Tinsley Pumping Station

PUMP AUDIT SUMMARY REPORT

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Content

1 Introduction

This report summarises the key findings of the desktop and site system audit for Tinsley Pumping Station (PS). The review is based upon:

- data provided by Canal and River Trust (The Trust)
- a preliminary site visit undertaken on 3rd July 2019
- a site investigation by Hidrostal and AMCO 23rd July on 2019
- a site audit by Arcadis and Samatrix on 13th September 2019

The site audit comprised pump performance testing carried out to establish pump duties and system curve (including rising main static head) alongside power monitoring. This incorporated recording of time-stamped data and real time measurement of pumped flow, pressure and wet well level using calibrated instrumentation and sensors in conjunction with measurement of key electrical parameters, e.g. current, voltage, power and power factor (P.F.), using power meter voltage probes and current transducers.

Figure 1 – Photographs taken during site audit (Top left: pressure transducer connected to top of check valve, Top right: Common discharge pipework and flow meter arrangement, Bottom left: 'Fluke' meter connected to terminals inside MCC; Bottom right: Data recorder and laptop)

2 System Description

2.1 Pumping Station

Tinsley PS is situated in the Northeast of Sheffield, UK and is located downstream of Tinsley No 9 Lock on the Sheffield & Tinsley Canal, which is part of the Sheffield and South Yorkshire Navigation.

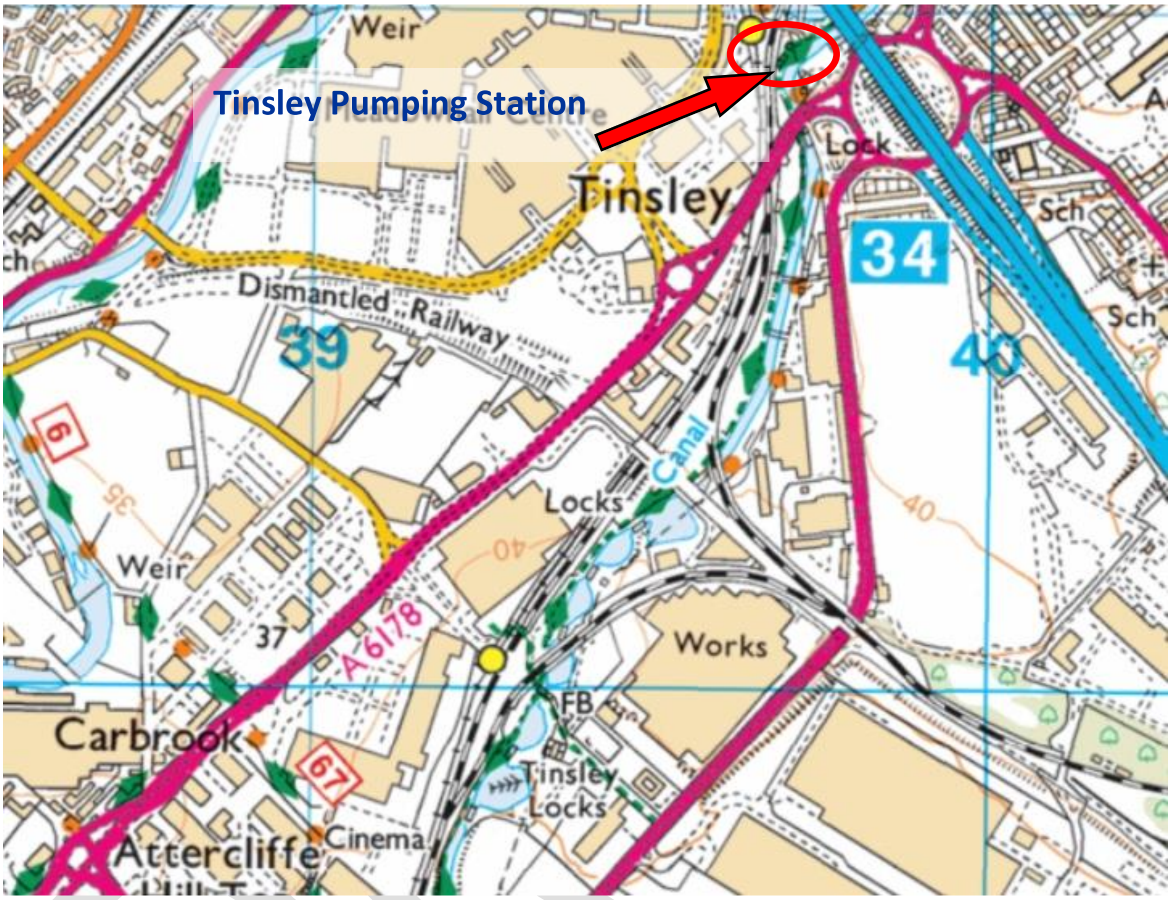


Figure 2 – Tinsley Pumping Station location

Tinsley PS was formerly a steam engine pumping station, which was replaced by a diesel engine in 1918, and comprises two brick buildings (one of which is derelict).

Tinsley PS now comprises 2No. fixed-speed, submersible pumps. The pumps are automatically controlled on a remote, upstream Supervisory Control and Data Acquisition (SCADA) system control level on a duty/standby basis. There is no downstream level measurement within the wet well. The pumps are reported to be occasionally run in 'HAND' and manually operated in parallel in a duty/assist mode during periods of particularly low canal level. The provided SCADA data appears to confirm this as flow rates of up to 200 l/s have been recorded.

The pumping station intake abstracts from the River Don via a 70 m long arched culvert complete with a bar screen and horizontal heading which has an intermediate manhole/access chamber. A wooden paddle gate located at the intake was previously creating a restriction to the incoming flow and has now been removed.

Figure 3 – Tinsley Pump Station building

The pumps are located within a wet well chamber and the well base is reported to have been modified in 2015 when the existing KSB KRT K150-401/654UG-S pumps were replaced. The provided information for current pumps indicate ex-hire Flygt NP3301.180 HT 456 with 370 mm diameter impellers, although there is some uncertainty over its accuracy for both pumps.

Figure 4 – Tinsley Pump Station basement area pipework

DN250 pump discharge pipework is located within the basement / lower level of the existing pumping station building. Each pump has a recoil swing check valve with pressure gauge and an isolation gate valve.

The discharge pipework from each pump combine into a DN300 common header pipe. There is also an air valve, with discharge piped back to the wet well, a flow meter and isolation valve on the common header pipework within the building.

The common pipework connects to existing cast iron pipework prior to exiting the pump house and then the pumps discharge to upstream of Tinsley Top Lock (Upper Flight) No.1. via an outfall pipe of approximately 600 mm diameter. There are no available records to confirm the actual rising main diameter.

Table 1 – Pump Details (based on information provided)

PARAMETER	DESCRIPTION
Pumps	Flygt NP3301.180 HT
No. of Pumps	2
Duty Configuration	Duty/Standby (Submersible)
Rated Motor Output	55 kW
Impeller Diameter	370 mm
BEP	98.7 l/s @ 36.5 m
Drives	Soft Start
Pipework	DN250 pump discharge; DN300 common header
Non-Return Valves	Recoil (Non-slam) Swing Check
Wet Well Level Sensor	None
Pump Level	29.22 mAOD (estimated*)

* Refer to Appendix F

The main incomer and associated electrical equipment are located at the upper level on a raised walkway with the pump Motor Control Centre (MCC) positioned on a steel access platform – the incoming power supply fusegear rating is 400 A. The pumps are provided with soft start drives that are set at 5 second ramp to full load current (FLC) and 10 second run-off.

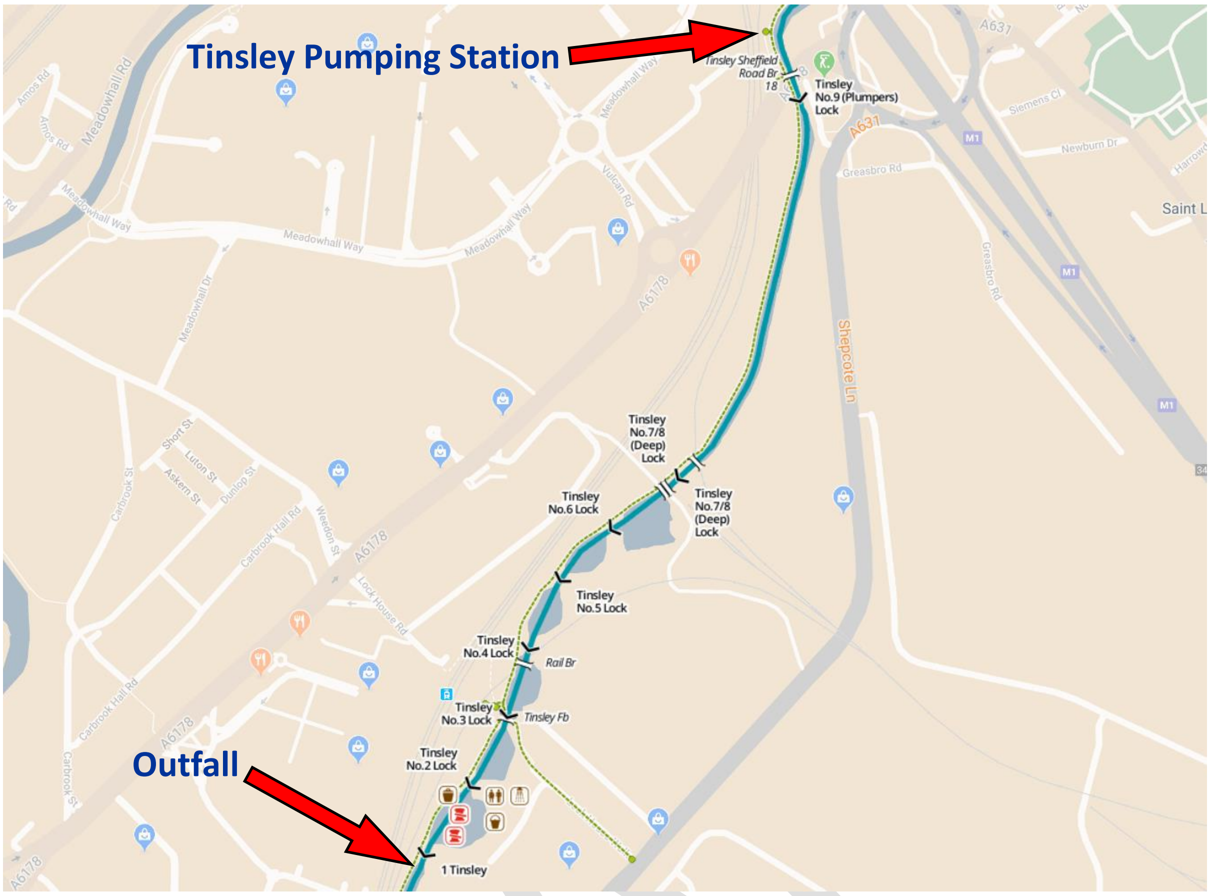


Figure 5 – Sheffield & Tinsley Canal Map, Tinsley Lock Flight

2.2 Rising Main

The rising main is an estimated 1300 m in length and manufactured from cast iron. The rising main age and condition are unknown but is reported to be original cast iron which could be up to 200 years old and has historically suffered two major blowouts.

The rising main route is unconfirmed but has been estimated from Geographic Information System (GIS) data. The outfall is assumed to be a 24-inch (circa 600 mm) diameter, free discharge open pipe. There are no isolation valves or off-takes reported on the rising main downstream of the pumping station.

Table 2 – Rising Main Details

PARAMETER	DESCRIPTION
Approx. Length	1300 m
Pipe Diameter	24" (assumed)
Discharge Level	51.934 mAOD (estimated IL)
Pipe Material	Cast Iron
Pipe Roughness	40 mm (estimated average)

2.3 Particular Issues

2.3.1 River Intake and Debris

There have been numerous reported instances of pump failures and blockages, mainly due to debris and rubbish entering the wet well, resulting in high maintenance costs from the associated pump damage/wear (Figure 6).

Provision of new pumps with a ‘non-clog’, hardened impeller is expected to reduce the frequency of issues with pump blockages and wear caused by silt and debris that may enter the wet well.

Blockage of the bar screen located at the intake on the River Don can also cause a restriction to the incoming flow, reducing the level within the wet well whilst the pumps are operating, and there is currently no method of monitoring this except by visual inspection.

Pending the improvement outcome of the pump impeller change, an alternative solution may be required in lieu of the bar screen, which is manually raked, in order to minimise these occurrences and associated operator intervention.

Figure 6 – Examples of pump blockages and damage associated with previous KSB installation

2.3.2 Wet Well Configuration and Flow Presentation

It is noted that the wet well diameter of 2300 mm is less than the Flygt minimum recommended diameter of 2500 mm for a NP3301 HT pump, but the separation distance between the pump units is adequate.

As shown in Figure 7, the orientation of the pumps is not aligned with the inlet, so it could be possible that the hydraulic presentation to each pump differs. The recommendation position of the inlet for Flygt pumps is with a 120° sector opposite the discharge pipes (Figure 8).

