

Waterloo Road Pump Station

Process Basis of Design and Process Description

Document number	Title	Revision	Date	Status
WRPS-PRO-001	Process Basis of Design and Process Description	A	11 August 2026	Issued for demonstration

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A	11 Aug 2026	First issue - demonstration environment	C. Huang	-	-

1. Purpose and scope

This document defines the process design basis for Waterloo Road Pump Station (WRPS), a three-pump transfer station with a buffered wet well, and describes how the station is intended to operate. It is the controlling process document for the station and is the parent document for the instrument index, equipment list and the control system functional design specification.

The station has been defined as a self-contained process reference for a control system demonstration environment. The design intent, hydraulics and instrumentation are complete and internally consistent so that control logic, operator interfaces and decision-support functions can be developed against a fixed and defensible basis.

Explicitly outside the scope of this revision

- Control logic, sequencing and duty selection rules. These are defined in the Functional Design Specification and are deliberately not fixed here.
- Downstream network hydraulics. Downstream storage is assumed unconstrained (see Section 9).
- Electrical distribution design, standby generation sizing and switchboard design beyond the interface points identified in Section 8.
- Odour control, site civil works, access and security.

2. Reference documents

Document number	Title
WRPS-DRG-001	Waterloo Road Pump Station - Piping and Instrumentation Diagram
WRPS-INS-001	Waterloo Road Pump Station - Instrument Index and Equipment List
WRPS-CTL-001	Waterloo Road Pump Station - Control Philosophy (to be issued)
WRPS-CTL-002	Waterloo Road Pump Station - Functional Design Specification (to be issued)

3. Design basis summary

The following parameters are the controlling design values for the station. Any change to a value in this table invalidates the derived quantities in Section 7 and requires the instrument index and control documents to be reviewed.

Parameter	Value	Basis
Design horizon	2045	Assumed 20-year planning horizon
Average dry weather flow (ADWF)	60 L/s	Design assumption, Section 9
Peak dry weather flow (PDWF)	110 L/s	1.8 x ADWF
Peak wet weather flow (PWWF)	300 L/s	5 year ARI, 5.0 x ADWF

Parameter	Value	Basis
Wet well plan area	120 m ² (12.0 m x 10.0 m)	Rectangular reinforced concrete
Wet well floor level	0.00 m (local datum)	All levels in this document are above floor
Spill weir level	6.00 m	Overflow to emergency relief
Working volume (stop to duty start)	360 m ³	3.00 m x 120 m ²
Emergency storage (duty start to spill)	240 m ³	2.00 m x 120 m ²
Number of pumps	3	2 duty + 1 standby, 3 x 50%
Pump duty point	120 L/s at 32 m total head	Static lift 22 m, friction 10 m
Motor rating	75 kW, 415 V, 3 phase	Approx. 50 kW absorbed at duty
Speed control	Variable speed drive, all three units	No fixed speed or DOL starters
Operating speed range	38 - 50 Hz	Minimum speed set by static lift
Firm capacity (2 pumps)	240 L/s	Largest unit out of service
Installed capacity (3 pumps)	360 L/s	Required to exceed PWWF
Inlet gravity main	DN600	1.06 m/s at PWWF
Rising main	DN400	0.96 - 2.86 m/s across operating range

4. Station configuration

Waterloo Road Pump Station receives flow by gravity through a DN600 inlet main into a single rectangular wet well, WW-101. Three submersible non-clog centrifugal pumps (PU-301, PU-302, PU-303) are installed on guide rails within the wet well. Each pump discharges through an individual DN300 riser fitted with a swing check valve and a manual isolation valve, into a common DN400 discharge manifold and rising main.

An overflow weir at 6.00 m discharges to an emergency relief structure. The station has no on-site treatment process: the entire process function is buffering inflow in the wet well and transferring it downstream.

All three pumps are driven by dedicated variable speed drives. This is a deliberate departure from the common arrangement of one variable speed unit with two fixed speed units. It allows any pump to be trimmed to match inflow, which removes the need for unmatched-duty compensation in the control logic and makes duty selection a free choice between three functionally identical units.

5. Process description

5.1 Inflow

Inflow is a gravity catchment and is not controllable from the station. Under dry weather conditions inflow follows a diurnal profile with a morning and evening peak, typically between 40 and 110 L/s. Under wet weather the catchment responds rapidly and non-linearly, and inflow may reach the design PWWF of 300 L/s. Inflow is measured directly by FIT-201, a full-bore electromagnetic flow meter installed in a submerged section of the inlet main, and is cross-checked against the volumetric rate of change of wet well level.

