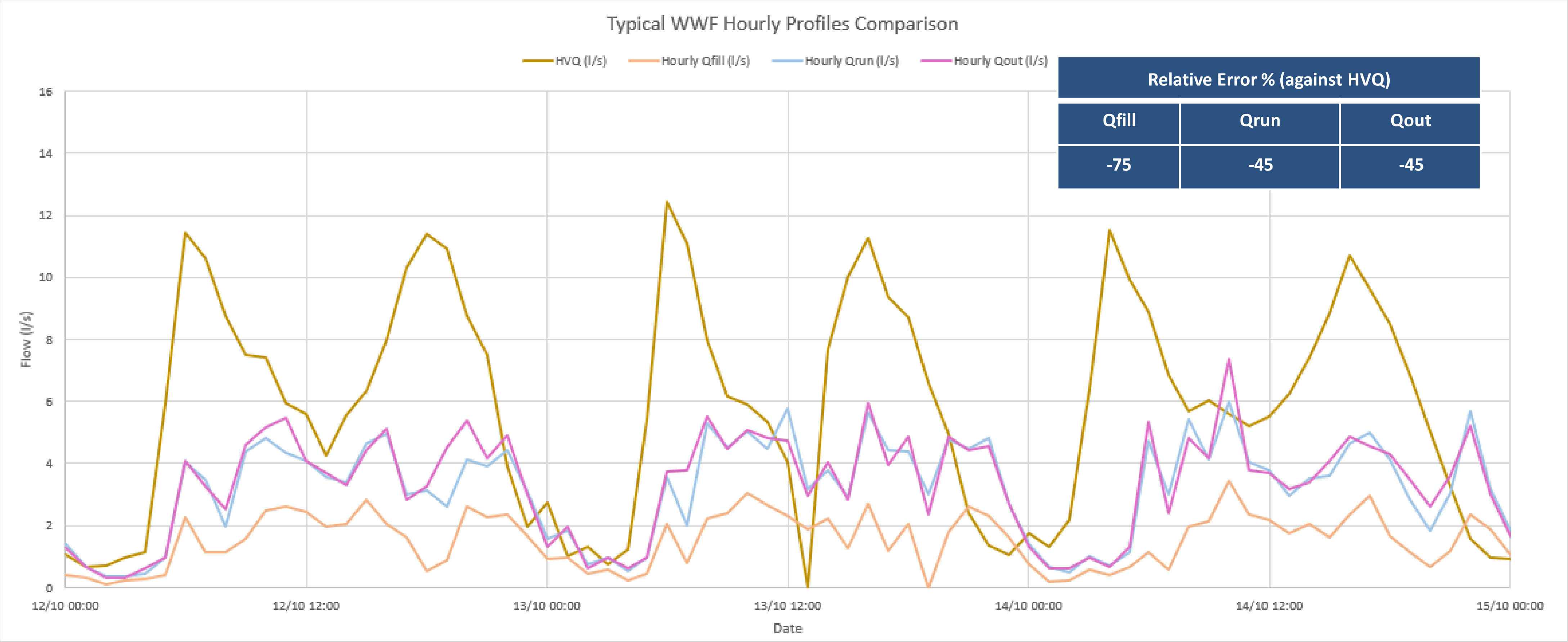
PS Capacity

PS146 Hourly Volumes Error Quantification – DWF Period



Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-70	-40	-40

PS146 Hourly Volumes Error Quantification – WWF Period



Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-75	-45	-45

Applications and Limitations – Flow Data Sources

Data Source	Inflow/ Outflow	Measured/ Calculated	Applicability		Limitations
			Model Calibration	Model Validation	
Flow Monitor (HVQ)	Inflow	Measured	√	√	• Gauge catchment area >10Ha. • Cost.
Magflow	Outflow	Measured	X	√	• Unreliable magflow.
Q(run)	Inflow	Calculated	X	√	• Requires reliable estimate of pump capacity. • Shared rising mains. • Variable speed pumps. • Requires wet well level of sufficient resolution to derive the peak inflows when the pump runs continuously/extended periods. • Pump stations that 'siphon'
Hourly Average Q(out)	Outflow	Calculated	X	√	• Requires reliable estimate of pump capacity. • Shared rising mains. • Pump stations that 'siphon'
Q(fill)	Inflow	Calculated	X	X	• Cost and time. • Pumps that run continuously/extended periods. • Requires extensive of inputs checking and data handling (level sensor scaling, pump station configuration, asset data to include storage from submerged incoming pipe/inline storage tank). • Only suitable for validation of Q(run).