Photo: 2_15a
37.2m, General Observation, Remark: Pumps at Pump Sump Chamber

Figure 7 – CCTV survey photo showing view of pumps from culvert at wet well inlet

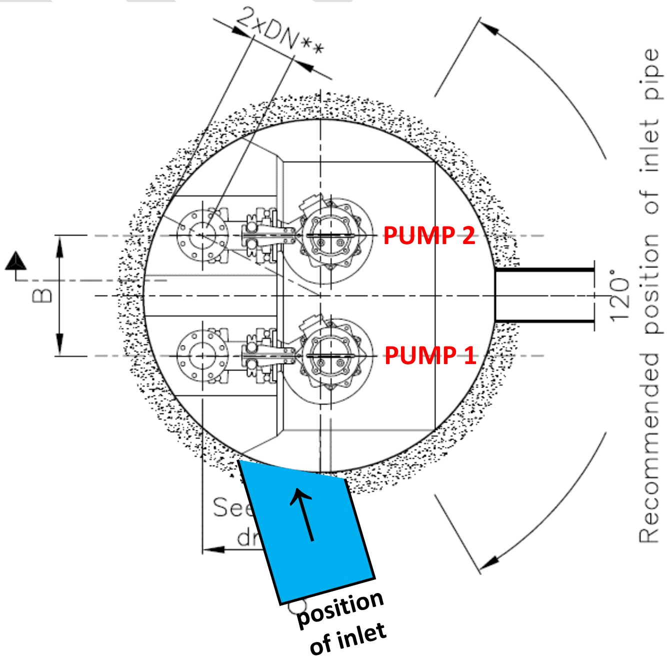


Figure 8 – Recommended pumping station intake positioning and approximate orientation of culvert

The orientation of the inlet culvert into the pump sump results in flows entering the pumps from the side, in addition it appears that the culvert may be offset from the centreline of the wet well. The operation of the far-side pump is more impeded by the near-side pump and this potentially could affect the pump performance.

Since the pumps do not normally operate in parallel, the effect on the hydraulics should be minimal. However, the far side pump could be encountering a degree of swirl or poorer flow presentation at the pump intake (possibly in the same direction of rotation as that of the pump impeller). Swirl can cause a change in the operating conditions of the pumps with a tendency for the flow capacity and efficiency to decrease.

2.3.3 Pump Capacity and Summit Pound Losses

Due to leakages at the summit pound, estimated to be 24.1 megalitres per week, the pumping station needs to operate all year round. If the pumps fail, the canal will become unnavigable within 3 days. The target flow rate needed in the order to meet the requirements is 130 l/s to 140 l/s.

The Trust previously reported that one pump is only able to deliver circa 105 l/s, which is sufficient only to maintain the upstream level. The other pump, however, can deliver circa 130 l/s which allows the level to be recovered. This difference in capacity between the two pumps is confirmed by the site audit data.

2.3.4 Surge and Transient Pressures

A pump trip scenario was simulated during the site audit, the results of which indicates transient pressures peaking at over 4 bar (Appendix E). This value is in line with expectations when compared with theoretical calculation of pressure due to water hammer for a 24” grey cast iron pipe using the Joukowsky equation.

2.3.5 Other Observations

- No up-to-date as-built/record drawings of wet well and pump station building are available. The KSB GA drawing as shown in Appendix D is not “as-built” although AMCO measurement reports during the dewatering in August 2019 suggest the KSB drawing wet well depth is within 50 mm accuracy and the well diameter within 10 mm accuracy.
- No up-to-date as-built/record drawings of rising main are available
- No O&M manuals appear to be kept on site; however, single line diagram and circuit chart are displayed on a wall inside the pump station building
- The installed pump pressure gauges were not functional during the initial site visit
- There is no connection for standby generator in the event of power failure at the site
- Nameplates on the MCC are for the previous KSB pump units and not current Flygt pumps
- Electrical installation and switchgear may no longer comply with current standards (e.g. BS EN 61439 or IET Wiring Regulations) due to age

3 System Curves

To evaluate the hydraulic performance of the pumps and pipeline, system curves are used. A guide to system curves and how to read them is provided in Appendix A.

The system curves have been derived based on site audit data and the information provided. Elevations and water levels have been based on site audit data in addition to river level data, and the desktop SCADA data and record drawings provided.

The installed pumps have a dissimilar performance. This is indicated by SCADA which shows two distinct flow rates (Figure 12).

The SCADA data also suggests flows of up to 210 l/s are present and this is supported by the site data which indicates flows in excess of 200 l/s when both pumps were operated at the same time as duty/assist.

A very high pipe roughness of 40 mm was needed in the system curve calculations to correlate with the site measured flow and pressure data. Possible reasons for this include:

- Heavy tuberculation due to the pipe age
- Possible restriction/blockage on the rising main
- A lower actual nominal rising main diameter (incorrect assumption)

Variations in pipe roughness and wall thickness along the rising main are also expected as cast iron pipe of this age is most likely to be vertically pit-cast.

As it can be seen from Figures 9 and 10, the measured Flygt pump performance varies significantly from the "as new" manufacturer pump curves.

Flow rates of 124 l/s for pump 1 and 109 l/s for pump 2 respectively were recorded during the site audit which verifies the difference in pump capacity (Figure 9, Figure 10 and Figure 12). There could be many reasons for the differences between pump 1 and 2 pump curves and the actual site measurements, with possibilities including:

- Different actual pump impeller diameter or model
- Poor wet well/sump hydraulics
- Data inaccuracies/incorrect assumptions regarding the existing pumps and rising main
- Heavy wear

Excessive pump wear could also be a cause of the difference and, or reduction in the expected pump capacity. Based on a 370 mm impeller, the measured pump flow rates would equate to approximately 5.7% wear for pump 1 and 10.2% wear for pump 2.

As stated in Section 2.3.2, swirl conditions may have a negative influence on the pump performance. This may be a factor here, but this extent of impact to the flows to the degree measured would not normally be expected to occur.

Given the significant variance in flows, the actual pump performance curves are suspected to be different, possibly same models with different impellers (or possibly different units altogether). Subsequent research into various other manufacturer pump curves was carried out, and it is thought that both units are Flygt NP3301 180 HT model pumps, and that pump 1 has a 456 370 mm impeller but that pump 2 may be fitted with a 458 350 mm impeller. The performance curves for these two impellers are compared to the actual measured pump performance in Figure 9 and Figure 10.

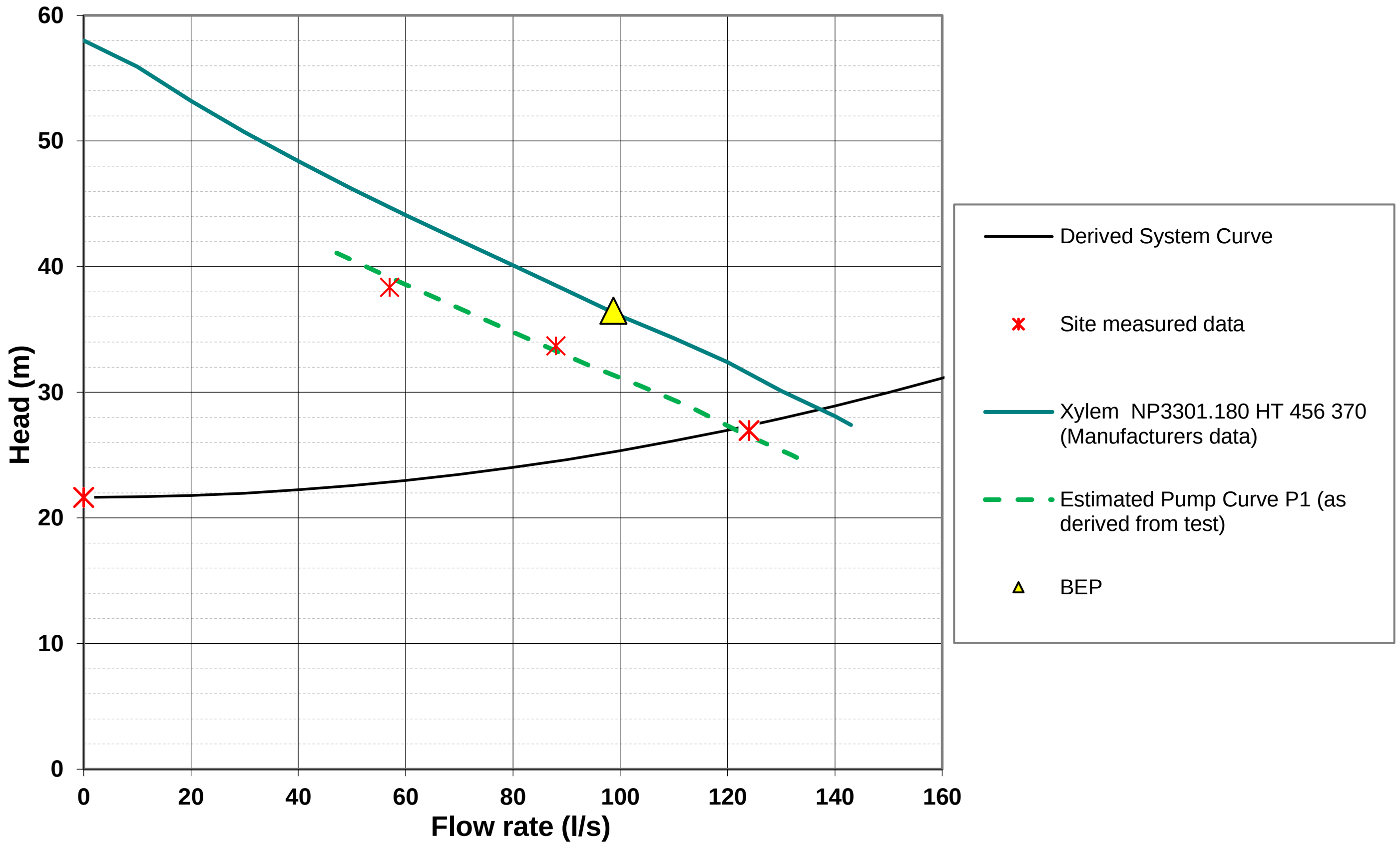


Figure 9 – Derived system curve and pump curves (Site data vs Xylem pump curve) for Tinsley PS, Pump 1

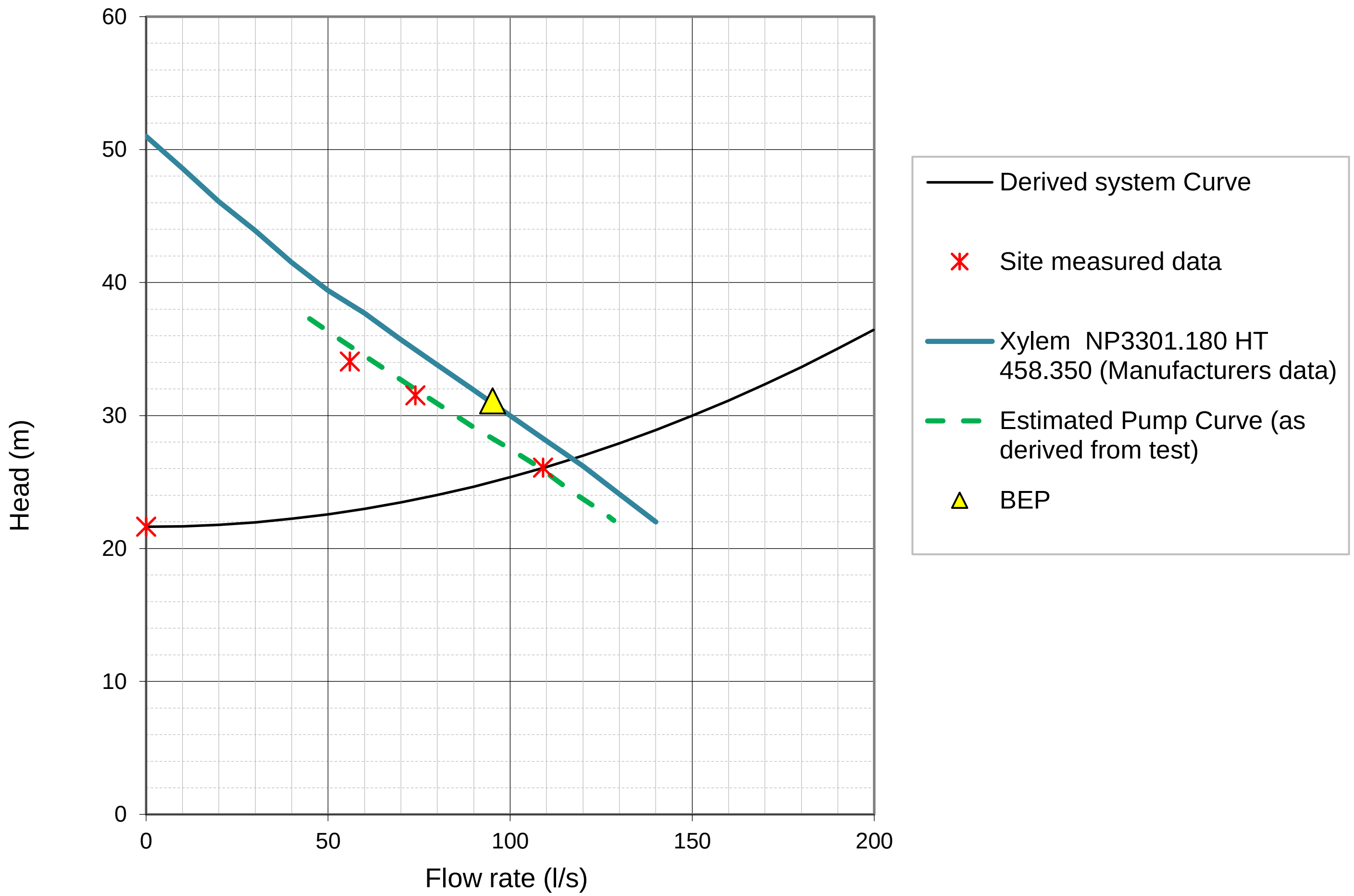


Figure 10 – Derived system curve and pump curves (Site data vs Xylem pump curve) for Tinsley PS, Pump 2

