

Selecting Pumps When the Records Are Missing: A Field-Based Reverse-Engineering Methodology

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Abstract

Pump replacement appears straightforward when the original pump schedule, model number, duty point, certified curve, as-built drawings and control philosophy are available. In practice, many ageing water and wastewater installations have none of these records. Nameplates may be missing or unreadable, equipment may have been modified, and the present operating condition may be substantially different from the original design.

This paper presents a structured field-based methodology for reconstructing the hydraulic duty and selecting replacement pumps under incomplete-information conditions. The method combines document recovery, physical inspection, suction and discharge pressure, flow, rotational speed, electrical input, liquid levels, pipe geometry, operating sequences and demand data. It distinguishes the output of the existing pump from the duty required by the system, develops a provisional system curve, tests alternative operating states and records uncertainty explicitly. The paper also addresses wastewater characteristics, suction conditions, net positive suction head, parallel operation, variable-speed control, motor selection, surge, maintainability and lifecycle requirements. The objective is not to guess the identity of an old pump, but to develop an auditable engineering basis for a safe, efficient and reliable replacement.

Keywords: pump selection; reverse engineering; field testing; system curve; pump total head; flow measurement; pump assessment; wastewater; hydraulic duty; incomplete records

1. Introduction

Clients frequently request assistance with a pump replacement but can provide little more than access to the pump station. The pump model tag may be absent, the motor nameplate may be damaged, and there may be no pump schedule, duty point, data sheet, performance curve, commissioning report, as-built drawing or reliable operating history.

The temptation is to select a new pump from the motor kilowatt rating, discharge pipe diameter or a single pressure reading. None of these is an adequate hydraulic duty. Two pumps with the same motor rating can have very different flow-head characteristics, and an existing pump may be worn, throttled, cavitating, rotating at reduced speed or operating against an abnormal system resistance.

The engineering task is therefore a reverse-engineering exercise. However, the purpose is not merely to identify the old pump. The purpose is to determine what the complete system must deliver now and over its future design horizon, and then to select equipment that can do so reliably.

2. Two Questions That Must Not Be Confused

A defensible assessment answers two separate questions:

- What is the existing pump delivering? This is established from concurrent field measurements of flow, pump total head, speed and electrical input.
- What duty does the system require? This is established from source and destination levels or pressures, pipe resistance, process demand, operating philosophy, future demand and abnormal scenarios.

The measured operating point of a deteriorated system is evidence, not automatically the replacement duty. If a worn pump currently delivers 60 L/s when the process requires 100 L/s, selecting a new pump for 60 L/s would preserve the failure. Conversely, selecting a larger pump simply because present delivery is inadequate can create excessive pressure, surge, power demand, short cycling or operation far from the best efficiency point.

3. Begin with Evidence Recovery

Before installing instruments, the assessor should search for indirect evidence. Useful information may exist in electrical single-line diagrams, MCC schedules, variable-speed drive settings, maintenance job cards, purchase orders, workshop reports, asset registers, photographs, operator logs, telemetry histories and supplier correspondence. Casting numbers, dimensional measurements and impeller markings may help an original equipment manufacturer identify the pump family even when the external tag is missing.

Operators are also important witnesses. Their observations can reveal normal pump combinations, valve positions, reservoir levels, wet-well cycling, recurring blockages, priming problems, vibration, noise, overheating and changes following pipe bursts or system extensions. Operator recollection should be corroborated, but it often identifies the conditions that need to be measured.

The physical survey should record:

- Pump arrangement, orientation, mounting and access constraints.
- Suction and discharge pipe diameters, materials, routes and elevations.
- Reducers, bends, non-return valves, isolation valves and control valves.

- Source and destination levels and their normal operating ranges.
- Motor, gearbox, coupling, impeller and drive information that remains legible.
- VSD frequency limits, acceleration and deceleration times, control setpoints and run histories.
- Electrical supply voltage, starter arrangement, protection settings and cable capacity.
- Evidence of leakage, corrosion, air ingress, cavitation, blockage, vibration or foundation distress.

A field sketch prepared during the inspection becomes the working as-built drawing and should identify every measurement point and its elevation datum.

