Flexible Operation of Water Networks Enabling Response Services (FLOWERS)

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1. Executive Summary

UK water utilities have historically had low participation in electricity distribution demand side response services (flexibility services), due to difficulties establishing a business case. Water utilities are also one of the largest electricity consumers. Peak water utility electrical demand aligns with peak usage of drinking and wastewater networks, with highs in the morning and evening. These sites consequently contribute to peak congestion on electricity networks, especially on high voltage and low voltage networks, where the majority of water sites are connected. However, water utilities have committed to achieve net zero in their operations, a proportion of which will be achieved through decarbonisation of electricity usage and connecting or enabling additional renewable generation.

The **Fl**exible **O**peration of **W**ater Networks **E**nabling **R**esponse **S**ervices (FLOWERS) project carried out a feasibility study of the capacity of South West Water's drinking water and wastewater networks to embed flexibility within their operational processes. Specifically, it investigated the capability to adjust the timing and control of operations in response to signals from the electricity network (referred to variously as "embedded flexibility" or "operative flexibility"). The electricity demand shifted to different times of the day could fulfil several use cases: reducing peak demand in constrained network areas, reducing the carbon intensity of water utility demand and reducing need for curtailment of renewable generation.

An initial feasibility assessment identified water network operations which could potentially be made flexible. This potential capacity which could be time-shifted was quantified and mapped onto South West Water (SWW)'s and National Grid Electricity Distribution (NGED)'s networks to identify areas of greatest potential benefit. A high-level architecture document was produced outlining potential methodologies for operative flexibility. The implementation of operative flexibility was modelled in six case study water network sites. A commercial proposal was produced for the incentive and reward scheme for embedded flexibility that could be developed in the current commercial and regulatory contexts.

The results of this investigation concluded that on South West Water's network there is between 18 and 34 MW of potential flexible demand, estimated at a potential value of around £5,000 per hour at the most common current flexibility product rate. The majority of accessible opportunities involve the planning and control of water pumping. Additional opportunities lie in the aeration and UV irradiation processes of wastewater treatment. Drinking and wastewater treatment sites are the largest energy consumers, and so initiatives which including these sites are likely to be of the greatest value.

The key challenges for long-term flexibility are developing the necessary forecasting capability – for seasonal drinking water and wastewater system flows and the associated electrical demand and its alignment with electricity network constraints – and ensuring firm electricity supply. The key challenges for short-term flexibility are obtaining sub-metering data and automating command and control capability of water networks for dispatching flexibility services and validating their delivery. Incentives for embedding operative flexibility could be built into connection agreements for renewable generation at water utility sites.

A proposed plan for a follow-on project, "Shifting Currents", to develop the proposed solutions from concept to trial on multiple networks has been produced. An Application for Strategic Innovation Funding discovery phase funding was made in November 2022.

2. Project Background

UK water utilities have historically had low participation in flexibility due to difficulties establishing a business case. However, water utilities have committed to achieve net zero in their operations. Due to the carbon inherent within the matter processed by wastewater networks, net zero solutions for water utilities must include a carbon offset, a proportion of which will be achieved by connecting or enabling additional renewable generation.

In the UK, water utilities are one of the largest electricity consumers. South West Water (SWW), the water utility contributing to this study, consumes over 300 GWh annually across its sites. Peak water utility electrical demand aligns with peak usage of the drinking and wastewater network, with peaks in the morning and evening. Water networks consequently contribute to peak congestion on electricity networks, especially on high voltage (HV) and low voltage (LV) networks, where the majority of water sites are connected. Carbon intensity of electricity supplies also tends to be highest during these peak hours so where consumption at these peak times can be avoided there is also likely to be an associated carbon reduction in the energy consumed. This would be of potential benefit to both water networks aiming to achieve net zero and electricity networks intent on reducing carbon intensive generators in the energy mix.

The timing and control of operations (and associated electrical demand) is driven by the internal state of the water network. There is a potential opportunity, therefore, to better align these operations to the state of the electricity network. For example, unlike electricity demand, where distribution can only take place as electrical energy is consumed, water operations only need to take place such that water is available at time of consumption or treatment. This can potentially be exploited. On drinking water networks, pumping could be carried out proactively ahead of demand, while wastewater pumping and treatment is held off for a set amount of time, shifting the electrical demand to less congested times of day.

A previous National Grid Electricity System Operator (NG ESO) project, “Enhancing Energy Flexibility from Wastewater Catchments Through a Whole System Approach”, examined flexibility in water networks. The focus of this project was constrained to headroom in rare weather event water catchments. FLOWERS aimed to build on this by looking at opportunities for flexibility across drinking water (DW) and wastewater (WW) pumping activities and taking a system interoperability approach with an array of potential triggers and processes.

3. Scope and Objectives

FLOWERS' aim was to increase the capacity embedded within water networks to deliver flexibility for electricity distribution networks. Water utilities are one of the largest consumers of electrical power, about 1TWh of demand across National Grid Electricity Distribution's four licence areas. South West Water contributes just over 300GWh of this demand. Developing new operational processes and removing commercial and regulatory barriers for water networks to deliver flexibility therefore presented a significant opportunity for unlocking of flexibility capacity which is value for money to customers.

The project built upon a Network Innovation Allowance (NIA) project delivered by National Grid ESO to investigate the potential flexibility capacity in storm drains and wastewater catchments, which quantified capacity but did not create a commercial model for accessing it. The aim was twofold: uncover flexibility capacity that could be embedded in an entire water utility's networks and develop a cost-saving commercial model for its delivery.