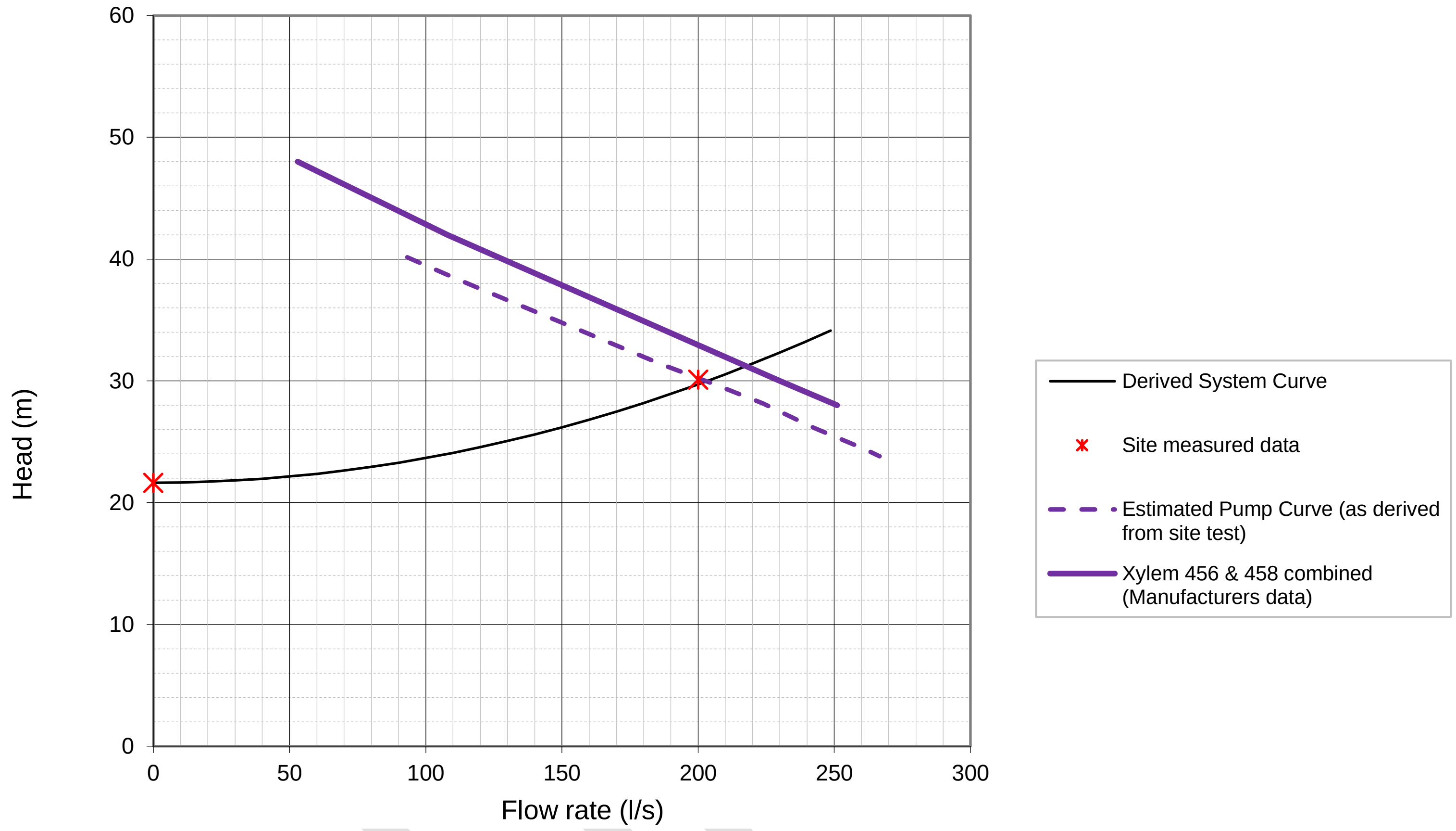


Figure 11 – Derived system curve and pump curves (Site data vs Xylem pump curve) for Tinsley PS, Two pumps in operating parallel

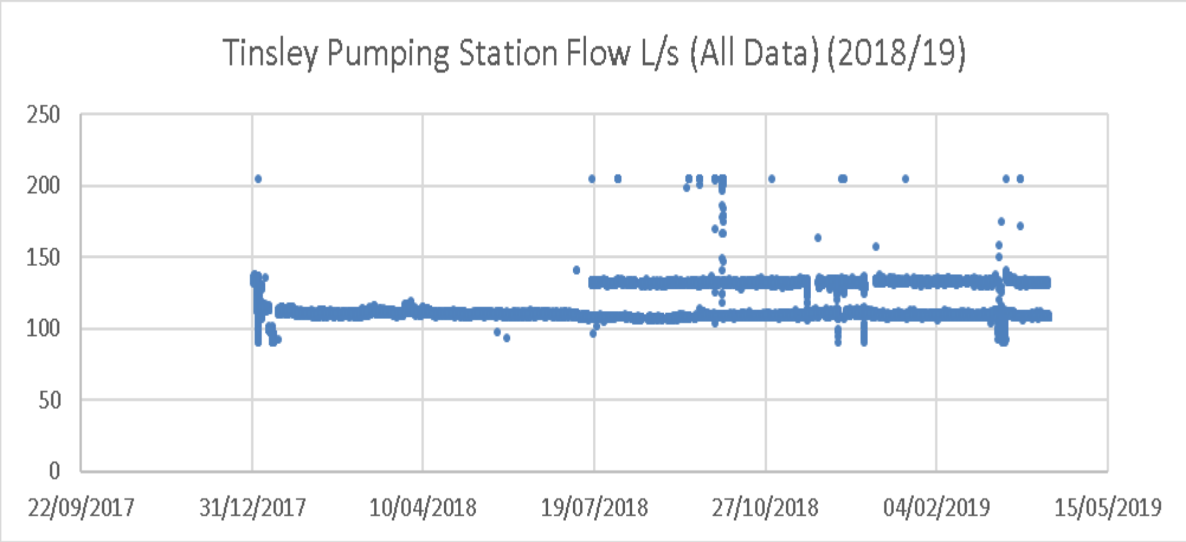


Figure 12 – Tinsley PS SCADA flow rate data 2018/19

4 Net Positive Suction Head (NPSH) and Submergence

A relative safety margin for NPSH of 30% or 2m is the WIMES[1] default requirement for submersible pumps. NSPH calculations have been undertaken and the results suggest that there is approximately a 1.2 m margin at the worst-case bottom water level (BWL), between NPSH required (NPSHr) and NPSH available (NPSHa) – see Figure 13. This BWL has been based on the recommended minimum 430 mm submergence depth for a NP3301.180 HT submersible pump at 29.221 mAOD and is 1.3 m below Minimum River Level (Appendix F).

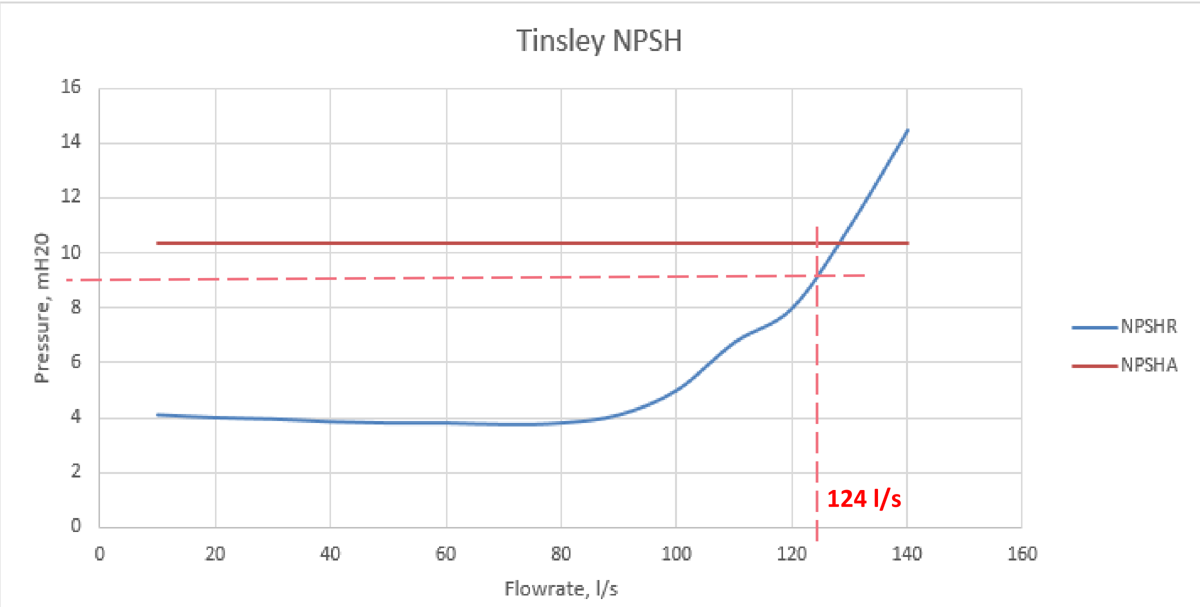


Figure 13 – Comparison of NPSHr curve for a NP3301.180 HT pump and NPSHa at Tinsley PS

[1] WIMES – Water Industry Mechanical Electrical Specification 1.02 – Submersible Pumps

The result is unsurprising given that the pump units are operating to the right side of their performance curve region and BEP. However, it is not known if any evidence of cavitation currently exists as none of the previous pump repair reports or photographs provided suggest this.

At present this does not appear to be causing any issues, but it should be noted that the difference between NSPHr (c.9.2 m) and NPSHa (c.10.4 m) of 1.2m does not meet design best practice when running at 124 l/s with the above BWL. This has the potential to cause issues with long-term operation and functionality, bearing in mind that 124 l/s is an average flow rate, particularly on occasions when the incoming flow is impeded as there is no low level/dry-run protection in the wet well.

Initial ANSI-98 submergence calculations, based on the levels shown on record drawings, indicate that there is sufficient water coverage above the pumps during normal operating river levels; therefore, submergence and the formation of surface vortices are not an issue at this station.

5 Energy Analysis

During the pump audit visit by Samatrix, a temporary "Fluke" power meter was connected at each individual pump starter compartment to record power into the soft start drives. From the measured power, flow and pressure data recorded, an analysis of pumping efficiency and the amount of energy needed to pump flows has been undertaken.

Table 3 summarises the measured input power, and derived efficiency and specific energy findings.

Table 3 – Summary of Input Power, Efficiency and Specific Energy from site audit measured data

PUMP CONFIGURATION	MEASURED FLOW RATE (L/S)	MEASURED POWER FACTOR	MEASURED POWER (KW)	OVERALL PUMP EFFICIENCY	SPECIFIC ENERGY (KWH/1000 M^3)
Pump 1	124	0.81	60	**53%**	**134.4**
Pump 1 (Throttled d/s* valve)	88	0.80	52	55%	164.1
Pump 1 (Throttled d/s* valve)	57	0.77	45	47%	219.3
Pump 1 + Pump 2 (Power measured at Pump 1)	200	0.80	57	51%**	155.6
Pump 2	109	0.95	59	**47%**	**150.4**
Pump 2 (Throttled d/s* valve)	74	0.96	53	43%	198.9
Pump 2 (Throttled d/s* valve)	56	0.97	51	36%	253.0
Pump 2 + Pump 1	200	0.96	55	48%**	155.6

PUMP CONFIGURATION	MEASURED FLOW RATE (L/S)	MEASURED POWER FACTOR	MEASURED POWER (KW)	OVERALL PUMP EFFICIENCY	SPECIFIC ENERGY (KWH/1000 M^3)
(Power measured at Pump 2)					

*d/s = downstream

** Averaged from both Pump 1 and Pump 2 individually measured power readings

As it can be seen, pump 2 is less efficient than pump 1 and the pumps are operating below their expected overall efficiency of around 65% to 69% based on the measured (input) power and the manufacturer pump curve – a reduction in overall pump efficiency of approximately 18.5% to 23.2% for pump 1 and 27.7% to 31.9% for pump 2.

