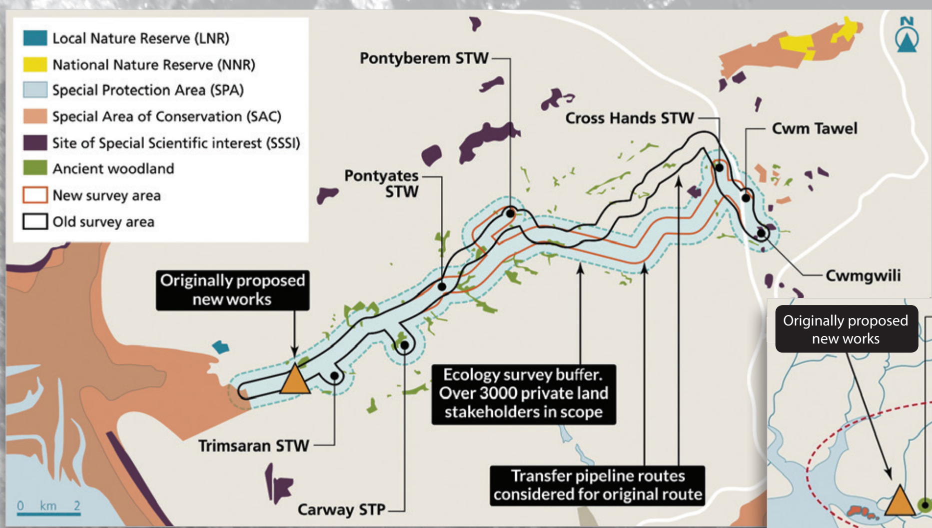
Dynamic Water Quality Assessment

phosphorous reduction: challenging traditional design approaches to reach better environmental and social outcomes for the Gwili & Gwendraeth Fawr rivers

by Sun Yan Evans & Yvonne Murphy

The River Gwili and River Gwendraeth Fawr in Wales have long suffered from poor water quality, often failing to meet phosphate targets. It was believed that the discharges from seven wastewater treatment works were contributing to deterioration in these two rivers. The need to improve the river water quality was established, but the means to achieve this was still to be determined. A phosphorus reduction target was set under the National Environment Programme (NEP) and subsequently, a new wastewater treatment scheme was proposed to transfer and treat the pollution load.



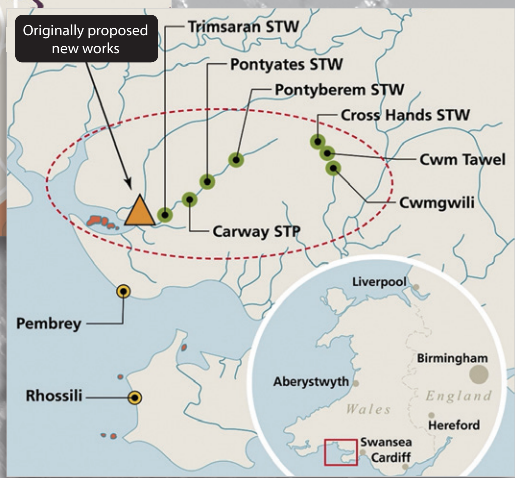


Figure 1: (above) Ecological designations informing the EIA of potential impacts due to the rising main construction corridor

Figure 2: (right) The proposed seven WwTWs to be decommissioned as part of the Gwili Gwendraeth Wastewater Treatment Scheme

Both images courtesy of ICE

Background

In September 2017, Welsh Water initiated the Environmental Impact Assessment (EIA) for a proposed wastewater treatment scheme. It was the largest wastewater capital project proposed for AMP6/7. Mott MacDonald was commissioned to gather evidence to inform the EIA to justify the proposed option and to consider alternatives as required by the Habitat's Directive Appropriate Assessment criteria.

The conventional solution, devised at feasibility stage, was to decommission the seven existing wastewater treatment works discharging into the Gwili and Gwendraeth, and re-purpose those sites as booster pumping stations. The raw sewage from their catchments would be transferred to a proposed new treatment works to be located downstream of Trimsaran close to the mouth of the Gwendraeth estuary via a 30km sewer transfer main across ecologically sensitive, privately owned land to improve river water quality (see Figures 1 & 2 - above).