4. Establish a Safe Measurement Plan

Readings should be taken simultaneously or time-synchronised, because flow, pressure, levels, speed and power can change rapidly. Instruments should have an appropriate range, recent calibration and a recorded accuracy. Measurement points should be located where the reading is representative and where disturbed flow, trapped air and local velocity effects are minimised.

Testing must be covered by an approved method statement and risk assessment. Electrical measurements require suitably competent personnel and appropriate arc-flash precautions. Pump isolation, confined-space exposure, rotating equipment, pressurised tapping points and sewage-related biological hazards require specific controls. A suspected blocked or closed discharge must never be investigated by allowing a pump to run at shut-off for an uncontrolled period.

5. Determine the Actual Operating Point

5.1 Flow

Preferred field methods include a permanently installed and verified flowmeter or a correctly applied clamp-on ultrasonic meter. A portable meter should be configured for the pipe material, outside diameter, wall thickness, lining and liquid, with adequate straight lengths where practicable. Poor acoustic coupling, partially filled pipes, entrained air, heavy solids or a badly corroded pipe can materially affect the result.

Other methods can be useful when applied correctly:

- A calibrated electromagnetic or insertion meter temporarily installed in the line.
- A timed-volume test into a tank of known geometry.
- Reservoir drawdown or fill testing, corrected for simultaneous inflow and outflow.
- Wet-well level-change testing for sewage pumps.
- A validated plant mass balance or downstream process meter.

For a wet-well pump-down test, the pump flow is not simply wet-well volume divided by time if sewage continues entering the well. Where the incoming flow is estimated from the level rise while the pump is off:

$$Q_p = A(\Delta h / \Delta t)_{\text{down}} + Q_{\text{in}}$$

where Q_p is pump discharge flow, A is the effective wet-well plan area over the measured interval, and Q_{in} is the incoming flow. Irregular well geometry, changing inflow and uncertain level calibration must be allowed for.

Estimating flow from a pump curve is only valid when the pump, impeller diameter, speed and condition are known. Using an unknown curve to establish flow, and then using that inferred flow to identify the pump, is circular reasoning.

5.2 Pump total head

A discharge gauge reading alone is not pump head. Pump total head is derived from the difference between the discharge and suction total heads, using a common datum:

$$H_p = (p_d - p_s)/(\rho g) + (v_d^2 - v_s^2)/(2g) + (z_d - z_s)$$

The terms represent pressure-head difference, velocity-head difference and elevation difference between the measurement points. Gauge zero checks, tapping condition, trapped air, pulsation, pressure units and instrument elevations should be documented. For a submersible pump without a suction tapping, the suction pressure can be derived from the liquid level above the pump datum, subject to correct atmospheric or absolute-pressure conventions.

Transient pressure should be logged rather than reduced to a single visual reading. Start-up peaks, valve events and pump changeovers may reveal surge conditions that are invisible in a steady-state value.

5.3 Speed and direction of rotation

Rotational speed should be measured with a non-contact tachometer, stroboscope, encoder or verified VSD output. VSD frequency is useful but should not automatically be treated as shaft speed because motor slip, pole count, control mode and drive limits matter. Direction of rotation must be confirmed; incorrect rotation can produce some flow and pressure while severely reducing performance.

For the same geometrically similar centrifugal pump and impeller, approximate affinity relationships are:

$$Q_2/Q_1 = N_2/N_1; \quad H_2/H_1 = (N_2/N_1)^2; \quad P_2/P_1 = (N_2/N_1)^3$$

These relationships are valuable for normalising test points taken at different speeds. They are approximations and do not remove the need for a manufacturer curve, particularly across large speed changes, different impeller diameters, viscous liquids or cavitating operation.

5.4 Electrical input and efficiency

Current alone is a weak proxy for pump duty. A three-phase power analyser should preferably record true input kilowatts, voltage, current, power factor, frequency, phase imbalance and harmonics. If only current is available, any inferred power is subject to uncertainty in power factor, motor efficiency, loading and VSD losses.