Originally, the scope of FLOWERS was to expand the search for capacity on water networks by quantifying the available capacity across both wastewater and drinking water systems within the inherent latency of their pumping operations. However, early on in the project it was concluded that focus on "latency flexibility" did not fully capture the range of related flexibility opportunities. As such, the scope expanded to include all feasible opportunities to embed flexibility in water network processes, referred to as "embedded flexibility" or "operative flexibility". This is discussed further in Section 7.

The objectives for FLOWERS are given in the table below. An explanation of the assessed status is given in Section 6 (Performance Compared to Original Aims, Objectives).

Table 3-1: Status of project objectives

Objective	Status
Assess the technical and legal feasibility of embedding flexibility on water networks within the latency of their internal pumping operational processes	✓
Quantify and map water latency flexibility capacity to understand the alignment between availability and network constraint zones	✓
Determine the commercial arrangements necessary to procure flexibility capacity within water network processes	✓
Understand the technical and operational requirements of the system that would trigger latency flexibility	✓

4. Success Criteria

The success criteria for FLOWERS are given in the table below. An explanation for the assessed status is given in Section 6 (Performance Compared to Original Aims, Objectives).

Table 4-1: Status of project success criteria

Success Criteria	Status
A business case and cost-benefit analysis for using water network latency as a flexibility source will be created	✓
The high-level specification of a latency flexibility system will be documented for implementation in an appropriate follow-on project	✓
The capacity for latency flexibility on SWW's network will be quantified, with a methodology that can be replicated by WPD or other DNOs for other water networks	✓
A commercial proposal will be submitted to Ofgem and Ofwat for the implementation of the latency flexibility product	✓

5. Details of the Work Carried Out

The project was delivered in a series of work packages as detailed below:

LFA1. Feasibility of latency flexibility

This work package explored potential operations on SWW's network which could be made flexible, assessing the feasibility of embedding this flexibility within SWW's system. A high level examination of SWW's energy consumption by site was also carried out.

Analysing the potential within water network operations began with workshops with and shadowing of operatives from the separate areas of SWW operations, including drinking water services (DWS), wastewater services (WWS) and the control room.

Within the activities, processes which could potentially be made flexible were documented and organised[1] into the following categories:

- **Low hanging fruit** – opportunities that are achievable, feasible and have clear benefits
- **More challenging** – opportunities that require some further investigation due to technical limitations or high risk
- **Worthwhile with focus** – opportunities where focus needs constraining to identify whole system benefits
- **Energy management/efficiency** – opportunities that align with energy management rather than flexibility, but were worth documenting due to potential additional benefits to the network if followed up outside of the project
- **Out of scope** – additional opportunities which relate to other potential learning that could be generated in a separate activity

Opportunities within the first three categories, which were considered to be actionable within the scope of FLOWERS, were each assigned an energy demand type of either Pumping, Aeration or Ultraviolet Light Emitting Diode (UV LED) irradiation. These are presented in Table 5-1 below.

Table 5-1. Categorisation of flexibility opportunities

Opportunity	Category	Energy Demand Type
1. 3-4 hour turndown or switch off of DWS and WWS pumps	Low hanging fruit	Pumping
2. Increasing and reducing (ramping) speed of aeration fans	Low hanging fruit	Aeration
3. Produce forecasted pumping schedules based on next day known factors	Low hanging fruit	Pumping
4. Pre-fill DWS reservoirs	Low hanging fruit	Pumping
5. Re-profile storage levels of WWS stations	Low hanging fruit	Pumping
6. Total review of DWS and WWS set points to align with current demand	Low hanging fruit	Pumping
7. Modularise UV treatment of waste with reduced flows	More challenging	UV LED irradiation
8. Increase and/or match pump size to shorten operating hours	More challenging	Pumping

[1] Feasibility Report

9. Enable WWS pre pumping with tidal flow forecasts	More challenging	Pumping
10. Install Variable Speed Drives (VSD) to manage demand profile	Worthwhile with focus	Pumping
11. Use storm tanks to reduced flows to treatment works	Worthwhile with focus	Pumping

Concurrently, a high-level evaluation of the connectivity and usage data for SWW MPANs on NGEDs network was carried out. Overall, SWW's four year average electricity consumption is 301.5 GWh, spread across 2,140 MPANs. These 2,140 MPANs are served by 1,932 NGED secondary substations, 195 primary substations and 29 bulk supply points across the South West licence area.

A stage gate in this work package concluded that there was enough justification that embedding flexibility in operations was feasible, and so to proceed with work packages LFA3 – LFA6.

LFA2. Regulatory feasibility and development of commercial and regulatory relationships

This work package considered the regulatory and commercial context and challenges to be overcome for embedding flexibility. In part one of this work package, a review was carried out of the current regulatory regime, identifying elements of the project hat presented challenges to the status quo. In part two, the outcomes of this were then turned into a commercial proposal document to be shared with regulators.

Part One

Part one saw close engagement with the regulator to get informal feedback on potential proposals. This focused on the Ofgem innovation team in the first instance, and included Elexon, BEIS and Ofwat. The costs and benefits of potential changes were considered, and the impact on flexibility and connection market stakeholders when developing proposals.