6 Potential Areas for Improvement

6.1 Pump Selection

The results of the audit indicate that Tinsley PS would obtain immediate benefits from installation of new, appropriately selected duty/standby pumps designed to operate between 80% to 105% of BEP, where possible, and with a maximum duty at around 120 to 125% of BEP.

The use of variable speed drives (VSDs) would bring operational flexibility based on the difference in recorded river levels of over 4 m and would allow for pipeline deterioration, and corrosion/wear of the pump units. However, VSD units are not 100% efficient and would introduce their own energy loss of approximately 4%, subject to manufacturer, model and operating frequency.

Both soft-start drives and VSDs help in the reduction of surge and water hammer. If fixed speed operation is to be retained, then new soft start drives would be beneficial to delivery main longevity.

Arcadis investigated potential pumps to replace the existing units based on the required flow rate of 130-140 l/s and the derived system curve, the results of which are indicated in Figure 14 and Figure 15, and Table 4 and Table 5.

Hidrostal previously offered an interim pump selection which was reviewed alongside an evaluation of alternatives using ‘Xylect’ (Xylem web-based pump selection software). The availability of IE3 motors is awaited, therefore IE2 motor figures have been used in Table 5. If IE3 motors are available, then the further savings of around 3% may be expected.

Taking into consideration the design system curve, (derived from site data) and possible future replacement both Xylem and Hidrostal provided acceptable pump unit selections.

The NPSHr at the operating duty point is much lower than the existing pump installation – 3.6 m and 4 m for the Xylem pump selection and the Hidrostal pump selection respectively – and thus provides more than adequate margin. The existing pump NPSHr most likely would exceed the NPSHa at BWL if running at 130 l/s (Figure 13) resulting in cavitation issues.

Table 4 – Summary of Pump Duty, NPSHr and Safety Margin for existing pumps and alternatives

PUMP UNIT	OPERATING DUTY POINT		NPSHR	NPSH SAFETY MARGIN*
	(L/S)	(M)	(M)	(M)
Existing Flygt Pump	124	26.9	9.2	1.2
Hidrostal F06G-EMU1+FEVV4-GSEK1AA	146	29.6	4	6.4
Xylem NP 3231/605 3~ 480 340 mm	142	29.2	3.6	6.8

* At wet well of 29.221 mAOD (430 mm off floor)

It should be noted that the Hidrostal pumps are immersible units, whereas the Xylem pumps are submersible units. Immersible pumps can be installed in the same manner as submersible pumps; however, submersible pump motors are cooled by conducting heat from the motor to the liquid in which it is submerged. This requires the motor to be submerged (at a minimum level) for normal and prolonged operation.

Immersible pump motors feature a closed loop cooling system that circulates fluid around the motor housing and exchanges heat through a finned plate at the bottom of the motor housing. This provides the added benefit in that the operating water level can be drawn down to the pump casing without risk of overheating the motor compared to a submersible pump.

Although the Xylem pump unit has a greater flow range, it requires a larger motor (70 kW) and is not available with an IE3 motor option. There is negligible margin within the pump capacity and the pump would also be operating to the left of its BEP at the design duty point; therefore, efficiency is likely to drop off over time.

In contrast, the Hidrostal pump unit is provided with a 55 kW IE2 motor, although an IE3 motor option is being investigated by them. The pump would operate to the right of its BEP at the design duty point with a higher overall efficiency (See Table 5).

The pump capacity has adequate headroom which would allow adjustment of the VSD over the operational life of the unit to maintain flow rate. The pump also has a large open passage impeller which should reduce the reduce the risk of blockage.

Therefore, the Hidrostal pump units are deemed to be the optimum pump selection for Tinsley PS and are recommended for installation.

Table 5 – Comparison of alternative selections for Tinsley PS replacement pump units

PUMP UNIT	OPERATING DUTY POINT		OPERATING FREQUENCY	SHAFT POWER	PUMP EFFICIENCY	OVERALL PUMP & MOTOR EFFICIENCY	STRING EFFICIENCY*	SPECIFIC ENERGY
	(L/S)	(M)	(HZ)	(KW)	(%)	(%)	(%)	(KWH/1000 M^3)
Hidrostal F06G-EMU1+FEVV4-GSEK1AA	146	29.6	50 (No VSD)	54	79	**72.3****	-	**111.6**
Hidrostal F06G-EMU1+FEVV4-GSEK1AA	130	28	46.5	41.7	79.5	**72.7****	69.8	**109.3**
Xylem NP 3231/605 3~ 480 340 mm	142	29.2	50 (No VSD)	58.4	69.1	**64.5**	-	**123.4**
Xylem NP 3231/605 3~ 480 340 mm	131	28.2	48.5	52.9	68.5	**64.1**	61.5	**126.1**

* Assuming VSD Efficiency of 96%

** Based on 4-pole IE2 motor minimum efficiency

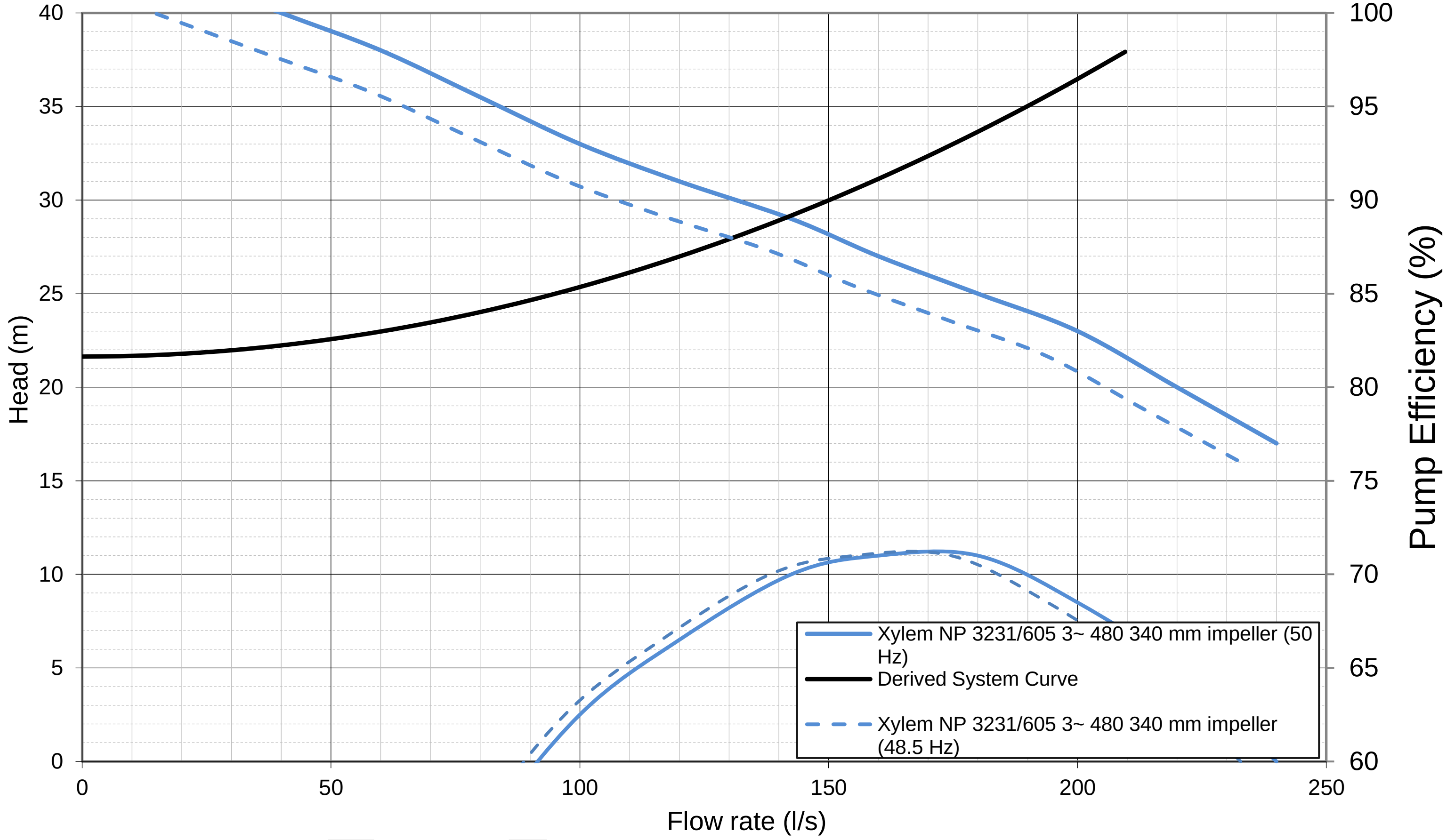


Figure 14 – Derived system curve with suggested Xylem replacement pump selection for Tinsley PS showing Full speed operation pump curve (at maximum capacity) and Reduced speed operation pump curve (to achieve minimum target flow rate)

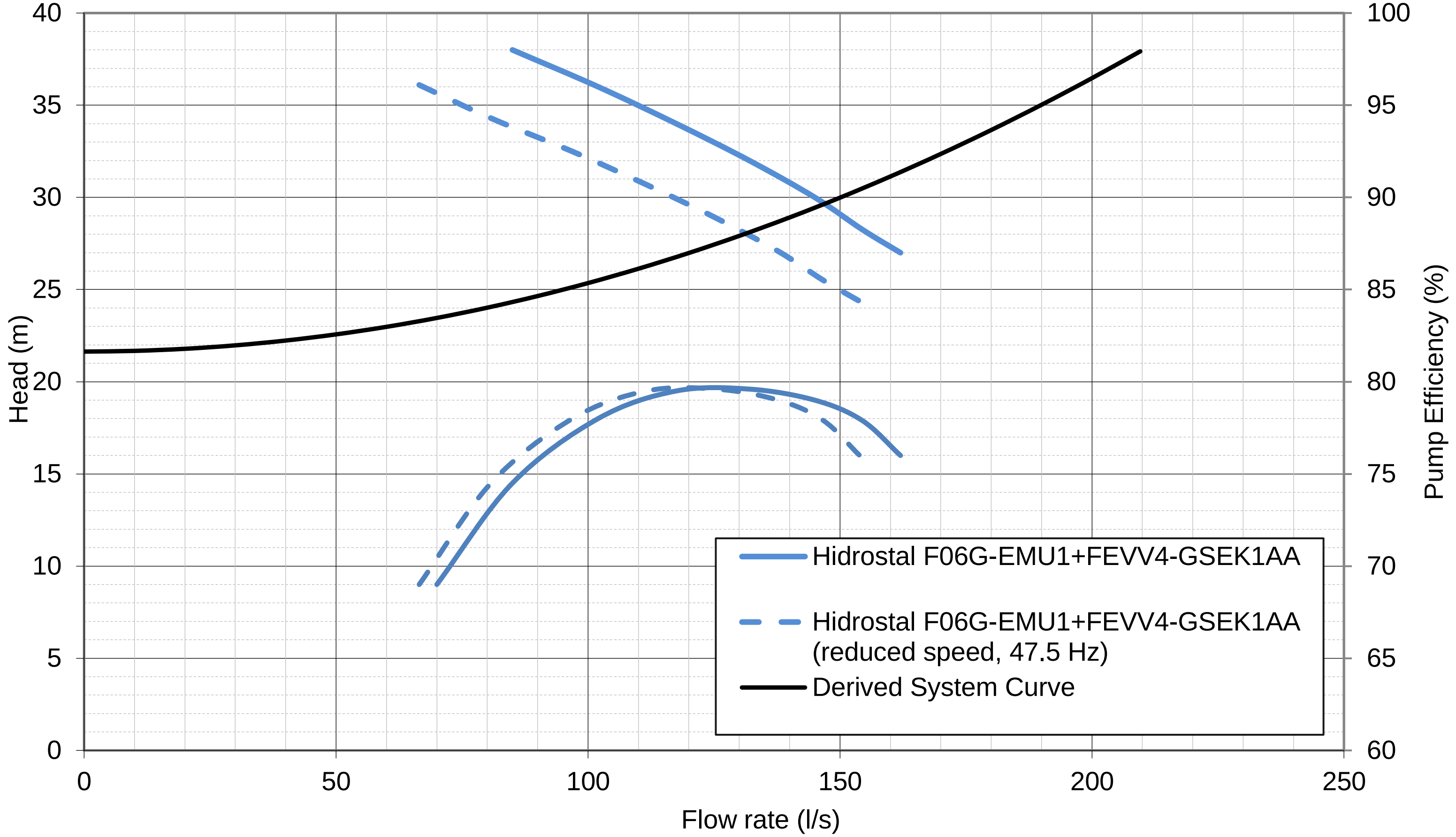


Figure 15 – Derived system curve with suggested Hidrostal replacement pump selection for Tinsley PS showing Full speed operation pump curve (at maximum capacity) and Reduced speed operation pump curve (to achieve minimum target flow rate)

The estimated relative annual energy consumptions between existing and new pumps are shown in Table 6.

Based on 2016-2018 flow figures, installing Hidrostal pumps in combination with VSDs could save approximately 125,000 kWh per annum.