↓ Flow resolution and Model calibration/validation accuracy decrease

Summary

- In-sewer gauging (HVQ) provides the highest resolution of flow and depth data.
- Where installing an HVQ is not possible, other alternatives such as PS SCADA data can be used to derive flows however accepting that the derived flows are of lower quality.
- SCADA data derived inflows (Qfill, Qrun) at a PS site is not recommended for use in model calibration given the uncertainties in the accuracy of the inputs.
- It is recommended that the hourly Q(out) methodology is adopted for model validation as it improves the following (if an accurate PS capacity estimate is available):
    - Efficiency in post-processing SCADA data for model validation
    - Accuracy of the derived flow volume

Acknowledgements

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- Nathan Shaw (HAL Consulting Ltd)

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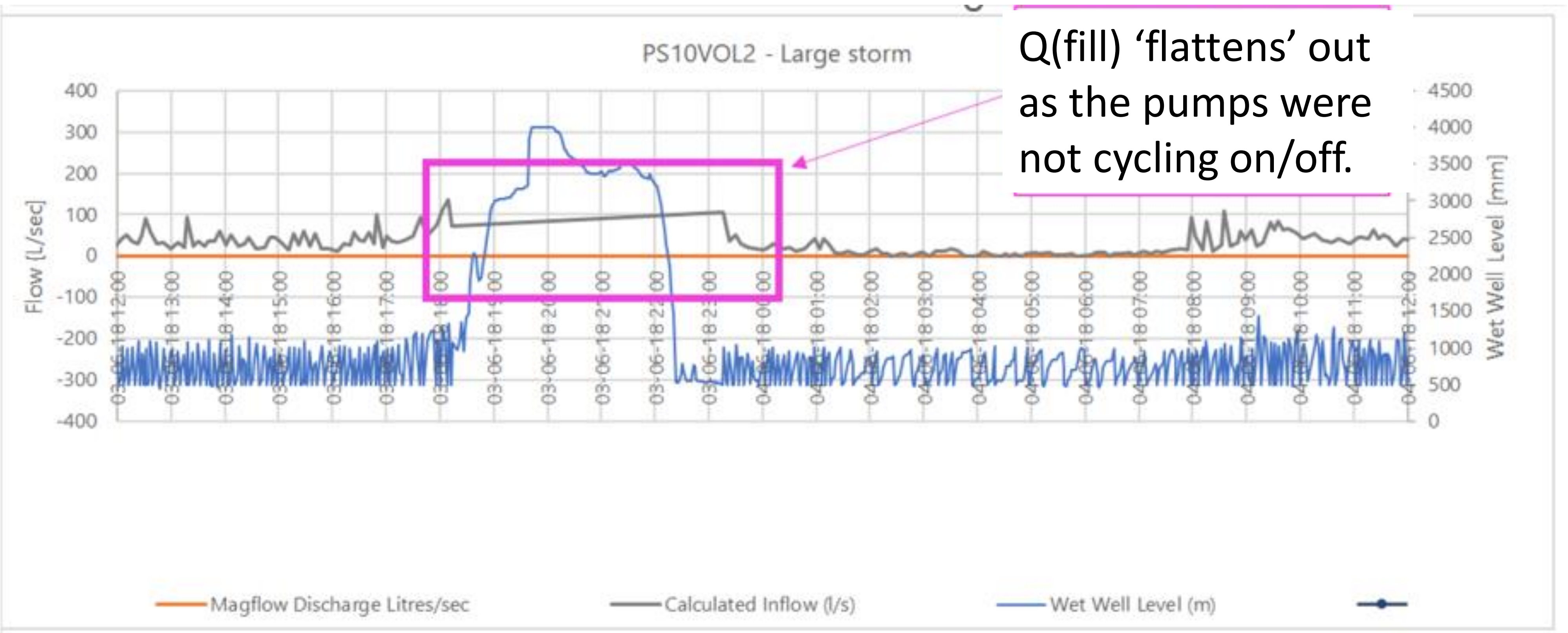
Thank you!
Questions? Patai?