This solution was supported by a SAGIS (Source Apportionment GIS) modelling approach and findings. This was a high carbon solution, both in construction and operation.

The road to Net Zero

The World is facing a climate crisis. The focus should be on *'building the right projects'* as well as *'building the projects right'*.

Approximately 70% of global greenhouse gas emissions emanate from infrastructure construction and operations. The ICE President for 2021, Rachel Skinner, announced a *"call to arms"* to minimise whole life carbon and climate change impacts; with the need to build smarter and to ask tough questions early to reach the right outcomes for society and the environment. The use of ever-increasing amounts of dosing chemicals is unsustainable.

Using a dynamic approach to inform the derivation of permits is becoming more important in the UK as phosphorus limits are being tightened progressively from 2mg/l in 1991 set by the Urban Wastewater Treatment Directive to ultra-low phosphorus consents of 0.25 mg/l, requiring more complex technologies, precise chemical dosing, and control. Limits are forecast to tighten further to 0.1mg/l as Best Available Technology (BAT) develops. In most cases, the permit provided to the water company is *'worst case'* and adds pressure to increase tertiary treatment using more carbon intensive processes to strip phosphorus.

On appointment, Mott MacDonald's technical team started to examine the potential impacts of decommissioning the existing seven wastewater treatment works, particularly in relation to the environmental flows in the two river systems. As they discharge treated effluent into the Gwili and Gwendraeth continuously throughout the year, they play a very important role in maintaining the environmental flows; especially in the summer months when the river base flows are extremely low. The team also focused on identifying opportunities for the existing treatment works, and opportunities to maximise their benefits, rather than decommissioning them.

State of the art technologies and modelling software, and bespoke and innovative modelling approaches were used to assess the effectiveness and potential impact of different phosphorus reduction options on the water quality in the river systems.

In addition to river hydrodynamic and water quality modelling, the two-year £2m programme mobilised more than 250 staff from Mott MacDonald's multi-disciplinary team including experts on planning, stakeholder engagement, BIM, ecology, environment (EIA, Habitat's Directive and Water Framework Directive), landscaping, heritage, archaeology, CAD, GIS, hydraulic/sewer network modelling, and engineering design (civil, structural, geotechnical, hydraulic, M&E and process/chemical) to investigate all relevant aspects of the project, including a whole life carbon assessment.

Project drivers

Drivers for the innovative water quality modelling approach were:

- Predicting water quality dynamically and more scientifically.
- Realistically representing spatial and temporal variations of discharges and pollutants from multiple sources across catchments.
- Realistically representing complex hydraulic structures and tidal conditions.
- Providing meaningful information with clear visuals to inform decision makers about when, where, and for how long river water quality would fail Water Framework Directive (WFD) standards and impact ecosystems and informing the most cost-effective means to intervene and improve these watercourses.
- Reducing whole life carbon and following the road to zero carbon principles.

Challenge & opportunities

SAGIS (Source Apportionment GIS) was developed for UK Water Industry Research (UKWIR), with support from the Environment Agency, SEPA and Natural England, to analyse sources of chemicals at river basin scale and identify measures to improve waterbody quality. National data on the source of chemicals from a range of point and diffuse sectors are processed to create inputs to the water quality model SIMCAT. However, SAGIS has limitations.

The SAGIS approach is widely used to inform wastewater quality permits in the UK, and this approach was used to support the conventional solution developed at feasibility stage. Mott MacDonald assessed that the SAGIS approach was not appropriate to assess the specific requirements of the Gwili Gwendraeth scheme for the reasons shown in Table 1 (below).

Therefore, an alternative and more scientific approach was developed and adopted. This alternative is a Dynamic Water Quality Assessment (DWQA) approach (see Figure 2: next page), which is not only capable of representing the physical features and the hydrodynamic nature of the river systems, but can also realistically simulate the dynamic interactions, chemical and biological processes that influence water quality in the river system.

DWQA enables positive interventions to be realised from project inception stage; to question *'business as usual',* and challenge our profession to strive for more creative lower carbon solutions.