The following was documented[2]:

- **Key concerns** for regulators, including the impact of changes on stakeholders, markets and the end consumer.
- **Arguments for and against** the FLOWERS approach, detailing perceived benefits and concerns.
- **Potential outcomes** and **specific regulatory considerations** of bespoke flexibility services embedded in water networks.
- **Payment for the service,** or rather whether it could be offered as quid pro quo in exchange for increased headroom to connect on-site generation.
- **Other mechanisms** that could realise the flexibility from water companies.
- **Market areas that could be impacted**, where water companies providing their flexibility via the FLOWERS approach could distort competition and fairness.

A stage gate in part one concluded that there no legal grounds for halting progress on the project to work packages LFA3 – LFA6.

[2] Interim Commercial and Regulatory Relationships Report

Part Two

Part two, which took place concurrently with the subsequent work packages, focused on outlining the services that could be established with the water industry through the method for embedding flexibility set out in the outcomes of work package LFA4 (discussed later in this section). A commercial proposal document was produced[3] as a starting position to embed operative flexibility within water networks. Its main considerations are discussed below.

Mechanisms for water industry flexibility

The use cases identified in FLOWERS present a variety of service types. This ranges from pre-emptive use on a scheduled basis over entire seasons through to quick response, short duration services to address acute constraint or post fault conditions. This broad spectrum would create many opportunities for participation by the water industry and its wide portfolio of operational processes and assets.

Indirect remuneration (“quid pro quo”)

As previously acknowledged, the participation of water utilities in distribution flexibility is limited. The commercial arrangements of operative flexibility must therefore establish a viable incentive for participation. This arrangement also needs to be considerate of the potential benefits and conflicts due to the participants being separately regulated utilities.

Market impact

The mechanisms and indirect remuneration methods described above are aimed at reducing water companies’ barriers to offering flexibility. This is important given the size of water companies demand and importance of multi-vector alignment for the net zero transition. However, it is acknowledged that providing flexibility via the FLOWERS approach could impact or distort other areas of the market.

LFA3. Mapping and case study selection

This work package quantified and mapped the capacity for operative flexibility from LFA1 onto SWW’s networks and NGED’s constraint map[4] to identify areas of greatest potential benefit. From this a shortlist of potential case study areas was produced, from which six representative sites were selected.

Quantification and mapping

A methodology was developed for estimating the electrical demand capacity that could be shifted for each of the opportunities described in Table 5-1. This was then applied to SWW sites across its entire DWS and WWS coverage areas and mapped against NGED electrical network areas.

All half hourly (HH) metered sites[5] on SWW’s network (excepting three hydropower generation sites) were arranged into four categories. Per each site category, it was determined which of the flexibility opportunities (as shown in Table 5-1) were applicable. This is shown in Table 5-2 below.

Table 5-2. Categorisation of sites and opportunities

Type of site	Reference	Number of sites	Opportunity categories applicable (as per Table 5-1)
Drinking Water – Water Distribution	DW-WD	61	1, 3, 6, 8 and 10

[3] Commercial Proposal Document

[4] Quantification and Mapping Report

[5] There were a significant number of sites which were non-half hourly metered and excluded from the analysis. However, these are smaller sites with more limited demand and flexibility potential than HH metered sites

Drinking Water – Water Treatment	DW-WT	61	1, 3, 4, 6, 8 and 10
Wastewater – Mains Distribution	WW-MD	188	1, 3, 6, 8 and 10
Wastewater – Sewage Treatment	WW-WT	158	1, 2, 3, 5, 6, 7, 8, 9, 10 and 11

Data inputs

The dataset used in quantification is shown in Table 5-2 below.

Table 5-2. Data inputs for LFA 3

Owner	Data used
NGED	• All NGED primary and secondary substations serving SWW sites • Constrained primary and secondary substations
SWW	• Sites' locational data • Site MPANs • HH sites' electricity usage data • On-site generation HH data • End user water consumption • Recorded rainfall

Assumptions and calculations

All assumptions were drawn from workshops with SWW operatives in LFA1 and LFA3.

Table 5-3 shows, for each site category, the assumed proportions of overall site maximum demand (MD) contributed by the three energy demand types.

No assumptions were made for the length of time the flexibility initiatives could be utilised for.

Table 5-3. Assumptions of total MD for each site category by energy demand type

	Proportion of total MD		
Site category	**Pumping**	**Aeration**	**UV LED**
DW WD	90%	-	-
DW WT	30%	-	-
WW MD	90%	-	-
WW ST	30%	30%	30%

The flexibility capacity for each site category was calculated as the relative proportion of the demand for each demand type that could be shifted using the operative flexibility initiatives described in Table 5-1. For Aeration and UV LED this was assumed to be 20% and 10%, respectively. For pumping, this was a combination of the initiatives applicable to the site category.

Case study selection

A set of criteria was established and applied to identify case study sites for LFA5, ensuring at least one of each of the four site types was included. These criteria included "must have" and "nice to have" characteristics for each site and locational criteria to ensure balance across the sites selected. These are presented in Table 5-4 below.

Table 5-4. Case study selection criteria

Criteria type	Selection criteria	
Must have	• Be in a Constraint Managed Zone (CMZ) • HH main meter • >1 year historic meter data available • Remote pumping control	• Pumping set points management system • Water flow measurement • Aeration control system (WW-ST only)
Nice to have	• Solar PV installed • Solar PV planned • Existing sub-metering	• Onsite CHP • Onsite Hydro • Ammonia treatment
Locational	• Urban • Rural • Coastal	• Seasonal population change • Topographically hilly catchment • Topographically flat catchment

The following case study sites were selected[6]:

Table 5-5. Selected case study sites

Category	Site(s)
DW WD	Dunsford Hill
DW WT	Pynes
WW MD	Pottington, Porthgwidden
WW ST	Ashford, Hayle

LFA4. Technical and operational system specification

This work package documented the technical and/or operational solutions necessary to implement operative flexibility[7]. While a full design specification is beyond the scope of a feasibility study, consideration was given to the key capabilities which need to be developed for a system for accessing operative flexibility embedded in water networks.

