Environmental Capacity in Industrial Clusters project - Phase 3

Technical Annex 4 HyNet Literature Review

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Contents

Appendices

List of Tables

List of Figures

Acronyms

ASU	Air Separation Unit
ATR	Autothermal Reformer
AWE	Alkaline Water Electrolysis
BOD	Biochemical Oxygen Demand
CAMS	Catchment Abstraction Management Strategy
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand
CP	Critical Period
CPI	Corrugated Plate Interceptor
DCWW	Dŵr Cymru Welsh Water
DI	Distribution input
DO	Deployable output
dWRMP24	Draft Water Resource Management Plan 2024
DWMP	Drainage and Wastewater Management Plan
DYAA	Dry Year Annual Average
EA	Environment Agency
ELMS	Environmental Land Management Schemes
ERF	Energy Recovery Facility
GHR	Gas-Heated Reformer
HAMP	Highway Asset Management Plans
HD	Hafren Dyfrdwy
HH	Household
HOF	Hands off flow
ITS	Isothermal Shift
KO pots	Knockout pots

LCH	Low Carbon Hydrogen
LWEC	Living With Environmental Change
MBR	Membrane Bioreactor
MDO	Minimum Deployable Output
MMO	Marine Management Organisation
NAV	New Appointment and Variation
NEP	National Environment Programme
NHH	Non-household
NRW	Natural Resources Wales
NVZ	Nitrate Vulnerable Zones
NWT	North West Transfer
OBH	Observation Borehole
PBDE	Polybrominated Diphenyl Ethers
PCC	Per Capita Consumption
PEM	Proton Exchange Membrane
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PSA	Pressure Swing Adsorption
PWS	Public water supply
RBMP	River Basin Management Plan
RCP8.5	Representative Concentration Pathway 8.5
RNAG	Reasons for Not Achieving ‘Good’ WFD status
ROG	Reactive Organic Gases
SAC	Special Area of Conservation
SPA	Special Protected Area
SRO	Strategic Resource Option
SSSI	Site of Special Scientific Interest
SSW	South Staffs Water
STT	Severn to Thames Transfer

SVT	Severn Trent Water
TraC	Transitional and Coastal (waters)
TSS	Total Suspended Solids
UKCP18	UK Climate Projections 2018
UU	United Utilities
WAFU	Water Available for Use
WFD	Water Framework Directive
WINEP	Water Industry National Environment Programme
WRMP	Water Resource Management Plan
WRSE	Water Resources South East
WRW	Water Resources West
WRZ	Water Resource Zone

1.Introduction

1.1 The HyNet NW area

HyNet describes itself as the UK's leading industrial decarbonisation project.[1] Located in the north-west of England, HyNet will include infrastructure to capture, transport, and store carbon dioxide and to produce, store, and transport low-carbon hydrogen across the north-west of England and North Wales.

The planned 'HyNet NW' network, illustrated in Figure 1.1, comprises multiple components including a hydrogen production plant, industrial carbon dioxide capture, underground hydrogen storage and industrial hydrogen users. The network extends across multiple river catchments and crosses the England-Wales border (Section 3.2). The network is located in an area with important national heritage and numerous protected sites, such as Sites of Special Scientific Interest (SSSIs) and Special Areas of Conservation (SACs), including some internationally important sites (Section 5.3) (Environment Agency, 2013; Environment Agency, 2020a).

The area south of the River Mersey is characterised by low-lying countryside with some heavily industrialised areas. Industry is densest around the Mersey Estuary and urban areas (Environment Agency, 2023b) and agriculture is dominated by dairy farming (Environment Agency, 2013). There are a variety of industries including power/energy, chemical, paper, and a history of salt mining (Environment Agency, 2020a). To the north and east of the River Mersey, land use comprises both rural and heavily urbanised areas. The large cities of Manchester and Liverpool are located nearby.

The most water intensive part of the proposed network is expected to be the low carbon hydrogen production plant on the south bank of the Mersey Estuary. While this annex will consider water availability for the entire HyNet NW area, there will be particular consideration for the areas closest to the hydrogen production plant.