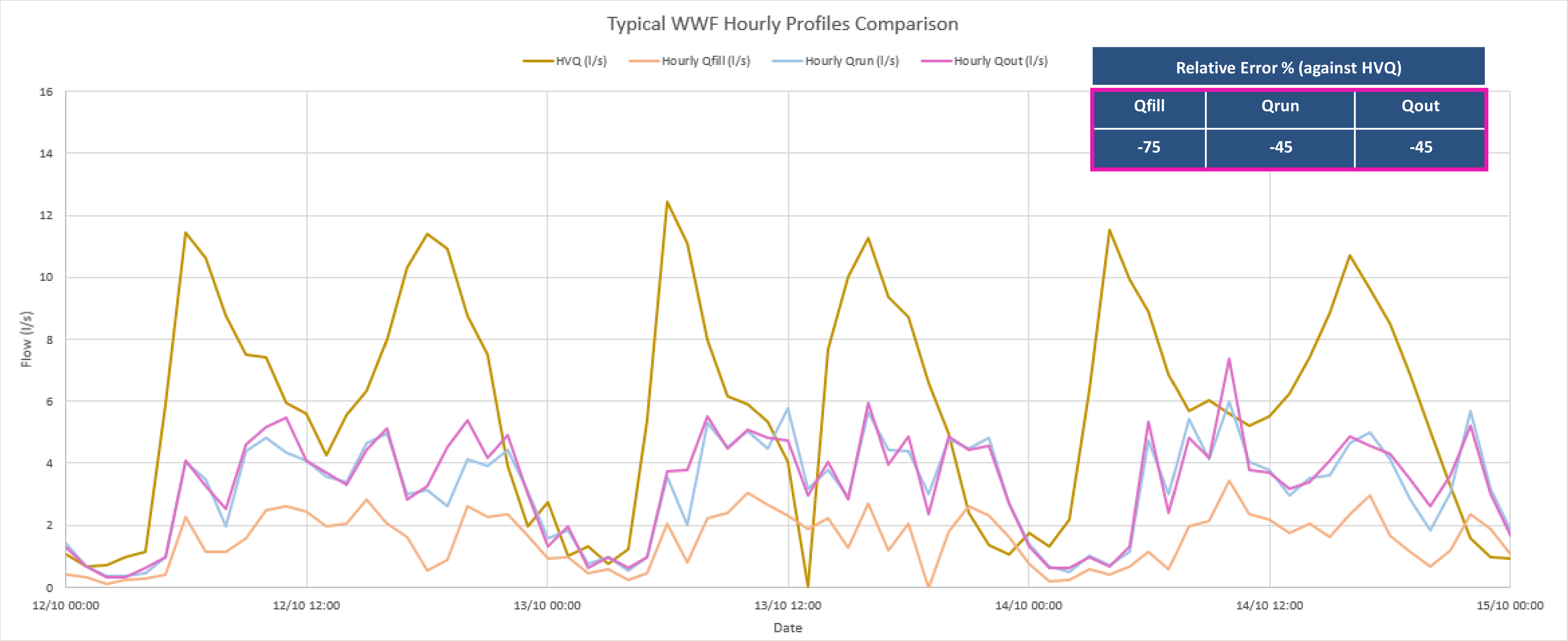
Supporting Info

Examples



PS10VOL2 - Large storm
Q(fill) ‘flattens’ out as the pumps were not cycling on/off.
Flow [L/sec]
400
300
200
100
0
-100
-200
-300
-400
Wet Well Level [mm]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Magflow Discharge Litres/sec
Calculated Inflow (l/s)
Wet Well Level (m)