The necessary technical capabilities are primarily informed by timescale. A seasonal approach to operative flexibility is substantively different from attempting to access operative flexibility post-fault. As such, five broad methodologies for operative flexibility were defined, which would inform the technical requirements of an operative flexibility system. These are summarised in Table 5-6 below.

[6] Case Study Selection Report

[7] Specification and High Level Architecture Document

Table 5-6. Broad methodologies for operative flexibility

Method	Description	Minimum capacity	Minimum duration
A	Pre-emptive seasonal approach intended to reflect the generally recognised demand and generation patterns for electricity.	50 kW	60 minutes
B	Weekly flexibility based on forecasting	100 kW	60 minutes
C	Manual or automated operation dispatched via API 30 minutes ahead of time	200 kW turn down 100 kW turn up	60 minutes
D	Automated operation 15 minutes ahead of time	200 kW turn down 100 kW turn up	30 minutes
E	Automated operation responding in 1 1 minute post-fault	200 kW turn down 100 kW turn up	15 minutes

LFA5. Case study modelling, simulation and cost-benefit analysis

This work package took the outputs of LFA 2-4 and modelled the implementation and procurement of latency flexibility in the selected case study sites[8]. It analysed the flexibility capacity that could feasibly be procured over a set time period and performed analysis to identify the potential benefits of the system.

For each of the case study sites the following was determined:

1. The practical feasibility of implementing flexibility
2. Specific site half hourly (HH) total and pumping energy demand
3. The SWW site specific NGED CMZ HH demand reduction requirements
4. Potential HH demand flexibility available at each site
5. Feasible HH demand flexibility available from SWW sites to the NGED CMZ

Heat mapping HH flexibility demand

The six sites have a combined MD of approximately 2.9MW, with a maximum 1.6MW assessed as potentially flexible. For each site, this potential capacity was broken down into half-hourly timeslots for each month, based upon a five-year average demand in each half hour. This was then mapped against the forecast flexibility requirements in the CMZ to which the site was connected. This allowed for assessment of the proportion of forecast flexibility requirements which could be met by operative flexibility. Additionally, where two sites were connected to the same CMZ, the combined flexibility available to the CMZ was also assessed.

It should be noted that this assessment could only be carried out for demand turn down type flexibility, as (Demand Turn Up) DTU forecasts are not currently being generated. This proportion was colour coded from green to red (0 – 100% respectively) to provide a heat map of the alignment between flexibility need and availability. Half hours with no requirement for flexibility were coded white. An example of the resultant heat maps is presented in Figure 5-1. This analysis showed that the sites,if implementing a 50% pumping perturbation, could feasibly provide between 53kW and 696kW of flexibility, depending on the timeslot, prior to NGED going out to the market via mechanisms discussed in LFA2.

[8] Case Study Report

Figure 5-1. Heat map of Ashford and Pottington combined potential CMZ requirements fulfilment

Month	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30
Jan															43%	6%	4%	3%	2%	2%	2%
Feb															100%	10%	4%	3%	2%	2%	2%
Mar															15%	6%	5%	4%	3%	3%	3%
Apr																60%	15%	6%	7%	9%	11%
May																		100%	24%	6%	6%
Jun																				100%	
Jul																			100%	87%	
Aug																			51%	9%	22%
Sep																			100%	18%	
Oct																59%	10%	8%	5%	6%	9%
Nov																98%	13%	14%	8%	7%	8%
Dec																8%	4%	4%	3%	3%	3%

Month	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30
Jan	2%	2%	2%	2%	2%	2%	3%	3%	3%	3%	2%	2%
Feb	2%	2%	2%	2%	2%	2%	3%	3%	4%	4%	2%	2%
Mar	3%	4%	4%	3%	3%	4%	7%	11%	16%	19%	6%	3%
Apr	11%	14%	100%	100%	100%							
May	13%	40%	31%	43%	100%							
Jun	100%	52%	100%									
Jul	9%					18%						
Aug	17%	12%	11%		100%							
Sep				22%	61%	42%						
Oct	11%	13%	12%	11%	11%	13%	44%	65%	4%	38%	3%	2%
Nov	9%	10%	9%	6%	5%	11%	34%	31%	36%	26%	7%	3%
Dec	4%	5%	5%	3%	3%	4%	6%	6%	6%	5%	3%	1%

Month	17:00	17:30	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00
Jan	1%	1%	1%	1%	1%	2%	3%	5%	14%						
Feb	1%	1%	1%	1%	1%	2%	2%	3%	7%	46%					
Mar	2%	1%	1%	1%	1%	1%	2%	3%	6%	87%					
Apr	18%	8%	5%	5%	6%	9%	10%	9%	26%						
May	100%	6%	4%	6%	6%	18%	92%								
Jun				100%											
Jul			12%	100%	12%	15%									
Aug		33%	15%	12%	20%	53%									
Sep	34%	10%	5%	6%	8%	9%	12%	53%							
Oct	1%	1%	1%	1%	1%	2%	3%	8%	100%						
Nov	1%	1%	1%	2%	2%	3%	6%	25%							
Dec	1%	1%	1%	1%	1%	2%	3%	7%	17%						

LFA6. Recommendation for follow on project and final report

This work package produced a report summarising the outcomes of the preceding five work packages[9] and recommendations for next steps acting on the learning from FLOWERS. The latter is discussed in Section 13 (Planned Implementation).