Table 6 – Existing and proposed pump energy comparison at Tinsley PS

PUMP	FLOW RATE (L/S)	SPECIFIC ENERGY (KWH/1000 M³)	VOLUME* (M³)	ENERGY (KWH)	POTENTIAL ENERGY SAVING (KWH)
Existing Pump 1	124	134.4			
Existing Pump 2	109	150.4			
Average of Existing Pumps	117	142.4	3,800,000	541,120	
Proposed Hidrostal Pump	146	111.6	3,800,000	424,080	117,040
Proposed Hidrostal Pump & VSD	130	109.3	3,800,000	415,340	**125,780**

* Based on telemetry data April 2016 to Apr 2018

6.2 Instrumentation, Control and Monitoring

Installation of an ultrasonic sensor, or other suitable instrumentation, for level measurement within the wet well would help provide additional pump control and protection, e.g. inhibit on low level, along with useful operational data.

Installation of a pressure transducer on the rising main located within the pump station building would allow continuous monitoring of the pressure within rising main. This information could then be used to help the Trust identify leakages and, or pipeline failure/bursts.

Provision of remote monitoring at the intake, with instrumentation linked to SCADA, would provide the facility to automatically notify the Trust of major blockages to the screen, e.g. via differential level, to ensure adequate inflow to the pumping station is maintained.

An 'intelligent' VSD/predictive monitoring system could be adopted at this site to encompass parameters such as flow rate, bearing temperature, power, efficiency, etc. This could be implemented based upon SCADA/telemetry data and programmed to allow automatic adaption and correction of operation, informative data analysis reporting, and preventative fault alarms to help save energy, reduce downtime and prevent pump blocking.

6.3 Pump Orientation

The proposed duty/standby Hidrostal pump units can fit within the existing wet well and meet the minimum recommended separation distance of 950 mm with 120 mm minimum clearance from the sump / wet well wall. However, the sump floor and wet well benching will need to be modified to accommodate the pumps and ensure that the volute is positioned at the correct height.

The pump orientation to the incoming flow into the well is not ideal, as summarised in Section 2.3.2; however, given the constraints of the well diameter and structure, plus close proximity of the pumping station building, it is not straight forward to reconfigure the pipework and pump stool location.

It is not possible to advise if tangible improvements will be realised with a relocation and/or reorientation of the pumps. Hydraulic modelling would be necessary to understand this and implement specific recommendations.

Due to the physical layout and position of the pump station building in relation to the wet well, changing the pump/pipework orientation is not feasible without major works. Therefore, there is a possibility that actual performance of a newly installed pump unit could be lower than manufacturer stated and, or estimated values.

It is suggested that bespoke baffles could be retrofitted if necessary, should detrimental flow performance from the new replacement pumps be evident.

6.4 Recommendations for Phase 2

1. Purchase Hidrostal F06G-EMU1+FEVV4-GSEK1AApumps and retrofit into the well, modifying the existing pipework to accommodate as required.

2. Produce “As Built” General Arrangement Drawings following installation, including consideration of point cloud survey.

3. Provide VSDs for optimum pump control.

4. Develop control algorithms/function blocks to monitor performance and automatically run at maximum efficiency / lowest specific energy.

5. Investigate the water losses at the summit pound

   Although this is a reasonable/rational option to conclude, it is understood that that costs to address these water losses would be prohibitively expensive making this an unviable solution in practice.

6. Monitor pump hydraulic performance of new installation

   If issues arise and persist, review the wet well/intake hydraulics and pump orientation to determine if potential improvements to the arrangement can be made.

7. a) Alter the current maintenance strategy to increase the frequency of inspection and consider incorporating additional inspections as required, e.g. following sustained periods of heavy rainfall or major storm events

   b) Consider alternative solution in lieu of a manually raked bar screen at the river intake to limit debris entering wet well

8. Investigate the condition of existing cast iron rising main and consider monitoring of the pipeline integrity periodically using on-line inspection techniques, either internal or external, or alternatively by hydrostatic testing.

   Traditionally, the overall assessment and management of pipeline integrity requires that all condition and inspection data is related and compared on a section by section basis along the pipeline. Condition monitoring would help establish a continued fitness for purpose assessment of the pipeline and potentially allow the Trust to monitor leaks and the risk of bursts / failure of the rising main.

   Due to the age of the rising main, external inspection , e.g. using non-destructive methods, is likely to be more practical than internal on-line inspection and could involve a corrosion protection close interval potential survey (CIPS) or a coating defect survey (Pearson).

9. Consider alternative pumping station location and, or options to replace/renew existing rising main for future resilience.

   The costs for replacing the rising main are prohibitive on the merit of energy saving alone. However, based on the roughness value of the pipeline alone and a 1.3 km long, 600 mm internal diameter pipe, it is estimated that replacing the rising main with a new HDPE/PE100 pipe could provide the equivalent of c.16,000 kWh per annum energy saving.

10. Undertake Electrical Installation Condition Report (EICR) / periodic inspection report (if not already carried out as part of Trust Planned Preventative Maintenance) to confirm whether or not the electrical installation at Tinsley PS is in a satisfactory condition

    EICR to detail any observed damage, deterioration, defects, dangerous conditions and any non-compliances with the present-day safety standard that might give rise to danger

11. Review the recent dredging activities at Tinsley and arrange if required.

APPENDIX A

Guide to System Curves and Pump Performance Curves

The System Curve

Consider a pump system (Figure 16) where water is required to be conveyed from Point A to Point B at a Flow Rate of Q_D.

As the elevation of the water surface at the delivery Point B is higher than at A, it cannot flow under gravity so pumps are required to lift the water. The elevation difference that the pumps are required to overcome is known as the static head, H_S, where H_S = Surface Elevation @ B – Surface Elevation at A.

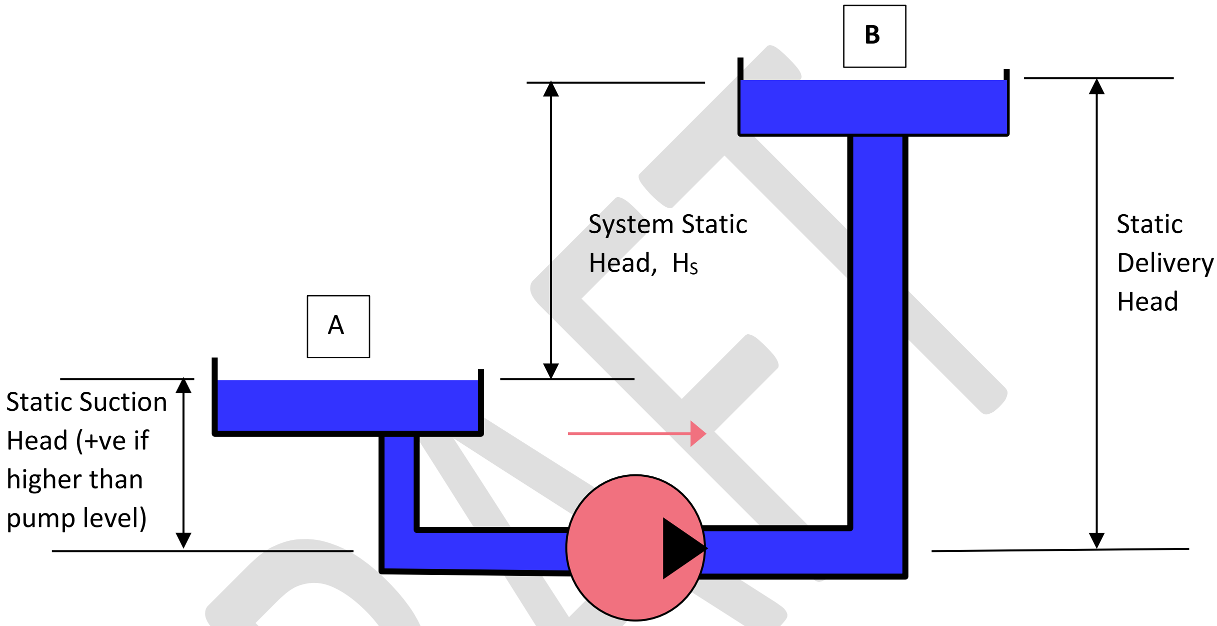
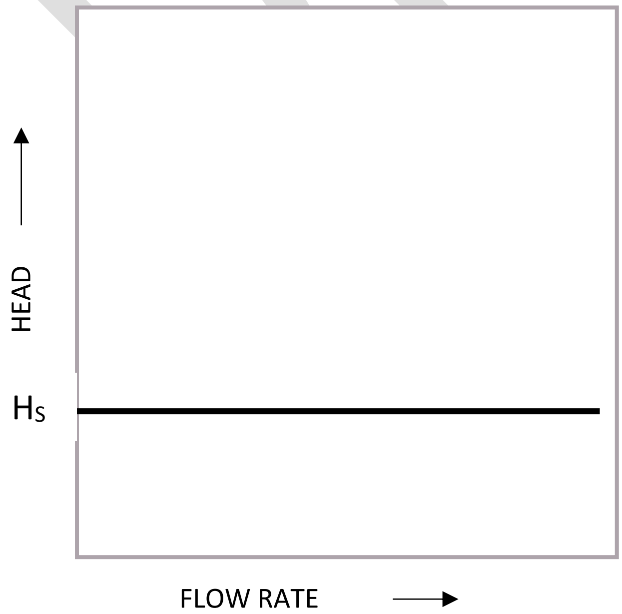


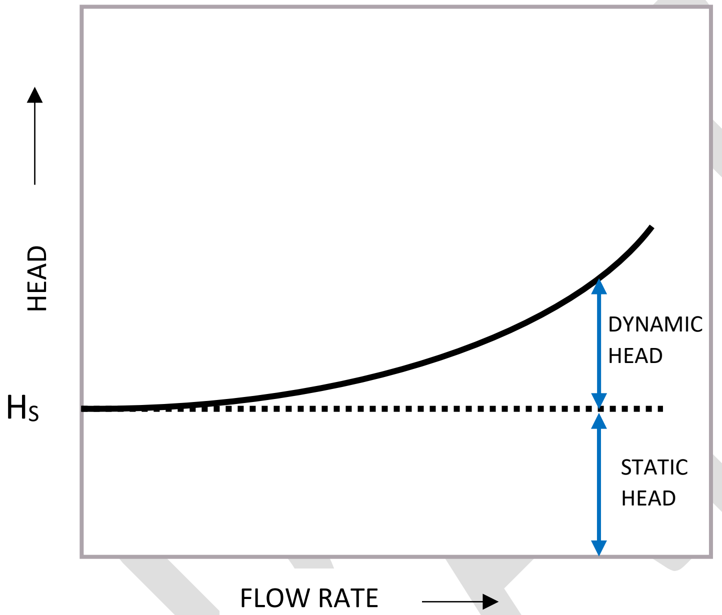
Figure 16 – Pump System Representation

The calculated static head can be represented on a chart with head on the y -axis and flow rate on the x-axis, as follows:

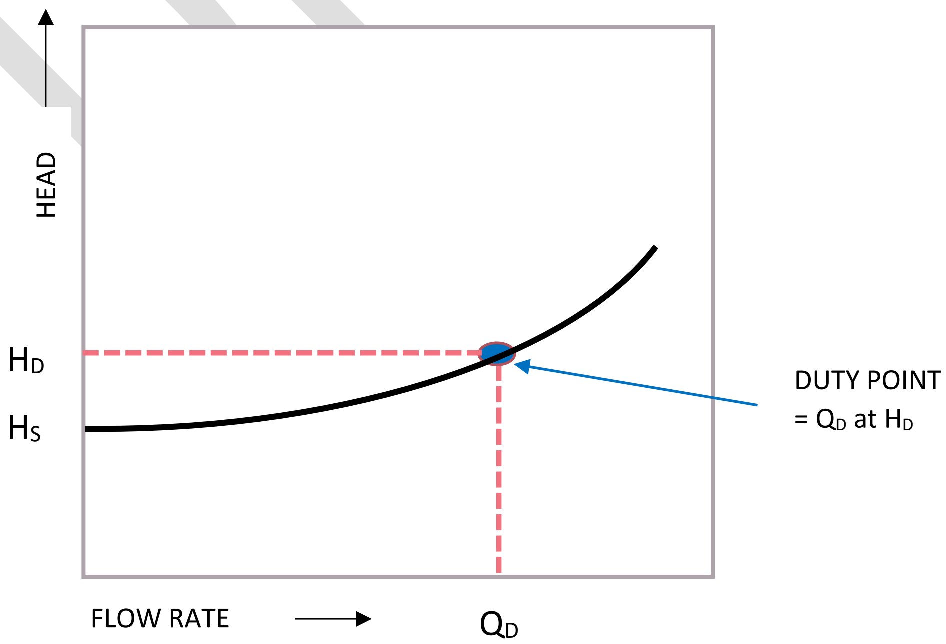


With an increasing flow rate, the flow resistance of the pipe and pipe fittings increases due to friction. So to achieve a higher flow rate, more pressure (or head) is then needed to be generated by the pump. The head losses due to friction increase proportionally to the square of flow velocity and is referred as "Dynamic Head". The Total Head for a given flow rate is the sum of Static Head and Dynamic Head.