SAGIS APPROACH	DWQA - MORE REALISTIC INPUTS
The effluent quality/load and flow from point and diffused sources throughout the year can only be represented as statistical mean values and standard deviation.	Can realistically represent the spatial and temporal variation of flows and pollutant loads from all sources.
Variance of frequency of operation of assets in the catchment throughout the year is not represented. The model always assumes the worst case.	Enables a full representation of any year or a typical year of measured data i.e., spill frequency and volumes and other time variant parameters, linking with the contributing sources dynamically.
Quantity of flow in the river is only based on the low flows derived for the catchment and does not adequately reflect actual river flow conditions.	Flows are varied throughout the year. Prolonged summer periods with low flow conditions in rivers and full discharges from wastewater assets result in poor quality in the rivers. In winter periods, very high river flow will have much greater dilution. The DWQA approach can fully represent this.
SAGIS APPROACH	**DWQA - MORE REALISTIC PROCESSES**
Temperature and daylight have major influences on water quality which are not captured.	The effects of photopheresis and natural decay are represented in addition to temperature and daylight effects.
Hydraulic structures such as movable sluice gates cannot be represented.	Can represent a full range of hydraulic structures on the river system and their effects on aeration and dispersion.
Tidal conditions and tidal locking effects are not represented e.g., tidal cycle hindering dispersion in the receiving watercourse.	The flow directions and velocity variations responding to flood tide and ebb tide of the tide cycle are realistically represented. The whole process is represented including freshwater mixing with tidal water and the attenuation effects caused by tidal locking and tide draw down conditions throughout the entire tidal cycle.
The whole process including physical, chemical, and biological process is a black box with fixed external conditions and state regardless of seasonality changes.	The whole process including physical, chemical, and biological process is dynamically linked, considering varied external conditions and seasonality effects.
SAGIS APPROACH	**DWQA - MORE USEFUL RESULTS**
The result only shows one water quality result for the entire year.	The visual display function can vividly display the water quality status throughout the year along the entire watercourse. It provides visibility of water quality changes over time and at different locations. This enables rapid diagnosis of how asset performance impacts water quality and supports identification of mitigation measures and permits.

Table 1: Comparison between SAGIS and DWQA approaches

Outcomes

DWQA modelling has overcome many of the limitations of the existing SAGIS approach from data input and representation, through to process considerations, and the robustness of the results and permit derivation. Its key innovations are:

- **Realistic representation considering WFD requirements (quality, quantity, and environmental flow):** DWQA is a dynamic approach that considers the water-body as a holistic system complete with the influences of its ecosystems and processes.
- **Informing creative sustainable low carbon catchment solutions:** DWQA modelling can accurately derive baseline levels and levels in rivers and can help identify their sources, informing catchment interventions to pollution contributions at source sustainably.

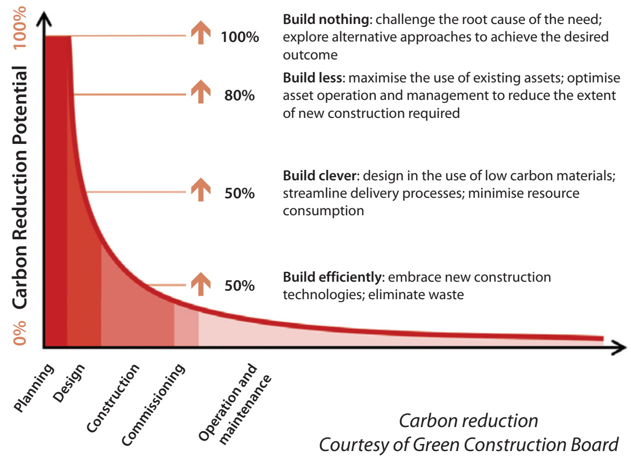
The project has provided Welsh Water and its regulator, Natural Resources Wales, with analysis and tools that will help to better understand and protect river water quality in Wales for years to come. The project also sets the parameters for further collaborative lower carbon approaches to address phosphorus reduction in rivers without building new wastewater treatment assets, adopting an innovative *'fair share'* catchment solution that considers whole life carbon, environmental, and social outcomes.

- Carbon reduction: 78% (100,000 tonnes)
- Transfer main eliminated: 30km
- Capital savings: 75% (£60m)

Achievements

The project has achieved several firsts:

- First prize in the Welsh Water excellence award 2020.
- First in the *One Mott MacDonald Global Project Awards 2021*.
- First in Wales to develop a catchment approach to permitting.
- First to engage with NRW, using their Sustainable Management of Natural Resources (SMNR) Principles to inform the development of the preferred option.