[9] Final Report

6. Performance Compared to Original Aims, Objectives and Success Criteria

Table 6-1: Performance compared to project objectives

Objective	Status	Performance
Assess the technical and legal feasibility of embedding flexibility on water networks within the latency of their internal pumping operational processes	✓	Early stage-gate milestones assessed whether there were no absolute technical or legal barriers. Assessment of the technical feasibility is documented in the deliverable for work package LFA 1. Discussion of legal feasibility is documented in the first deliverable for work package LFA 2.
Quantify and map water latency flexibility capacity to understand the alignment between availability and network constraint zones	✓	The maximum flexibility capacity across South West Water's network was mapped against CMZs in LFA 3. Mapping alignment to half-hourly CMZ requirements for case study sites was carried out in work package LFA 5.
Determine the commercial arrangements necessary to procure flexibility capacity within water network processes	✓	A commercial proposal document identifying potential arrangements necessary for embedded flexibility was produced as the final deliverable for work package LFA 2.
Understand the technical and operational requirements of the system that would trigger latency flexibility	✓	A high-level architecture report discussing technical and operational requirements of embedding flexibility was produced as the final deliverable for work package LFA 4.

Table 6-2: Status of project success criteria

Success Criteria	Achieved	Performance
A business case and cost-benefit analysis for using water network latency as a flexibility source will be created	Yes	An assessment of the value of unlocked flexibility was produced in the deliverables for work packages LFA 3 and LFA 5, against a counterfactual of the cost of procuring flexibility capacity through current market mechanisms. Due to the high-level nature of the technical assessment, the costs of implementation are not included in this analysis.
The high-level specification of a latency flexibility system will be documented for implementation in an appropriate follow-on project	Yes	Five potential methodologies for implementing embedded flexibility on water networks were defined in work package LFA 4. The key capabilities and challenges to overcome were documented as learning from this work package to form a basis for follow-on activities.
The capacity for latency flexibility on SWW's network will be quantified, with a methodology that can be replicated by WPD or other DNOs for other water networks	Yes	A methodology for quantifying flexibility capacity in water network operations was produced. It is described in the first deliverable for work package LFA 3 for other DNOs or water utilities to replicate or adapt. The methodology is not specific to South West Water's network.

Success Criteria	Achieved	Performance
A commercial proposal will be submitted to Ofgem and Ofwat for the implementation of the latency flexibility product	Yes	The commercial proposal document for embedded flexibility produced in LFA 2 was developed with engagement from regulators.

7. Required Modifications to the Planned Approach during the Course of the Project

“Latency Flexibility”

The initiation of the project expected to focus on exploiting varying the time difference between pumping operations and the utilisation or treatment of drinking water and wastewater to unlock flexibility capacity. While this latency-type flexibility remains a core element of the potential capacity, it is limiting or limited in a number of fashions. It transpired that a more generally process focused approach to flexibility could unlock further capacity under the same operational mechanisms. For example, wastewater treatment requires delicate control of biological processes that cannot be delayed by storing wastewater on site for longer during treatment. However, the same effect of flexibly shifting load could potentially be achieved by modifying arrival times of wastewater at treatment works through coordination of upstream and downstream pumping.

Consequently, the approach was changed to identify opportunities under a holistic banner of embedded flexibility or “operative flexibility”. Operative flexibility is defined as a capability to adjust the timing and control of operations in response to signals from the electricity network.

Flexibility Service vs Flexible Connection

The above notwithstanding, the mechanisms for delivering and embedding flexibility in water networks blurs the distinction between flexibility products and a flexible connection. Flexibility is typically a service voluntarily offered to the DSO post-connection through market products. A flexible connection is one in which load or export may be limited by the DNO to remain compliant with operational and security of supply conditions by means required by the connection design and agreement. A process by which water networks can connect distributed generation through flexibility offerings embedded in the connection crosses both definitions.

While the project does not answer how blurring this distinction might be resolved, the approach to next steps was adapted to include consideration of the need to engage flexible connection stakeholders.

Technical Architecture

Due to the feasibility study nature of the project, “high-level specification” would always be exactly that. However, it was anticipated that some identification of individual processes would be included. In the course of the project, this proved not to be true. The first reason for this is the amount of variation between the operation and control of South West Water’s network site-by-site. A too detailed process specification would likely exclude sites in the first instance, before development of processes on a more case-by-case basis. This does not even include comparisons with other water company’s operations.

Secondly, it was also recognised that the timescale of planning, dispatch and implementation of embedded flexibility would have a significant implications for the process requirements. As such, high-level specification was specified across five potential methodologies rather than a singular method.

Cost-Benefit Analysis

The above two changes in scope had implications for considering the cost-benefit of embedded flexibility. By pulling back focus from individual assets and processes across the water network, it is difficult to identify specific costs for implementation of embedded flexibility on DW and WW systems. As such, more focus was placed upon estimating the potential value of the flexibility to DNO customers, as was reported in the D3-1 and D4-1 deliverables. This quantification of potential benefit can be considered in comparison to the cost of a follow-on development and trial project to demonstrate if continuation of this investigation is value for money.