Using established equations and loss coefficients the head unique to the pipe system can be calculated at various flow rates and its curve plotted as shown below. This is known as the "SYSTEM CURVE" or "SYSTEM CHARACTERISTIC".

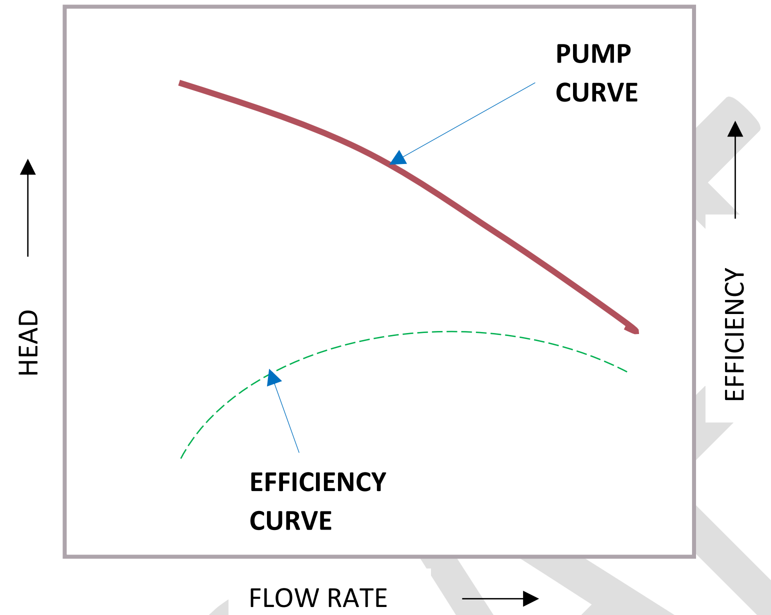


To select a pump for the desired flow rate, Q_D, the intersection point at H_D, is translated from the system curve. This is known as the desired "Duty Point".



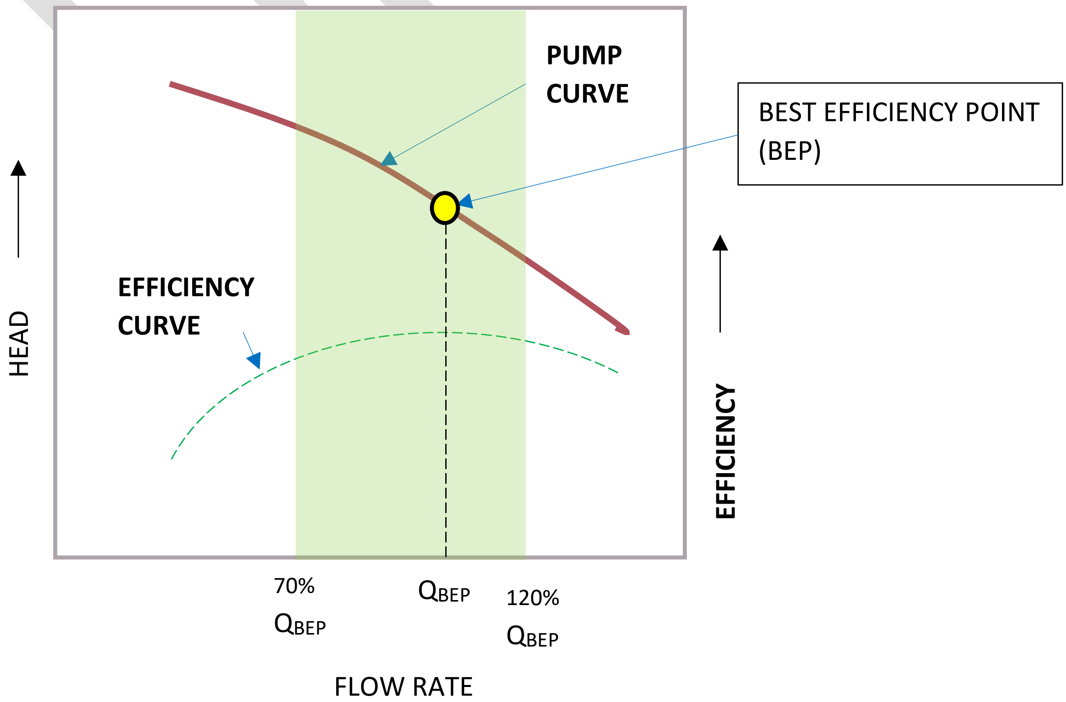
Pump Performance Curves

Centrifugal pumps have a flow-head characteristic known as the “PUMP PERFORMANCE CURVE” or “PUMP CURVE”. This shows the flow rate that can be generated by the pump for a given head. The pump curve will typically fall as flow rate increases. The pump efficiency will typically vary with flow rate, initially rising to a peak and then falling away at higher flow rates. These can be represented by curves aginst flow rate as shown below.



The point on the pump curve where efficiency is highest is known as the “BEST EFFICIENCY POINT”, abbreviated to “BEP”. The flow rate at this point is abbreviated to Q_{BEP}.

Well selected pumps generally perform at flow rates within 70%< Q_{BEP} < 120%, in what is known as the “PREFFERRED OPERATING REGION” as highlighted below.



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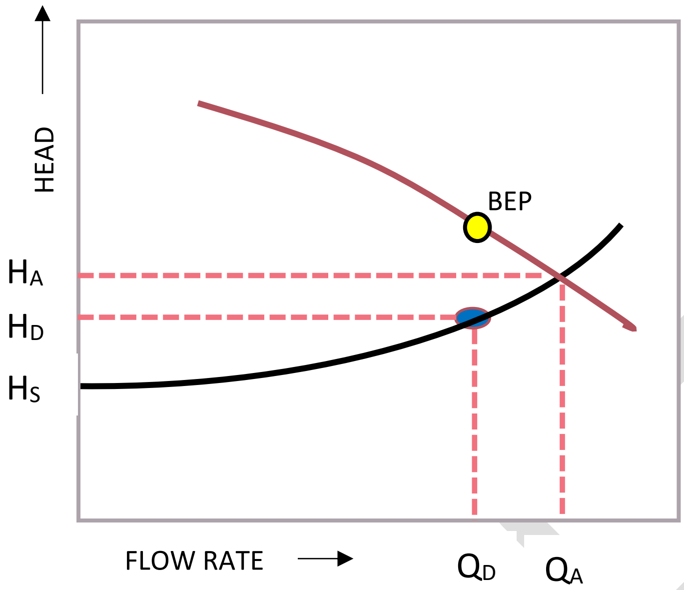
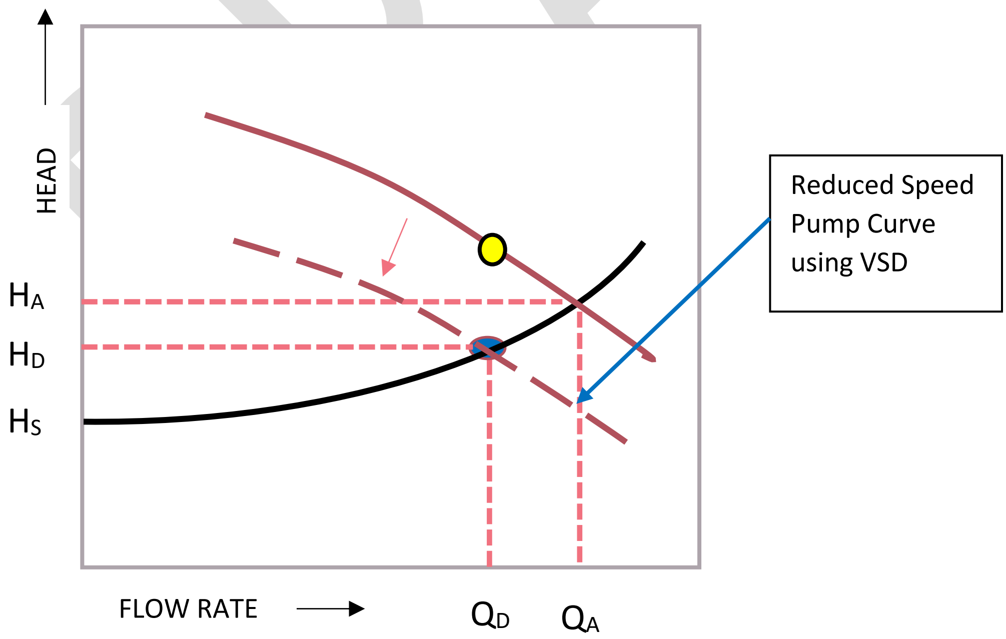
Combining System and Pump Performance Curves

The performance curve for a pump can be overlaid on the system curve. The expected flow rate for a particular pump is indicated where the pump curve intersects the system curve.



In the above example, the pump will pass forward a flow rate, Q_A at a head of H_A (Actual Duty Point) which is higher than the desired duty flow rate, Q_D and higher than (to the right) of its best efficiency flow rate, Q_{BEP}.

Pump Manufacturers can provide a pump curve reflective of a particular model of pump "as new". Sites tests can provide an actual pump performance curve through varying pump speed or adjusting valves and measuring flow rate and pressure.



Using variable speed drives it is possible to change the pump speed by changing the frequency of input power to the pump motor. This varies its performance curve meaning that it can meet a desired flow rate In this example the speed is reduced to meet the desired duty flow rate, Q_D.

APPENDIX B

Existing KSB pump performance curve

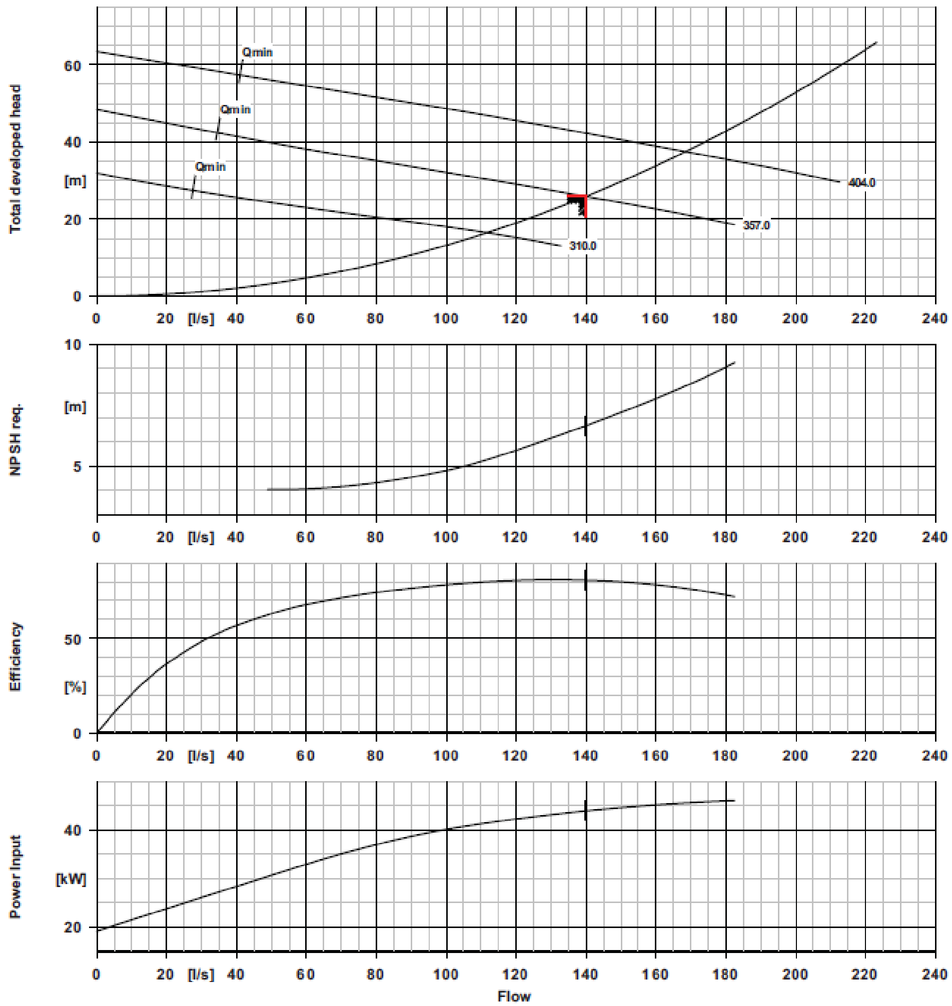
Performance curve

Customer pos. no.:
Inquiry date: 2012-10-31
Inquiry no.: Nomenca Sheffield
Quantity: 1,000

Number: 4001760802 - 689
Line: 000100
Date: 2012-10-31
Page: 5 / 7

KRTK 150-401/654UG-S

Version no.: 1



Curve data

Speed of rotation	1482 rpm	Efficiency	80.9 %
Fluid density	998 kg/m³	Power absorbed	43.89 kW
Viscosity	1.00 mm²/s	NPSH required	6.66 m
Flow rate	140.000 l/s	Curve number	K42484s
Requested flow rate	140.000 l/s	Effective impeller diameter	357.0 mm
Total developed head	25.89 m	Acceptance standard	ISO 9906 class 2 / 2B
Requested developed head	25.89 m		

APPENDIX C

Existing Flygt pump performance curve (P1)