Carbon reduction
Courtesy of Green Construction Board

Further applications

Reducing carbon is not just about building new assets in a more intelligent way; it is about demanding better performance from what we already have. Systems thinking and holistic approaches are necessary given the failure of linear interventions to have transformative results.

Dynamic modelling, such as Mott MacDonald's DWQA approach and methodology, representing rivers more realistically is the best way forward to devise more accurate and beneficial holistic solutions. There are many future benefits to be realised including strategic phosphorus removal such as Gwili Gwendraeth, Storm Overflow Assessment Framework (SOAF) modelling and other water quality driven challenges.

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For additional graphs and further details of the model results visit: https://waterprojectsonline.com/custom_case_study/dwqa-2022

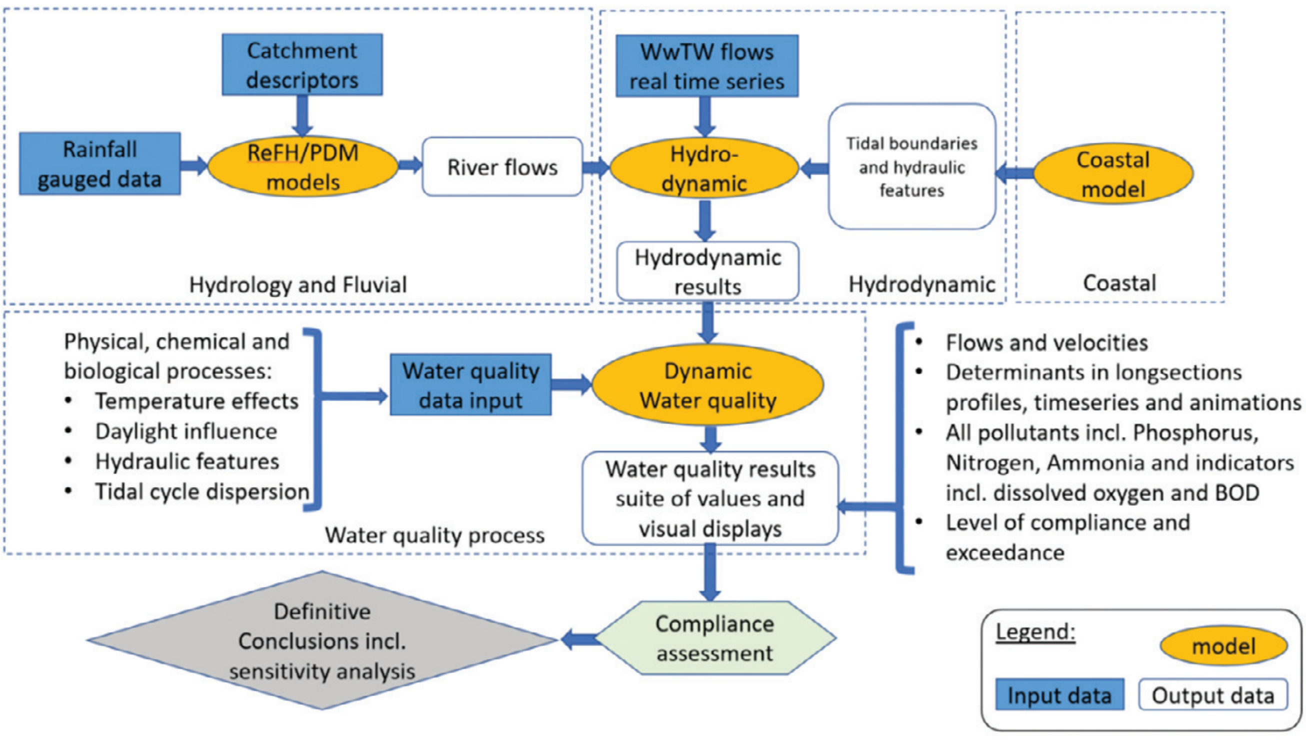

Figure 2: DWQA approach and methodology - Courtesy of Mott MacDonald