PS146 Hourly Volumes Error Quantification – WWF Period



Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-75	-45	-45

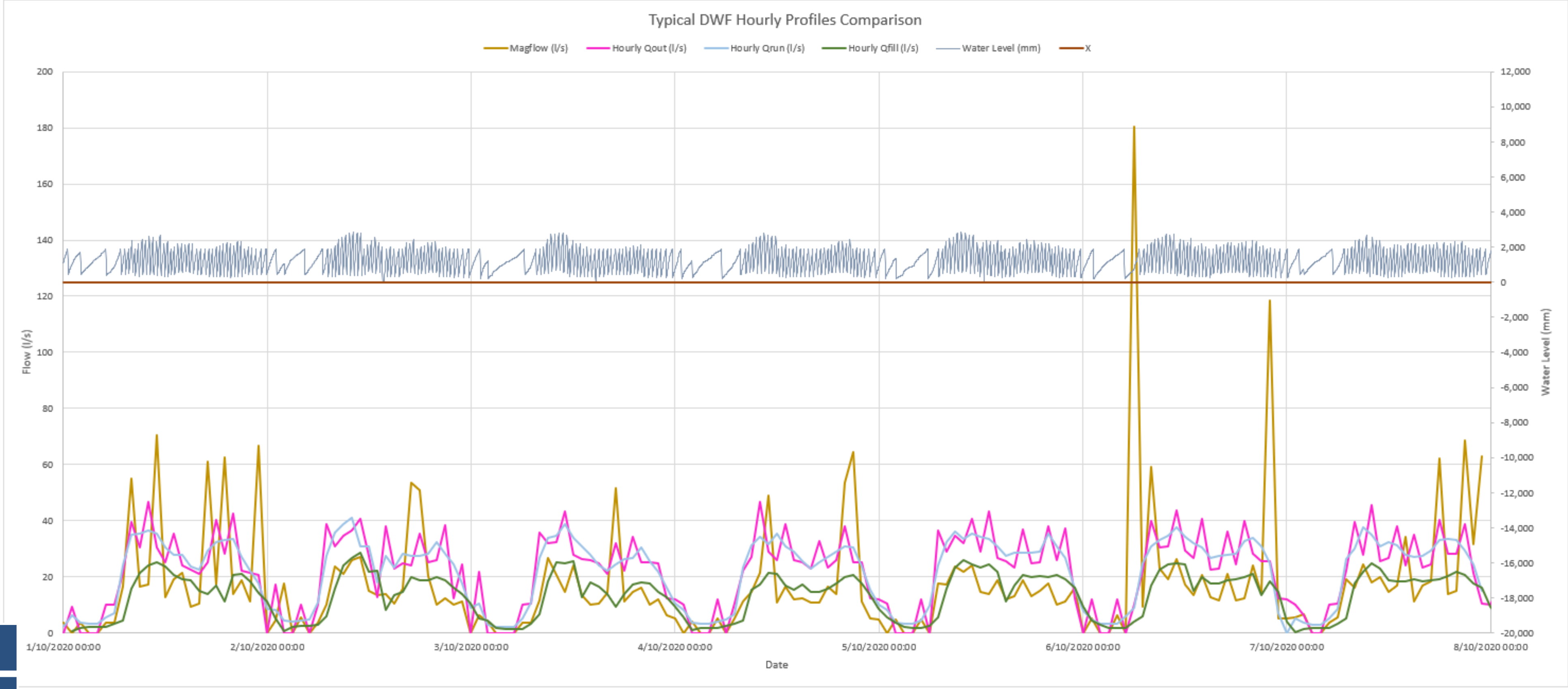
PS130 Hourly Volumes Error Quantification - DWF

PS130 Fun Facts

- Measured PS capacity 125 l/s-160 l/s
- Average pump run time ~5mins
- Average wetwell filling time ~30mins