FLYGT

PERFORMANCE CURVE

PRODUCT	TYPE
NP3301.180	HT

DATE	PROJECT	CURVE NO	ISSUE
2015-11-17		53-456-00-0150	2

	1/1-LOAD	3/4-LOAD	1/2-LOAD
POWER FACTOR	0.84	0.81	0.73
EFFICIENCY	92.0 %	93.0 %	93.5 %
MOTOR DATA	---	---	---

RATED POWER	55	kW
STARTING CURRENT ...	435	A
RATED CURRENT ...	103	A
RATED SPEED	1475	rpm
TOT.MOM.OF INERTIA ...	0.81	kgm2
NO. OF BLADES	2	

IMPELLER DIAMETER 370 mm

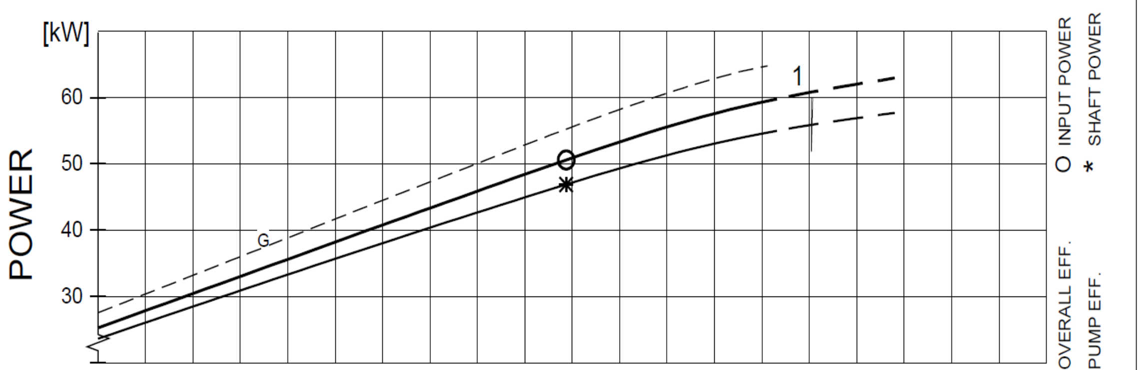
MOTOR #	STATOR	REV
35-25-4AA	01D	10

FREQ.	PHASES	VOLTAGE	POLES
50 Hz	3	400 V	4

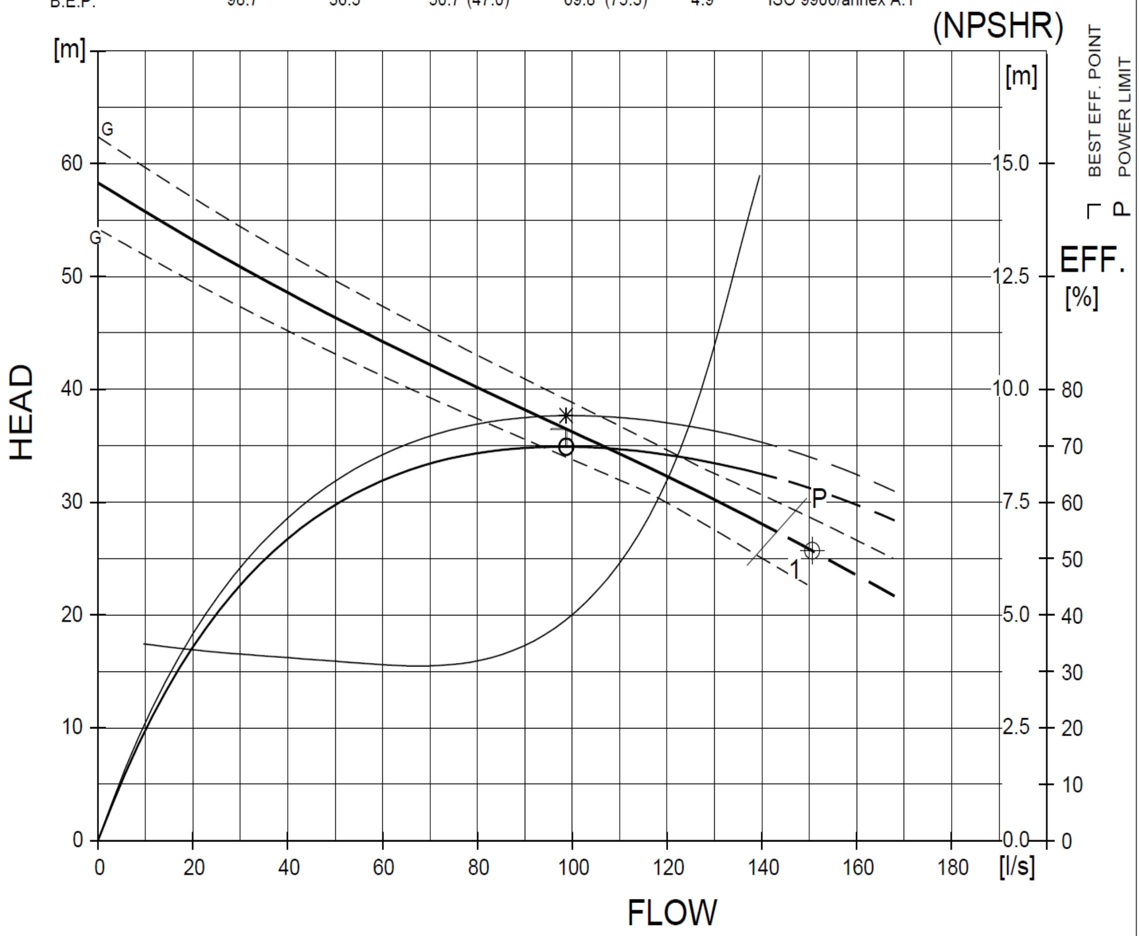
GEARTYPE	RATIO
---	---

COMMENTS

INLET/OUTLET	IMP. THROUGHLET
-/150 mm	---



DUTY-POINT	FLOW [l/s]	HEAD [m]	POWER [kW]	EFF. [%]	(NPSHR)[m]	GUARANTEE
1	151	25.7	61.0 (56.0)	62.4 (67.9)		
B.E.P.	98.7	36.5	50.7 (47.0)	69.8 (75.3)	4.9	ISO 9906/annex A.1



FLYPS3.1.6.6 (20090313)

(NPSHR) = (NPSH3) + margins

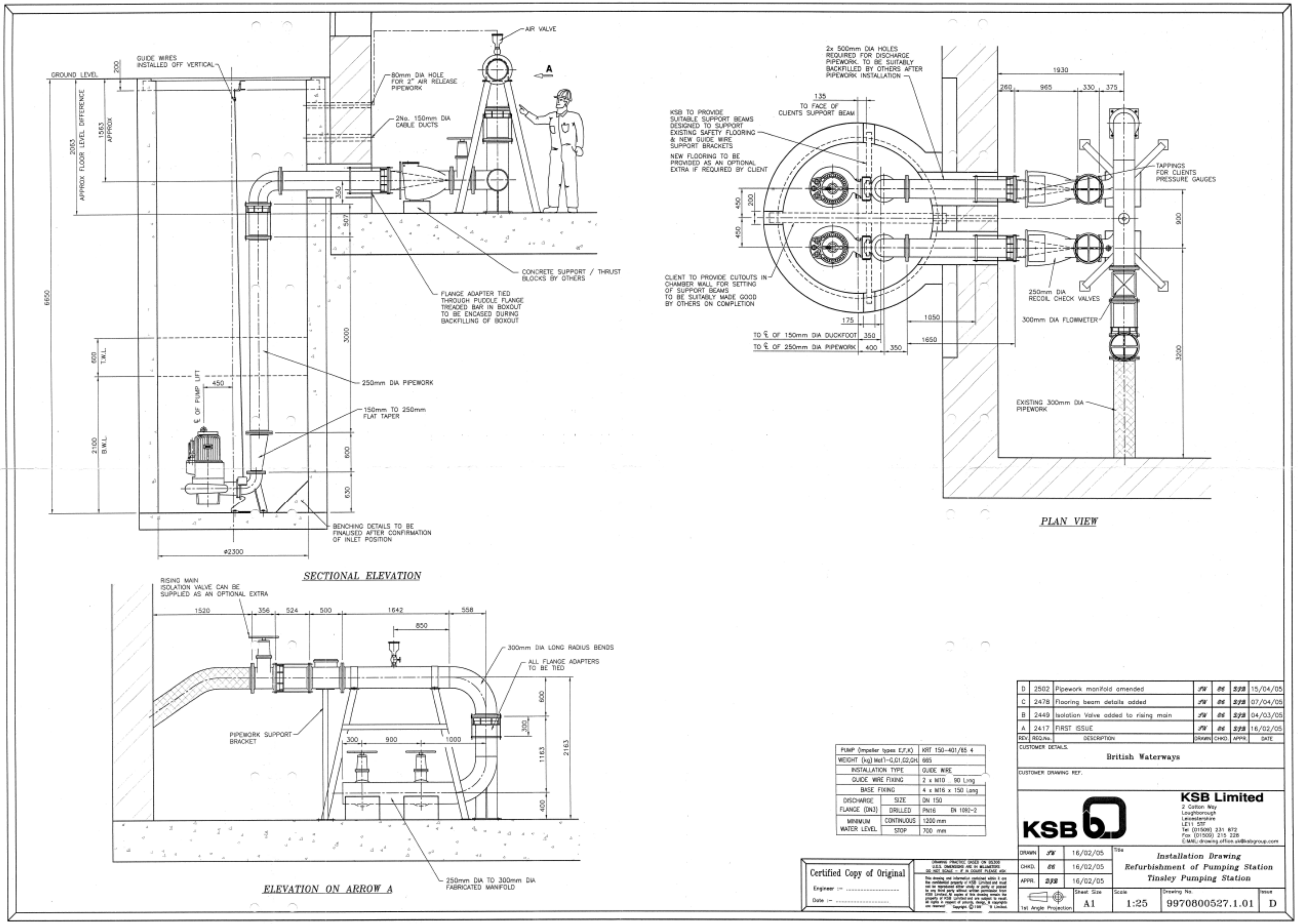
Performance with clear water and ambient temp 40 °C

GUARANTEE BETWEEN LIMITS (G) ACC. TO

ISO 9906/annex A.1

APPENDIX D

Tinsley PS Installation Drawing



PUMP (impeller types E,F,K)	KRT 150-401/65 4
WEIGHT (kg) Wet')-G,G1,G2,GH	665
INSTALLATION TYPE	GUIDE WIRE
GUIDE WIRE FIXING	2 x M10 .. 90 Long
BASE FIXING	4 x M16 x 150 Long
DISCHARGE FLANGE (DN3) SIZE	DN 150
DISCHARGE FLANGE (DN3) DRILLED	PN16 EN 1092-2
MINIMUM WATER LEVEL CONTINUOUS	1200 mm
MINIMUM WATER LEVEL STOP	700 mm

REV.	REQ.No.	DESCRIPTION	DRAWN	CHKD.	APPR.	DATE
D	2502	Pipework manifold amended	JW	GG	SJB	15/04/05
C	2478	Flooring beam details added	JW	GG	SJB	07/04/05
B	2449	Isolation Valve added to rising main	JW	GG	SJB	04/03/05
A	2417	FIRST ISSUE	JW	GG	SJB	16/02/05

CUSTOMER DETAILS: British Waterways

CUSTOMER DRAWING REF.