5.2 Wet well

WW-101 provides both operational working volume and emergency storage. The 3.00 m band between the stop-all level and the duty start level provides 360 m³ of working volume, giving long pump cycles and low start frequency at dry weather flows. The 2.00 m band above the duty start level provides 240 m³ of emergency storage before the spill weir is reached.

Level is measured continuously by LIT-101, a non-contact radar transmitter with a 0 to 7.0 m range. Two independent discrete switches provide protection that does not depend on the analogue measurement or on the PLC: LSHH-102 at 5.50 m and LSLL-103 at 0.60 m. LSH-104 in the overflow structure detects an actual spill event.

5.3 Pumping

Each pump delivers 120 L/s at 32 m total head at rated speed. The system head curve comprises 22 m of static lift and approximately 10 m of friction at duty flow. Because static lift dominates, no flow is delivered below approximately 38 Hz, and this is set as the minimum operating speed. Between 38 and 50 Hz each unit delivers approximately 65 to 120 L/s.

Pumps operate in parallel into a common rising main. Because friction head rises with total flow, per-pump flow reduces as additional units are started: three units running together deliver approximately 360 L/s in total rather than three times the single-pump duty. Individual pump discharge pressure is monitored by PIT-311, PIT-321 and PIT-331 to confirm delivery and to detect a closed valve or a blocked impeller.

5.4 Level control

The station operates on wet well level. Pumps are started at ascending level thresholds and all pumps stop at a common low level. Once running, the duty pump is modulated by a closed-loop level controller acting on drive speed, with the objective of holding level near the control setpoint rather than cycling between fixed start and stop points. Minimum run and minimum off timers protect the motors from short cycling.

Which pump starts, in what order, and how run hours are shared between units are control decisions and are defined in the Functional Design Specification. The process basis requires only that all three units are hydraulically and functionally interchangeable, which the all-variable-speed arrangement guarantees.

5.5 Protection and interlocks

The following protection functions are required by the process basis. Their implementation is defined in the Functional Design Specification and the cause and effect matrix.

Function	Initiator	Required action
Dry run protection	LSLL-103, hardwired	Stop all pumps, inhibit start until level recovers
High high level	LSHH-102, hardwired	Start all available pumps at maximum speed, alarm
Spill detection	LSH-104	Alarm and log spill event, record start and end time
Motor thermal	TE-312 / 322 / 332	Trip the affected unit, lock out until reset
Seal failure	MSE-313 / 323 / 333	Alarm, permit continued operation, flag for service
Excess vibration	VE-314 / 324 / 334	Alarm on high, trip the affected unit on high high
No flow on start	PIT-311 / 321 / 331	Trip the affected unit, start next available unit
Level signal failure	LIT-101	Alarm, fall back to discrete switch control

5.6 Discharge

Combined discharge flow is measured by FIT-301 and manifold pressure by PIT-302 in the valve chamber downstream of the manifold. FIT-301 provides the pumped volume used for mass balance against FIT-201 and for pump performance monitoring. Downstream storage is treated as unconstrained: the station is never required to throttle or stop on account of downstream conditions, and no downstream level feedback is provided.

6. Level schedule

All levels are metres above the wet well floor (local datum, floor = 0.00 m). Volumes are cumulative from the stop-all level.

Level (m)	Volume above stop (m ³)	Designation	Tag	Function
6.00	600	Spill weir	-	Overflow to emergency relief structure
5.50	540	High high level	LSHH-102	Hardwired, start all available pumps
5.20	504	High level alarm	LIT-101	Operator alarm, no automatic action
5.00	480	Start pump 3	LIT-101	Third unit start threshold
4.50	420	Start pump 2	LIT-101	Second unit start threshold
4.20	384	Control setpoint	LIT-101	Closed-loop speed control target
4.00	360	Start duty pump	LIT-101	First unit start threshold
1.00	0	Stop all pumps	LIT-101	Common stop level
0.60	-48	Low low level	LSLL-103	Hardwired dry run protection

7. Hydraulic capacity and headroom

7.1 Capacity check

Firm capacity with the largest unit out of service is 240 L/s, which exceeds PDWF of 110 L/s with substantial margin but is below PWWF of 300 L/s. All three units are therefore required to be available to pass the design wet weather flow, and the station relies on wet well storage to absorb the shortfall during any period when only two units are available.