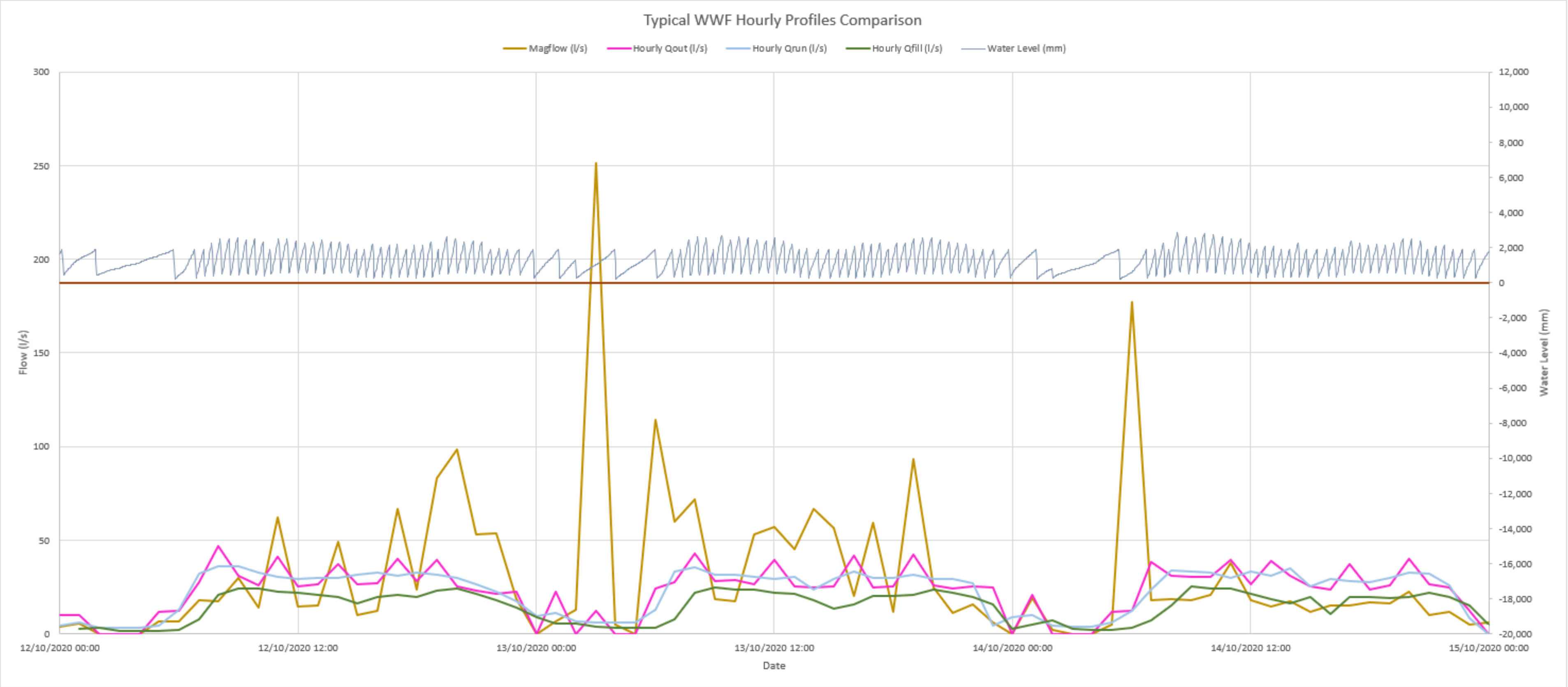
Key Findings

- Hourly Q(out) and Q(run) matched well against each other.
- Magflow and Q(fill) matched well against each other.
- Q(run) and Q(out) are significantly higher than magflow (~50%)
- Q(run) ≠ Q(fill) ?



Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-5	-55	-55

PS130 Hourly Volumes Error Quantification - WWF



Key Findings

- Hourly Q(out) and Q(run) matched well against each other.
- Multiple spikes in the magflow readings – possibly just 'noises'.
- Q(run) and hourly Q(out) total volumes underestimated by ~30%.

Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-55	-30	-30

PS095 Error Quantification - DWF

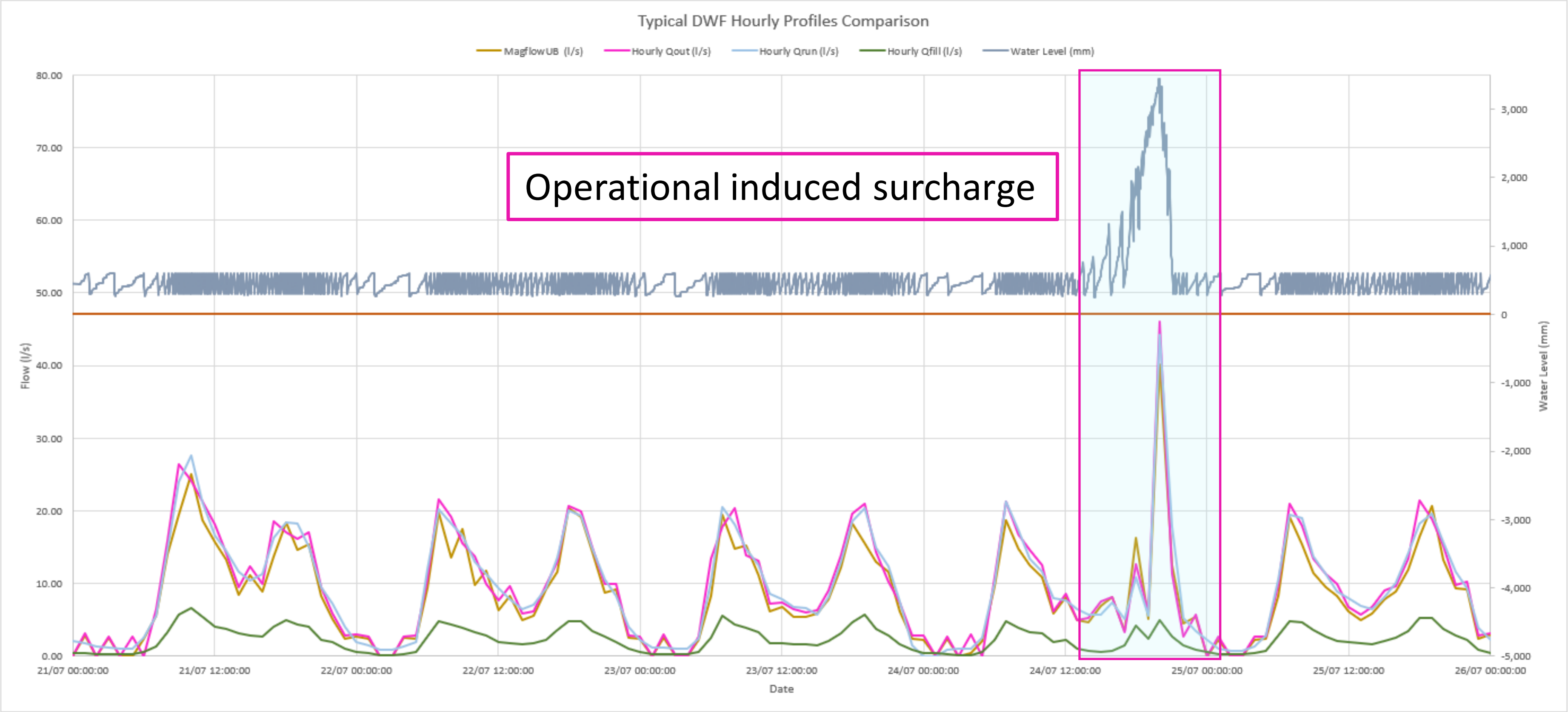
PS095 Fun Facts

- Measured PS capacity 56 l/s-85 l/s
- Average pump run time ~3mins
- Average wetwell filling time ~15mins

Key Findings

- Hourly Q(out) and Q(run) matched well against the magflow data. An error of 10%
- Q(fill) was significantly underestimated potentially because of:
    - Level sensor scaled incorrectly
    - Additional volume unaccounted for from the submerged storage pipe.

Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-65	-10	-10



PS064 Error Quantification - DWF

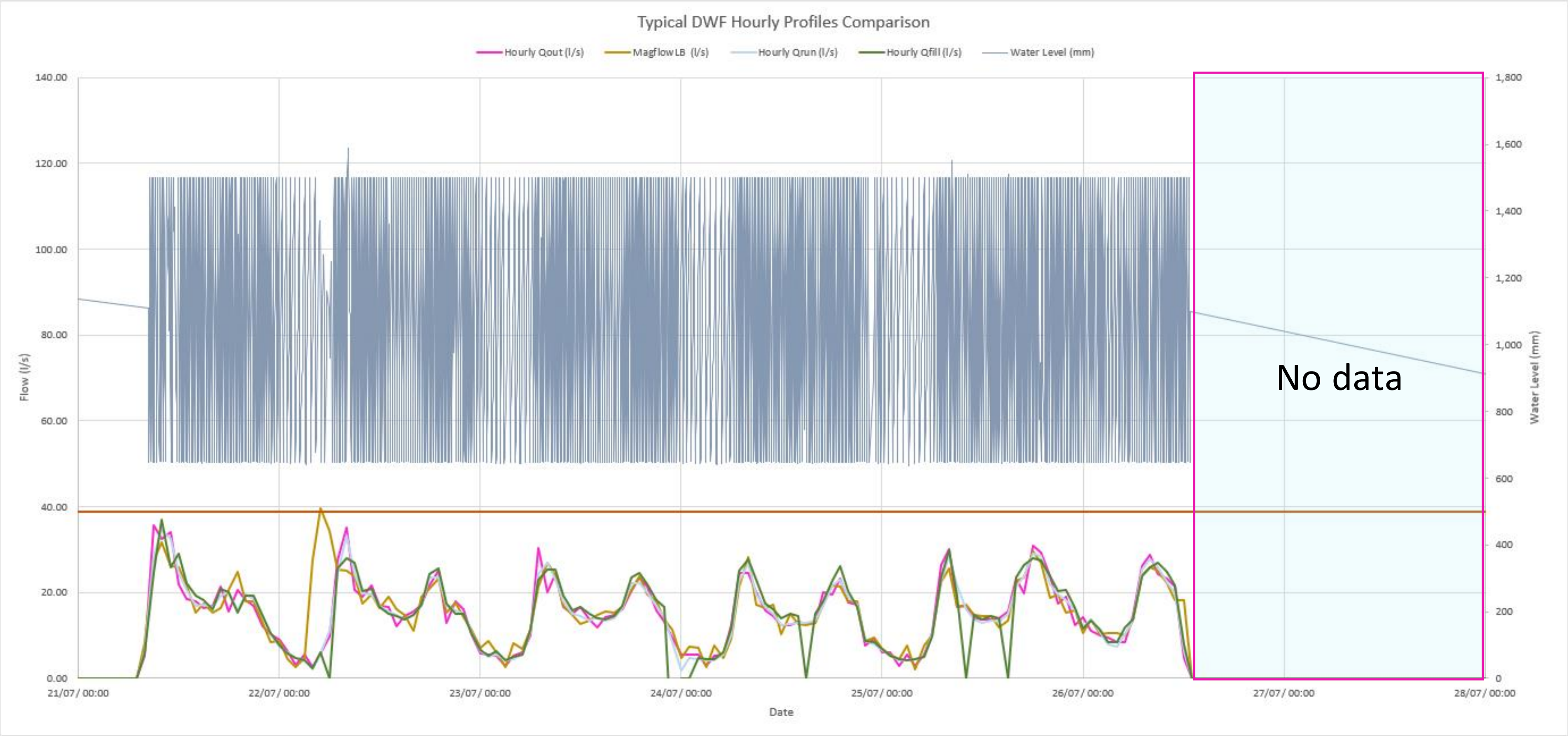
PS064 Fun Facts

- Measured PS capacity 80 l/s
- Average pump run time ~7mins
- Average wetwell filling time ~15mins