With concurrent flow and total-head measurements, the overall wire-to-water efficiency can be estimated:

$$\eta(\text{wire-to-water}) = \rho g Q H_p / P_{in}$$

This is a diagnostic value combining drive, motor and pump losses. It can reveal deterioration or poor operating location, but it cannot by itself identify the exact pump model.

5.5 Condition and process observations

Vibration, bearing temperature, noise, seal leakage, casing temperature and visible solids should be recorded with the hydraulic readings. Cavitation, air binding, ragging, worn impellers, clogged suction screens, leaking non-return valves and partly closed valves can shift the measured operating point. These conditions must be corrected or explicitly reflected in the interpretation.

6. Use More Than One Operating State

One measured flow-head point establishes only one point on the combined pump-system interaction. It does not define either curve uniquely. Stronger evidence is obtained by testing several safe operating states, for example:

- Different VSD speeds.
- Each pump individually.
- Permitted combinations of pumps in parallel.
- Normal minimum and maximum source or destination levels.
- Controlled changes in a regulating valve where the system and procedure allow it.

Every state should record the same variables: time, running pumps, valve positions, source and destination levels, flow, suction pressure, discharge pressure, speed, input power and relevant process demand. Testing pumps individually can reveal unequal wear, incorrect impellers or a non-return valve allowing reverse flow. Parallel-pump tests show the actual incremental flow from adding another pump; it is rarely equal to the single-pump flow because the system resistance rises.

7. Reconstruct the System Curve

For many water systems operating in a turbulent regime, the system head can be represented approximately as:

$$H_{\text{system}} = H_{\text{static}} + KQ^2$$

Static head includes the elevation and pressure difference between the source and destination boundary conditions. The KQ^2 term represents pipe, fitting, valve and equipment losses. If static head is known reliably, one measured operating point can provide a first estimate of K . Several points at different flows allow regression and provide a much stronger curve.

The system curve should be prepared for the range of credible conditions, not one average case. Depending on the installation, this may include minimum and maximum wet-

well levels, reservoir levels, network pressures, alternate discharge routes, dirty and clean screens, different valve states and future pipework. Where the network branches or pressure-controlled valves operate dynamically, a hydraulic model may be more appropriate than a single quadratic curve.

The reconstructed curve should be checked against a separate calculation from surveyed elevations, pipe lengths, diameters, roughness and minor-loss coefficients. A material difference between the calculated and measured curves can indicate an unknown restriction, closed valve, internal pipe condition, leak, meter error or incorrect boundary assumption.

8. Establish the Required Design Duty

The final selection duty should be derived from the service requirement. For potable or process water this may include peak demand, reservoir recovery time, required terminal pressure, treatment throughput and future growth. For wastewater it may include peak inflow, storage volume, maximum permissible starts per hour, emergency storage, minimum cleansing velocity, solids passage and the need to avoid excessive detention time.

At least the following duties should be defined where applicable:

- Normal duty at typical boundary conditions.
- Maximum required flow at the worst credible system head.
- Minimum continuous or controllable flow.
- Duty with one unit unavailable.
- Emergency or peak condition and its permissible duration.
- Future design condition, clearly separated from current demand.

A design margin should respond to identified uncertainty; it should not be an arbitrary percentage added to both flow and head. Excessive margin can oversize the pump and reduce reliability. When uncertainty is material, staged verification or temporary instrumentation is preferable to compounding conservative assumptions.

9. Selection Factors Beyond Flow and Head

Flow and head locate the hydraulic duty, but they do not complete the selection. The assessment must also consider:

- Liquid properties: temperature, density, viscosity, pH, chlorides, abrasives, fibrous solids, maximum particle size, gas content and chemical compatibility.
- Suction conditions: atmospheric pressure, liquid vapour pressure, suction losses, minimum liquid level, submergence, vortex risk, air ingress and required priming arrangement.
- NPSH: net positive suction head available must be calculated for the worst credible suction condition and compared with the manufacturer's NPSH required using

an appropriate margin. NPSH required is pump-specific and cannot be derived from motor size.