8. Project Costs

Table 8-1: Project Spend

	Budget (£)	Actual (£)	Variance(£)
SGC Overall network investigation, workshop leads, technical and commercial development, data preparation	£156,400.00	£158,526.53 (= £156,400 + £2,126.53 from contingency)	-£2,126.53
South West Water Internal project management and advocacy, water network technical expertise, data provider	£54,600.00	£54,600.00	£0.00
NGED Project management	£50,572.00	£57,577.96 (= £50,572.00 + £7,005.96 from contingency	-£7,005.96
Contingency	£26,157.20	(£9,132.49)	+£17,024.71
Total	**£287,729.20**	**£270,704.49**	+£17,024.71

The project was delivered for £271k, £17k under its £288k budget.

The costs for Smart Grid Consultancy (SGC) were increased to include expenses for site visits. Initially it was intended that all workshops would be held virtually. However, it was identified in the first workshops that it would generate additional learning to carry out visits to selected water sites. This allowed the project team to gain perspectives from a wider pool of South West Water operational personnel and deliver more robust outcomes for work packages LFA1 and LFA5.

9. Lessons Learnt for Future Projects and outcomes

The learning from the FLOWERS project has been captured and shared in a variety of ways:

1) The final summary report documenting key learning from the entirety of the project[10]
2) A report on the feasible initiatives for embedding flexibility in water networks[11]
3) A report on quantifying the potential flexibility capacity unlocked from implementing these initiatives[12]
4) A case study report examining the impact of feasible initiatives on a variety of water network site types[13]
5) A report on the potential operational methodologies for embedding flexibility, the capabilities which require development and the operational and technical barriers to implementation[14]
6) Two documents identifying the main commercial and regulatory challenges for embedding flexibility and proposing the commercial and regulatory arrangements to meet these challenges[15]
7) The final project dissemination webinar

A summary of the main conclusions from the project is presented below:

- The majority of accessible opportunities involve the planning and control of water pumping.
- Additional opportunities lie in the aeration and UV irradiation processes of wastewater treatment.
- Drinking and wastewater treatment sites are the largest energy consumers, and so initiatives including these sites are likely to provide the greatest return in terms of flexed capacity.
- Even with conservative estimations, the value of the unlocked flexibility in a single water utility could amount to thousands of pounds an hour.
- The first key challenge for long-term flexibility are developing the necessary forecasting capability which integrates predicted water network operational electrical demand (including weather and seasonal population factors) and electricity network headroom and congestion.
- The second key challenge for long-term flexibility is ensuring firm electricity supply in order to guarantee the availability of flex weeks or months in advance.
- The key challenges for short-term flexibility are obtaining sub-metering data and automating command and control capability of water networks for dispatch and validation.
- Incentives for embedding operative flexibility could be built into connection agreements for renewable generation at water utility sites. These incentives would be aimed at achieving whole system net zero, and would include restrictions to prevent flexibility or connection market distortion.

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[10] Final Report

[11] Feasibility Report

[12] Quantification and Mapping Report

[13] Case Study Report

[14] Specification and High Level Architecture Document

[15] Interim Commercial and Regulatory Relationships Report, Commercial Proposal Document

- The proposed mechanisms for embedding operative flexibility crosses distinctions between flexibility services and flexible connections and subsequent work should engage stakeholders on both sides on how best to resolve this crossover.

Learning from the project undertaking is presented in Table 9-1 below.

Table 9-1. Learning from FLOWERS

Workstream	Learning Detail
LFA 1	An unforeseen issue with modifying pumping capacity for coastal water networks may be the infiltration of sea water. In some cases, the condition of the pipes results in an estimated 90/10 ratio between sea water and waste water in water network pipes. As such, wastewater pumping in these areas is near constant and potential to vary this may be slim.
LFA 1	SWW departments were fairly siloed from one another, with limited communication. This presents additional challenges for integrating solutions across operational areas.
LFA 1	SWW's control room is entirely reactive, responding to alarms related to minimum and maximum set points for pumping stations, with no forward forecasting or proactive pumping. This presents an opportunity, as the introduction of proactive pumping could have electricity network triggers baked in, but would necessarily require additional software and equipment.
LFA 1	There is an issue in water networks of pumps tripping when the electricity network is in abnormal running conditions. This is due to legacy overcurrent protection being too sensitive to voltage changes, even though these are within statutory limits.
LFA 1	Scheduled testing of backup generators could be flexed to provide a network benefit. Testing involving switching to local generation could be timed to coincide with when the electricity network is high demand and/or carbon intensity, to both reduce network demand at peak times and ensure that testing reduces carbon intensive energy use rather than renewables. There may be an opportunity here, but it will require coordination between disparate departments.
LFA 1	SWW has switched electricity supplier contract to one that is 100% green energy. This arguably decarbonises all SWW energy usage. However the carbon intensity of the grid at time of use is an important factor, as SWW's demand will show up in the peak demands which require a more carbon intensive energy supply at those times.
LFA 2	The Environment Agency plays a nearly equal role to OFWAT in the regulatory structure with which water networks must comply, and will be an important party to engage with for the commercial proposal for FLOWERS.
LFA 2	Ofgem's Significant Code Review will introduce new limits on curtailment on generation by DNOs. Limits will be agreed between generators and DNOs, and if these are exceed the DNO will be required to make a payment to a generator for the equivalent amount of flex. This presents both opportunity and risk. On one hand, shifting water network demand to peak generation times would reduce curtailment, strengthening the business case for FLOWERS flex. However, this may also incentivise a reduction of the price of flexibility to reduce curtailment penalties, diminishing the business case for FLOWERS flex by reducing its competitive value.
LFA 2	Operative flexibility would in most cases become an embedded service capability to be utilised prior going to the wider market for flexibility providers. Deferred flexibility market costs would be recovered from customers. Operations that could be performed ahead of need (e.g. pre-filling of DWS