KSB Limited
2 Cotton Way
Loughborough
Leicestershire
LE11 5TF
Tel (01509) 231 872
Fax (01509) 215 228
E.MAIL: drawing.office.uk@ksbgroup.com

DRAWN	JW	16/02/05
CHKD.	GG	16/02/05
APPR.	SJB	16/02/05

Title: Installation Drawing
Refurbishment of Pumping Station
Tinsley Pumping Station

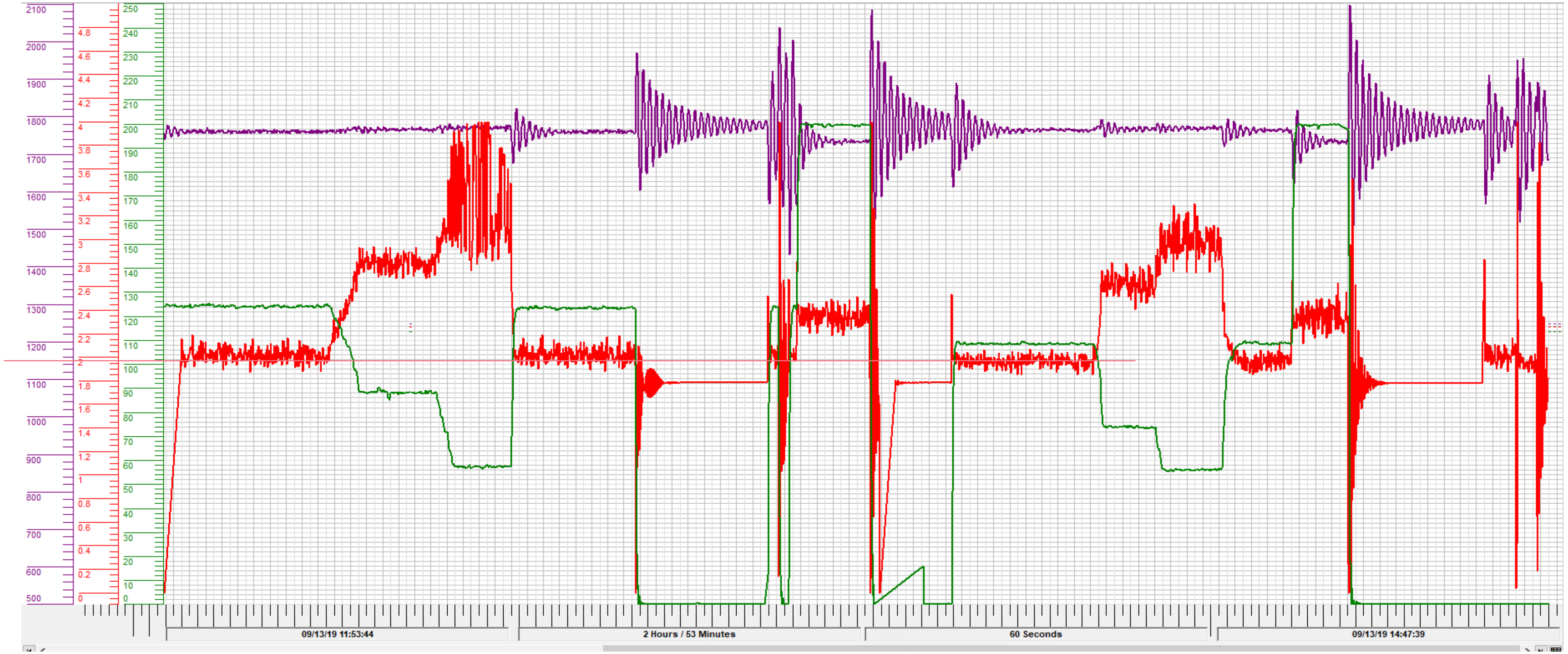
1st Angle Projection	Sheet Size	Scale	Drawing No.	Issue
	A1	1:25	9970800527.1.01	D

Certified Copy of Original
Engineer :- ....
Date :- ....

APPENDIX E

On Site Measurements – Pump Audit Test Data

Pump No. (s)	Test Point	Start Time	Frequency	Flow (l/s)			Delivery Pressure (Bar)			Upstream Level (m)			From Fluke Power Meter (Average Over Cycle)										
													Volts						Amps			PF	kW
			(Hz)	Min	Max	Average	Min	Max	Average	Min	Max	Average	L1-L2	L1-L3	L2-L3	L1-N	L2-N	L3-N	L1	L2	L3		
1	Duty - Full Flow	11:56	50	123	125	124	1.78	2.16	2.00	1.75	1.77	1.76	423	423	422	244	244	244	101	101	100	0.81	60
1	Duty - 70% Flow	12:31	50	85	90	88	2.67	2.94	2.80	1.76	1.77	1.77	423	423	422	244	244	244	90	90	89	0.80	52
1	Duty- 50% Flow	12:39	50	58	58	57	2.74	4.00	3.35	1.76	1.78	1.77	429	428	428	248	247	247	80	79	78	0.77	45
1	Pressure Transient	12:52					-0.17	2.07	1.70	1.60	1.97	1.78											
1+2	Duty - Full Flow	13:16	50	199	200	200	2.23	2.45	2.34	1.70	1.79	1.73	429	429	428	247	248	247	96	97	96	0.80	57
2	Duty - Full Flow	13:35	50	108	110	109	1.85	2.07	1.97	1.69	1.82	1.76	432	432	432	249	250	249	82	82	83	0.95	59
2	Duty - 70% Flow	13:50	50	73	75	74	2.41	2.80	2.63	1.75	1.78	1.77	432	432	431	249	250	249	74	73	74	0.96	53
2	Duty- 50% Flow	13:59	50	55	57	56	2.72	3.30	2.93	1.76	1.78	1.77	433	433	432	249	250	249	70	69	70	0.97	51
2+1	Duty - Full Flow	14:15	50	198	200	200	2.12	2.63	2.35	1.67	1.78	1.73	430	429	428	248	248	247	77	77	78	0.96	55
2+1	Pressure Transient	14:19					-0.24	3.52	1.75	1.51	2.10	1.79											
	Static Head (1)	11:27					1.78	1.78	1.78	1.77	1.79	1.78											
	Static Head (2)	12:58					1.78	1.79	1.78	1.73	1.83	1.78											
	Static Head (3)	14:27					1.78	1.78	1.78	1.71	1.84	1.78											



Upstream Level in mm

Delivery Pressure in bar

Flow rate in l/s

APPENDIX F

Level Data

River water levels (as per Hadfields monitoring station)

Station name: Hadfields
Station ID: 8090
River name: River Don

Site datum: 30.21 mAOD

Normal level in average weather conditions is between 0.32 m and 0.53 m (it has been between these levels for at least 152 days in the past year)

Typical range: 0.355 m to 0.900 m (it has been between these levels for 90% of the time since monitoring began)

Highest level on record: 4.675 m on 25th June 2007
Lowest level recorded: 0.311 m on 14th August 1976

River levels
30.521 mAOD minimum
34.885 mAOD maximum
30.565 mAOD to 31.110 mAOD typical range
30.530 mAOD to 30.740 mAOD average
30.551 mAOD on 18th September (recorded at 0.341 mAOD)

Pump station levels (derived from above river levels, measured site data and record drawings)
28.791 mAOD wet well sump floor IL (water level of 1.76 m recorded on 18th September)
29.221 mAOD pump level (assumed based on Flygt NP3301.180 HT min. level of 430 mm)
35.441 mAOD ground level
51.934 mAOD IL of outfall pipe

APPENDIX G

Recommended Pump Selection Data Sheet

Immersible Pump: F06G-EMU1 + FEVV4-GSEK1AA + ND1B6EM-15

Project / Date:
Customer:
Job No. / Order No.:
Pump Title:

Hydraulic

Suction Nozzle:	200 mm drilled to PN 10
Discharge Nozzle:	150 mm drilled to PN 16
Type:	F06G
Regulable:	no
Impeller:	EMU
Free passage:	120 mm
Inspection cover:	yes

Motor

Type Hidrostal:	FEVV4 - immersible
Nominal Rating Pn:	55.0 kW
Voltage / Frequency:	400 V / 50 Hz
Speed:	1480 rpm
Nom. Current / cos ϕ:	98.0 A / 0.89
Starting Current IA/IN:	8.5
Winding Protection:	Bimetal switch
Starting Method:	Y/Δ
Cable length:	15 m
Cable details:	2x 4x16mm², Ø26.0mm, 4x1.5mm², Ø10.7mm
Cable mat. / screened:	EPR/PUR / yes
Ex-Proof:	no
Enclosure:	IP 68
Insulation:	F
Fly Wheel:	no
Insulated Roller Bearings:	no
Oil volume:	31.0 l

Material of Hydraulic

Volute Casing:	0.6025 (GG25)
Impeller:	0.7060 (GGG60)
Liner:	0.6020 (GG20)
Seal parts:	0.6020 (GG20)
Shaft:	1.4021 (X20Cr13)
Seal motorside:	76 mm / F-Type - C/SiC
Seal pumpside:	75 mm / G-Type - SiC
O-Rings:	Nitrile

Instrumentation

Conductivity probe:	yes
Float Switch:	no
Bearing Temp. Probe:	no
Temperature probe:	no

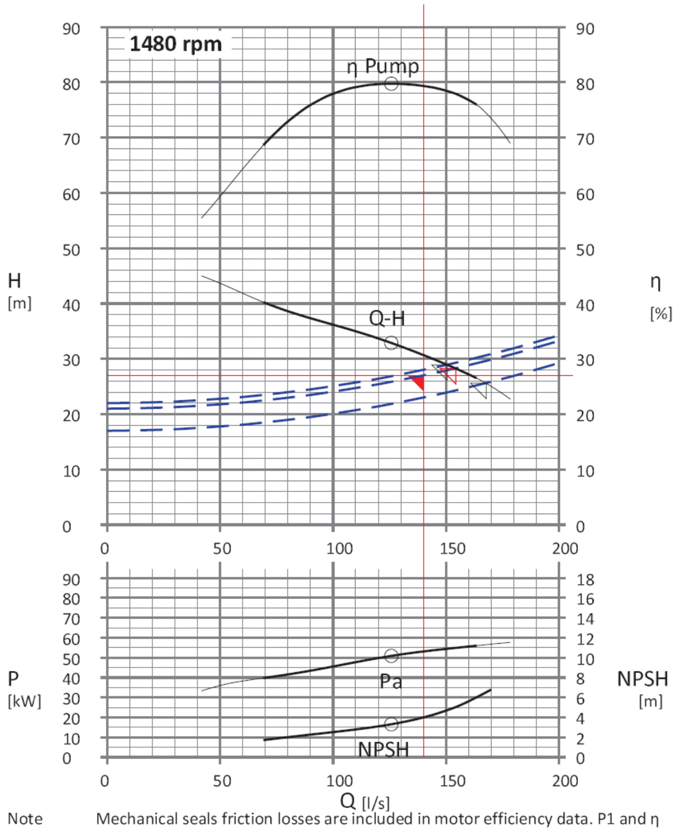
Miscellaneous

Pump Weight:	~ 803 kg
Painting:	Standard Painting
Paint Thickness:	150µm, Standard RAL 5010

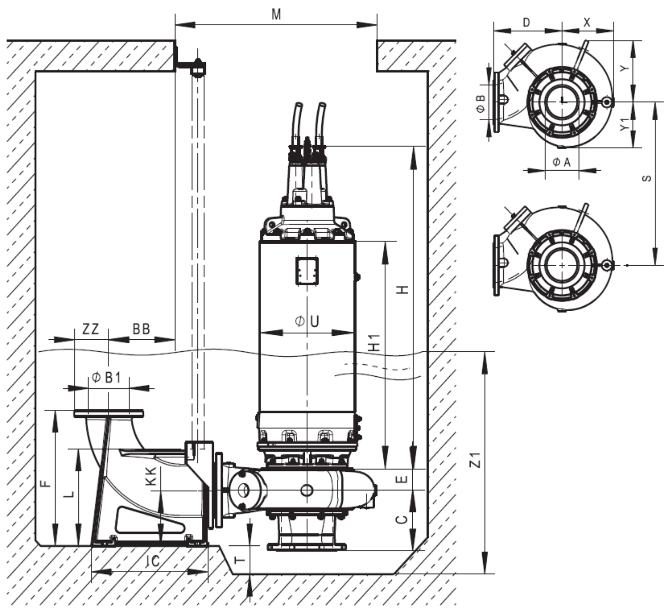
Accessories

Lowering Device:	AB+AS-06/08
Discharge Nozzle:	200 mm drilled to PN 10
Chain Type and Length:	
Weight:	80 kg

actual Guarantee Point:
Static Head Design = 21.00 m
Speed = 1480 rpm
Q = 154.4 l/s - H = 28.26 m
η Pump = 77.9 %



Note: Mechanical seals friction losses are included in motor efficiency data. P1 and η overall are only valid for direct grid operation without VFD Testing according to ISO 9906:2012-3B



Drawing dimensions

A	200 mm	KK	180 mm
B	150 mm	L	310 mm
C	273 mm	M	1000 mm
D	410 mm	S	950 mm
E	108 mm	T	213 mm
X	315 mm	Z1	2 * (v2 / 2g)
Y	340 mm	ZZ	170 mm
Y1	275 mm		
H	1456 mm		
H1	970 mm		
U	415 mm		
B1	200 mm		
BB	250 mm		
F	500 mm		
IC	410 mm		

Subject to change without notice
Drawing does not always show the exact pump design.

printed by: Malcolm
Date printed: 29/10/2019

No.: CDS-1260a-1480

APPENDIX H

Missing Phase 1 Asset/Equipment Information

Table 7 – List of Asset Information Status

DATA SET	STATUS
Intake/Culvert	• No "As Built" Drawings available • CCTV report available
Pump Station Drawings (Civil / Structural)	• No "As Built" Drawings available
Pump Station Drawings (Mechanical / Pipework)	• No up-to-date "As Built" Drawings available (KSB Drawing "Installation of refurbishment of Pumping Station - Tinsley Pumping Station" #9970800527.1.01 Iss D. Not "As Built" status.) • No P&ID available
Rising Main, incl. Long Sections	• No drawing information available of rising main including long section • No trial hole information
Outfall/Discharge Structure	• No drawings available
Electrical Cabling Installation	• None
MCC Panel Drawings	• None
O&M	• No up-to-date O&M manual available (2005 O&M manual still references existing KSB pumps)
Other	• Inspection/Dewatering report available (Ref. TO-322)

Interreg
North-West Europe
Green WIN

Canal & River Trust
Making life better by water

LIÈGE université

Ministerie van Infrastructuur en Waterstaat

Waterways Ireland
Uiscebhealaí Éireann
Watterweys Airlann

vnf
Voies navigables de France

VLAAMSE LAND MAATSCHAPPIJ