7.2 Time to breach

The governing operational quantity at this station is not level but the time remaining before the spill weir is reached. It is derived from remaining storage volume and the net rate of accumulation:

$$\text{time to breach} = \text{remaining volume to spill} / (\text{inflow} - \text{total pumped flow})$$

Where total pumped flow exceeds inflow the expression is negative and the wet well is drawing down. The quantity is meaningful only while net accumulation is positive.

The following cases are derived from the design basis in Section 3 and bound the expected operating envelope.

Case	Inflow (L/s)	Pumps running	Net (L/s)	Storage remaining (m ³)	Time to spill
Dry weather, filling	60	0	+60	600	2 h 47 min
Dry weather, duty running	60	1 at 120 L/s	-60	-	Drawing down
Reference condition (Section 7.3)	165	1 at 120 L/s	+45	240	1 h 29 min
Two units, wet weather	300	2 at 240 L/s	+60	240	1 h 07 min
Three units, design PWWF	300	3 at 360 L/s	-60	-	Drawing down

7.3 Reference operating condition

A single reference condition is defined so that control logic, alarm response times and operator interface behaviour can be developed and tested against a repeatable case. It represents an early wet weather event with the duty pump already running.

Quantity	Value
Wet well level	4.00 m (duty start level)
Inflow	165 L/s and rising
Pumps running	One unit at rated speed, 120 L/s
Net accumulation	45 L/s
Storage to spill weir at 6.00 m	240 m ³
Time to spill	5 333 s, approximately 89 minutes
Time to high high level at 5.50 m	4 000 s, approximately 67 minutes

Note: time to breach assumes inflow holds at its current value. In wet weather inflow is the least predictable variable at the station, and any operational decision that consumes headroom must reserve margin for forecast error, pump start time and one failed start. The size of that reserve is a control system design parameter and is set in the Control Philosophy.

7.4 Pump cycling

At ADWF of 60 L/s the wet well fills the 360 m³ working volume in approximately 100 minutes and a single pump at rated speed draws it down in approximately 100 minutes, giving a cycle time of about 3.3 hours and approximately seven starts per day per unit. Start frequency is therefore not a constraint on this station, and level control may be tuned for stability rather than for cycle minimisation. A minimum run time of 5 minutes and a minimum off time of 5 minutes apply as motor protection.

8. Interfaces and non-process inputs

The following data are available at the station but do not form part of the base process control function. They are recorded here because they influence operational decisions and will be consumed by higher level functions.

Input	Source	Process relevance
Time of use energy tariff	Retailer schedule, imported to the control system	Affects preferred start timing. Does not affect any protection function and cannot defer a start required to protect headroom.
Pump run hours	Accumulated in the control system per unit	Basis for duty rotation and for service interval tracking.
Service interval status	Maintenance management system	Influences which unit is preferred, never whether a unit runs. A unit due for service remains fully available.
Weather forecast	External feed	Advisory only. Not used in any automatic action in this revision.

The ordering above is deliberate and is a process requirement, not a preference. Spill is irreversible; energy cost and asset wear are recoverable. No input in this table may override a start required to protect wet well headroom.

9. Assumptions register

Each assumption below is a value adopted in the absence of measured data. Each requires closure before the design could be used for construction.

ID	Assumption	Impact if incorrect	Status
A01	ADWF of 60 L/s and PWWF of 300 L/s	Pump duty, number of units and wet well sizing	Open - no historical flow record
A02	Downstream storage is unconstrained	Removes the need for downstream level feedback and for any discharge restriction logic	Closed by direction - fixed for this revision
A03	Static lift of 22 m	Minimum operating speed and the shape of the flow versus speed relationship	Open - to confirm against survey
A04	Wet well plan area of 120 m ² is uniform over the operating depth	All volume and time-to-breach figures in Section 7	Open - to confirm against civil design
A05	Inlet main flows full at the FIT-201 location	Validity of the inflow measurement, and therefore of time-to-breach	Open - to confirm by hydraulic check
A06	Three pumps in parallel deliver approximately 360 L/s	Whether design PWWF can be passed without spilling	Open - to confirm against pump and system curves

10. Basis for downstream documents

The instrument index and equipment list (WRPS-INS-001) is derived directly from this document and from WRPS-DRG-001. The control philosophy and functional design specification will be derived from the level schedule in Section 6, the protection functions in Section 5.5 and the decision ordering in Section 8.

This document defines what the station is and how it must behave. It does not define how the control system achieves that behaviour, and it should not be amended to record control logic decisions.