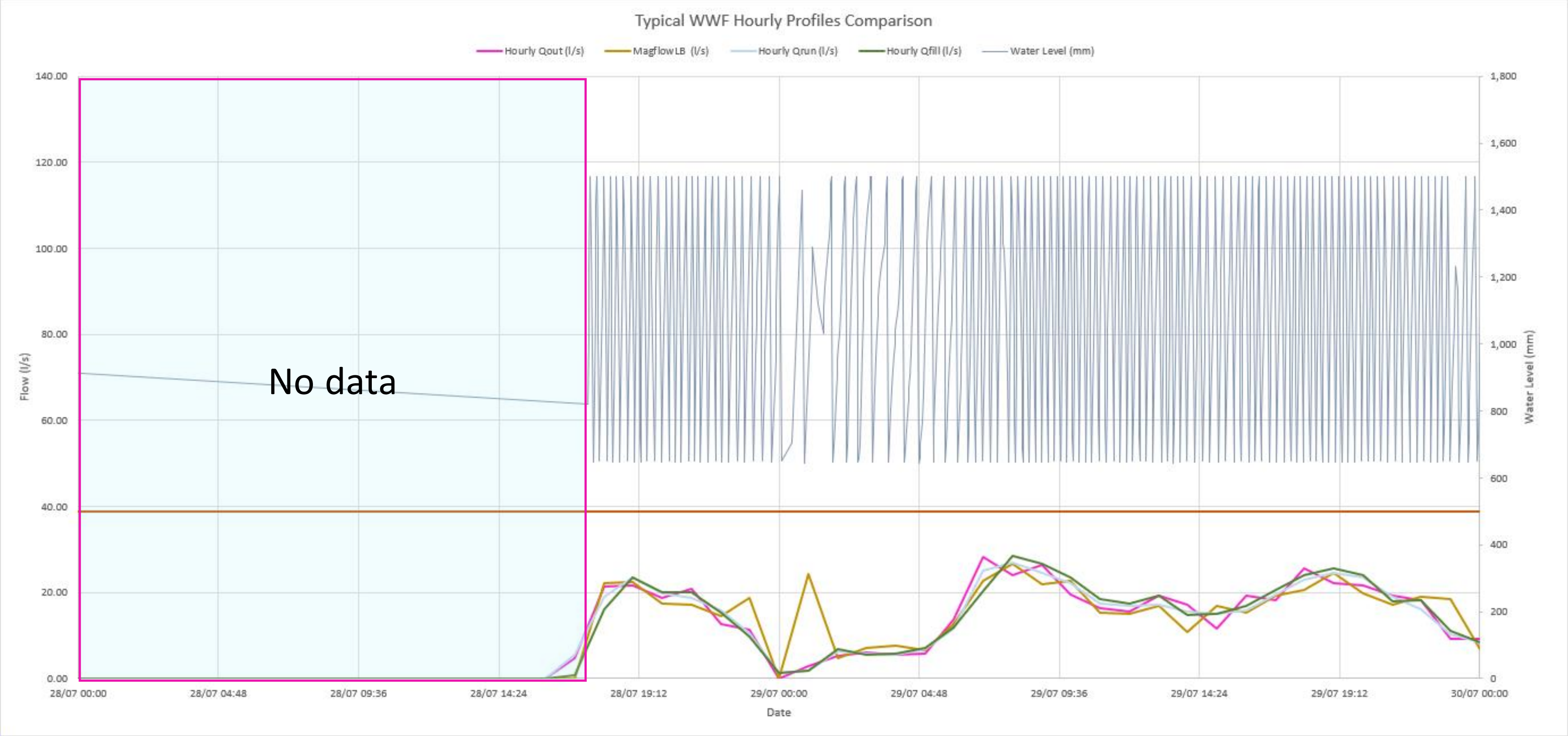
Key Findings

- Hourly Q(out), Q(run) and Q(fill) matched well against the magflow data.
- A consistent error of less than 5% was achieved for all methodologies.

Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-5	-5	-5



PS064 Error Quantification - WWF



<u>Key Findings</u>

- Hourly Q(out), Q(run) and Q(fill) matched well against the magflow data.
- A consistent error of less than 5% was achieved for all methodologies.

Relative Error % (against HVQ)		
Qfill	Qrun	Qout
-5	-5	-5

Case Study Findings

Inflow - Q(fill)

- Has the biggest error band when compared to the independent source of inflow (HVQ or Magflow).
- Relies on the wetwell level sensor being scaled correctly and accurate wetwell dimensions - good auditing tool to cross validate the reliability and accuracy of the inputs, e.g. pump rates, wet well dimensions and levels.
- Useful to determine the incoming DWF flow and the capacity of the incoming pipe if the inputs are relatively reliable and accurate.

Inflow - Q(run)

- Oversized pump station (short pump run times) has a greater error band compared to pump stations that have longer run times.
- Not suitable for use where a pump station 'siphons'.
- Requires high resolution water level data to derive the inflows when the pump runs continuously/extended periods.
- Every pump station is different, which makes applying Qfill and Qrun difficult i.e. limited economies of scale.

Hourly Outflow - Q(out)

- Q(run) is effectively Q(out) when volumes are derived at an hourly basis.
- A simpler methodology to calculate the volumes and lesser number of variables to maintain.

Recommendations

- Adopt the Qout calculation for use in the next phase of model validation
- Sampling of pump stops and starts to enable the derivation of pump run times and cross validate this against the magflow readings.
- Totalise magflow volumes (pulsing on volume and totalize on a 30min or hourly basis to save storage space) to minimize manual calculation errors.
- Temporary strap on flow meters are installed at key pump stations that pump into shared rising mains.
- Comparison of Qout estimates vs temporary strap on flow meters records should be completed to determine the improvement in measurement accuracy that can be achieved by the strap of flow meters.