	reservoirs) could offer demand turn up services. This would absorb excess export generation and reduce curtailment.
LFA 2	Additionally, DNOs could also use operative flexibility as an alternative to Active Network Management (ANM). This could be beneficial as ANM is only available in limited locations and has a high associated cost. Improving operational coordination and direct communication may allow additional generation without the need for an expensive system to manage asset limits.
LFA 2	Incentivising water network participation in flexibility could be addressed through the connections process for distributed generation. As noted above, achieving UK water utilities' net zero commitments will involve decarbonisation of energy supply and the addition of renewable generation at water sites. Operative flexibility could therefore be embedded into water site connection agreements in order to guarantee network headroom for any on-site renewable generation. This could also include guarantees that reductions in the carbon intensity of the local network by using operative flexibility to increase utilisation of existing renewable generation could be reported by water utilities as a carbon offset.
LFA 2	Embedding operative flexibility in this manner could also be attractive to utility regulators. Electricity network and water utility customers are by and large one and the same, as most owners of an electricity connection will also have a water supply, and vice versa. Consequently, any benefits derived for either side of the flexibility agreement would be double-stacked for customers.
LFA 2	Impacted areas include flexibility markets, where water companies' flexibility could be seen a substitute or distortion to these markets. It is expected the basis of most objections will relate to how the additional capacity offered by the water industry could impact flexibility providers from all other industries and how they are likely to be rewarded for that capacity.
LFA 2	The existing DNO connection and queue management process would also be affected. The FLOWERS approach could give water companies another route to connecting generating assets compared to the traditional connection route. It is important to avoid impacts for other prospective network users in the same queue.
LFA 2	To limit any market distortion, and to ensure that the motivation for water companies is to support net zero, it will be necessary to enforce limits of use. It was concluded that any assets would not be able to participate in ancillary services such as the capacity market or frequency services. These can be highly competitive, and any advantage offered in the connection of assets would be at the expense of other participants operating within a neutral market. Only in circumstances where a service or market is otherwise unable to attract sufficient liquidity should it be possible for water companies to offer operative flexibility.
LFA 3	An important distinction for understanding the scale of opportunity at a water site is whether the site is in an urban or rural location. However, neither NGED or SWW have a commonly established definition for this
LFA 3	A substantial number of non-half hourly metered SWW sites are in NGED CMZs. The opportunities for flex at these sites cannot be quantified currently. However, SWW are considering installing smart meters at these sites in the near future.
LFA 3	Drinking and wastewater treatment sites needs to maintain the biological environment for processing may limit the capability for operative flexibility. The opportunities here my lie in the timing and use of onsite backup generation

LFA 3	In urban areas, runoff is much higher as the built environment significantly reduces the ability for the soil to absorb the rainfall event. This results in an increased amount of rainwater entering the wastewater network, increasing energy demand.
LFA 3	Topography also has an impact on SWW's energy consumption. High-level analysis indicates that the impact of this on energy demand sees rural sites having a 5% higher energy demand than urban sites.
LFA 3	The impact on energy demand due to seasonal population growth (e.g. to coastal areas in summer) is in the region of a 16% increase
LFA 4	All methods for implementing operative flexibility would require development of the following capabilities: • Half-hourly sub-metering of the separate operational loads to confirm each operational loads' demand. • Pump workload forecasting using weather and demand data to enable future planning for provision of energy flexibility. • Live storage tank fill levels and forecast fill levels for all sites visible to the control room to enable confirmation of flexibility and to enable the management of storage between linked sites. • A common centralised approach for the remote control of pumping at all sites. • A close to real time methodology to confirm to the DSO the sites' ability to be dispatched (this is needed due to the exponential impact recent and forecast weather has on energy demand).
LFA 4	Method A and B would require on-site energy storage to ensure the energy demand perturbation could be implemented regardless of weather impact.
LFA 4	Method C would require the establishing of a monitored 'endpoint' to receive API notifications
LFA 4	Method D and E would require automated implementation of energy perturbations and confirmation of implementation back to the DSO.
LFA 5	The months of drought in 2022 over the summer are showing the dramatic differences rainfall patterns can have energy usage, even when comparing the same time of year against each other. In the wastewater distribution case study, for example, energy usage dropped by as much as 45% against the five year average in some half hours
LFA 5	The delivery of flexibility, greater than day ahead of real time, will fundamentally be impacted by: recent weather; forecasts for weather, DWS demand and WWS treatment volumes; and current water volumes being processed and stored at relevant sites.
LFA 5	The rates and volumes of water it is mandatory to treat, as stipulated by the relevant licences, could impact the ability to deliver operative flexibility.
LFA 5	The main energy load centres, the treatment works, will not necessarily be able to be perturbed in isolation of the pumping stations upstream and downstream.
LFA 5	The level of drinking water storage of the distribution reservoirs needs to align with forecast demand before pumping of the treated water from the treatment plant can be turned down.
LFA 5	For pre-planned flexibility, months ahead, the only firm perturbation method would be to source the electricity needs from an alternative source than the electricity network.