- Operating region: the expected duty range should remain within the manufacturer's allowable operating region and preferably near the best efficiency point, subject to application-specific constraints.
- Motor and electrical system: absorbed power across the full curve, motor service factor, starting method, number of starts, VSD compatibility, cooling at reduced speed, supply quality, cable capacity and protection coordination.
- Controls: level or pressure setpoints, sequencing, duty rotation, minimum run time, anti-cycling, low-flow protection, dry-run protection and failure modes.
- System effects: parallel and series operation, minimum line velocity, valve behaviour, non-return-valve closure, surge and maximum allowable system pressure.
- Physical integration: flange positions, footprint, lifting arrangement, guide rails, access, baseplate, pipe loads, civil openings and maintainability.
- Reliability and lifecycle: duty/standby philosophy, critical spares, local technical support, interchangeability, energy use, maintenance requirements and total cost of ownership.

10. From Provisional to Final Selection

A responsible reverse engineered selection should use decision gates.

Gate 1 - Provisional duty. Compile the available evidence, establish preliminary boundary conditions and identify the uncertainties that could change the selection.

Gate 2 - Field verification. Obtain simultaneous flow, head, speed, power and level readings over enough operating states to reconstruct credible performance and system curves.

Gate 3 - Hydraulic and multidisciplinary review. Confirm demand, suction adequacy, NPSH, pipe velocities, surge, controls, electrical capacity, civil fit and maintainability.

Gate 4 - Manufacturer selection. Obtain certified or published curves for the proposed pump, impeller and speed. Check head-flow, efficiency, absorbed power, NPSH required, allowable operating region and motor rating across all defined scenarios.

Gate 5 - Validation after installation. Commission the pump against measurable acceptance criteria. Record flow, pump total head, speed, true input power, vibration, controls and operating levels. The verified data become the new baseline and should be issued with updated schedules, curves, settings and as-built information.

11. Managing Uncertainty

The assessment report should separate measured facts, calculated values, assumptions and information supplied by others. Each key input can be assigned a confidence level:

- High confidence: calibrated direct measurement or verified record.
- Medium confidence: repeatable indirect measurement or corroborated operating evidence.

- Low confidence: assumption, unverified recollection or inference from incomplete data.

A sensitivity test should show whether plausible variation in the low-confidence inputs changes the pump model, impeller, motor or control strategy. If it does, the correct response is further investigation, not false precision. The selection can be issued as preliminary, conditional or final according to the evidence available.

12. Common Errors

Several shortcuts repeatedly lead to poor selections:

- Selecting solely from the existing motor kilowatts.
- Treating discharge pressure as pump total head.
- Inferring flow from current without a calibrated relationship.
- Using one operating point as a complete system curve.
- Ignoring suction conditions and NPSH.
- Measuring pumps in parallel but assigning total flow equally without verification.
- Treating VSD frequency as exact shaft speed.
- Using a degraded operating point as the required design duty.
- Adding excessive safety factors to uncertain flow and head.
- Checking only the nominated duty point instead of the full operating range.
- Replacing the pump before investigating pipe restrictions, leaks, valve condition or abnormal controls.

13. The Metsiworx Approach

Metsiworx applies this reverse engineering process as an engineering investigation rather than a catalogue exercise. The assessment brings together hydraulic, mechanical, electrical and control information so that each recommended pump is supported by a traceable duty and a defined set of system conditions.

This approach protects the client from two opposite risks: under-selection, which fails to restore the required service, and over-selection, which can increase energy use, pressure, surge, wear and lifecycle cost. It also converts an undocumented installation into a maintainable asset by leaving behind a field-verified schedule, operating data, selected curves, control settings, acceptance results and updated drawings.

14. Conclusion

Missing tags and drawings do not make pump selection impossible, but they change the nature of the work. The engineer must reconstruct the system from physical evidence, field measurements and operating requirements. No single pressure, current, flow or speed reading is sufficient on its own.

The most reliable method combines simultaneous measurement of flow, pump total head, speed, electrical input and liquid levels across several operating states; develops and cross-checks the system curve; establishes the service duty independently of the present degraded

performance; and then evaluates the complete hydraulic, mechanical, electrical and control system.

Reverse engineering should therefore produce more than a replacement pump model. It should produce an auditable design basis, an explicit statement of uncertainty, measurable commissioning criteria and a new set of records that the next generation of operators and engineers will not have to reconstruct again.

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