LFA 5	There is no common methodology for the control of pumping, with some pumping controlled both remotely and on-site. However, the majority of the pumping stations feeding into treatment works are not able to be remotely controlled.
LFA 5	There is no HH sub-metering of the separate operational loads. Therefore, determining each operation's load demand relies on estimates from on-site teams.
LFA 5	With regard to the above, upon further investigation it was concluded that pumping at the DW WT site was closer to 66% of total site demand
LFA 5	Perturbing the operation of aeration and UV LED treatments is likely to increase operational risk due to the impact upon biological processes. As such, these are not considered feasible without further detailed study.

10.The Outcomes of the Project

The outcomes of the project are as follows:

- The project has generated a set of reports on learning on the potential for embedding flexibility in the operations of water networks, including technical, operational and commercial considerations.
- A set of drinking water and wastewater system processes has been identified which could have flexible operation embedded within them. The development process included significant water operative expertise to validate the assumptions as genuine and feasible.
- Reasoned assumptions have been generated for the impact of these opportunities on NGED's network, in a manner which is replicable for other DNO/DSOs and water companies.
- The value of the potential embedded flexibility has been calculated for SWW's sites, both in terms of power and customer financial benefits. The quantitative data for this valuation is presented in the D3-1 and D5-1 reports. The calculation method is applicable to all DNOs, based on their own per MWh valuation of flexibility. This is typically the same as NGED's, as the majority of DNOs share the Flexible Power platform.
- Five potential methodologies for embedding flexibility in operations have been developed by the project, differentiated by the timescales over planning, dispatch and implementation. The main technical and operational challenges for each method have been document.
- The project has highlighted the commercial incentives and company priorities which would drive greater water utility engagement with flexibility, particularly surrounding the achievement of water company net zero objectives.
- A commercial proposal for implementing embedded flexibility has been delivered to address the regulatory and commercial challenges. It focuses on an alternative process for connecting renewable generation at water network sites, with appropriate restrictions to prevent distortions to the commercial flexibility and generation markets.
- An application has been submitted to Ofgem innovation funding for a follow on development and demonstration project. A set of alternative options for pursuing further learning has been produced.
- Learning from project FLOWERS has been informally shared with additional water companies. Consequently, most water companies across NGED's licence areas are partners to funding applications.
- The project has increased knowledge sharing and engagement between electricity and water industries and begun to break the silos between them, including identifying separate potential areas of enquiry.
- The project has highlighted additional learning on the energy efficiency and maintenance of water networks that could produce additional benefits to electricity and water network customers.

11. Data Access Details

No new data has been generated for this project, only existing NGED and SWW data has been used in the analysis.

NGED data can be requested via the National Grid Connected Data Portal (https://connecteddata.nationalgrid.co.uk/).

South West Water asset and demand data was obtained to facilitate analysis of capacity. This data is confidential to South West Water and can only be released to interested parties with South West Water consent. This can be requested by contacting Angus Berry, Energy Manager at aberry@southwestwater.co.uk.

12. Foreground IPR

New foreground IPR has been created in the project reports. These are published and freely available on the NGED Innovation website.[16]

13. Planned Implementation

FLOWERS was a feasibility project intended to identify potential embedded flexibility initiatives that could be developed and trialled in a follow on project. However, the assumptions of replicability across the UK need to be tested and there was no real-life demonstration. Doing so carries significant risk due to the technical challenges to be overcome, such as coordinating between up and downstream water sites or accurately forecasting generation intensity and risk of curtailment. These innovations are significantly different than typical DNO flexibility procurement, and the development of this capability is not within the capacity of these business as usual (BAU) activities.

Consequently, planned implementation is directed towards further development to BAU readiness via follow on innovation projects. One application has been submitted to Ofgem Innovation processes, and alternative options are in scope if this is unsuccessful.

A follow on project would ideally look to develop the proposed solutions from concept to trial on multiple networks and in the following steps:

1. Assess the applicability of the FLOWERS solutions for each water network partner
2. Identify any additional requirements and challenges to overcome
3. Identify potential trial sites across a variety of network and geographical areas
4. Produce a roadmap for design, trial and BAU
5. Develop a full system specification and design
6. Validate the design in electricity and water network models
7. Design and plan trials
8. Prepare trial sites as per the specification
9. Run the trial on a single site and evaluate the outcomes
10. Adapt and run the next trial on multiple sites, evaluating against success criteria
11. Finalise the BAU roadmap

[16] FLOWERS web page

14. Contact

Further details on this project can be made available from the following points of contact:

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15. Glossary

Abbreviation	Term
BAU	Business As Usual
CHP	Combined Heat and Power
CMZ	Constraint Management Zone
DNO	Distribution Network Operator
DSO	Distribution System Operator
DTU	Demand Turn Up
DWS	Drinking Water Services
DW-WD	Drinking Water – Water Distribution
DW-WT	Drinking Water – Water Treatment
FLOWERS	Flexible Operation Of Water Networks Enabling Response Services
HH	Half Hourly
HV	High Voltage
LV	Low Voltage
MD	Maximum Demand
MPAN	Meter Point Administration Number
NGED	National Grid Electricity Distribution
NG ESO	National Grid Electricity System Operator
NIA	Network Innovation Allowance
PV	Photovoltaic
SWW	South West Water
UV LED	Ultraviolet Light Emitting Diode
VSD	Variable Speed Drive
WWS	Wastewater Services
WW-MD	Wastewater – Mains Distribution
WW-ST	Wastewater – Sewage Treatment