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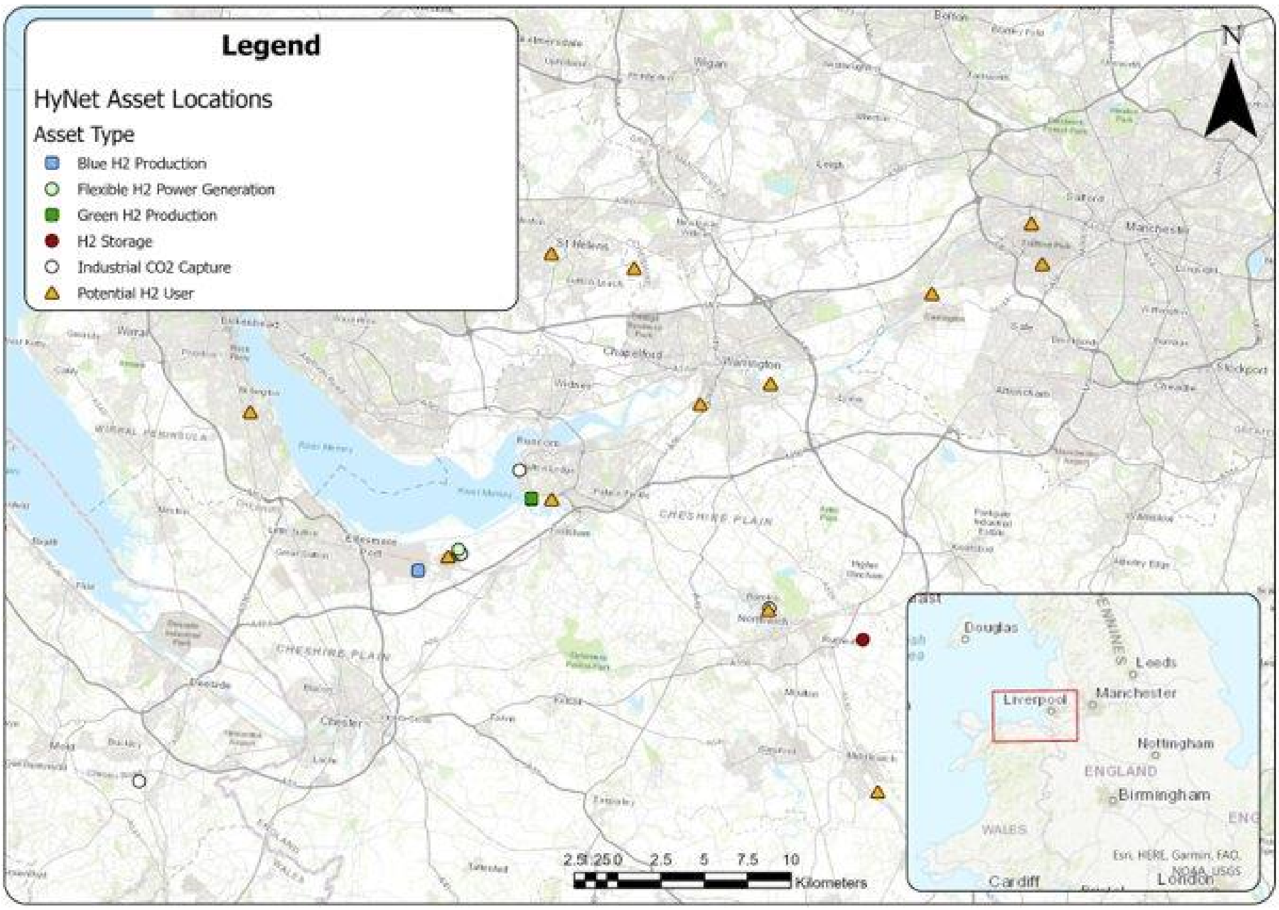
[1] https://HyNet.co.uk/

Figure 1.1 HyNet NW location and network



1.1 Time horizons

The EA has asked WRc to assess the impacts of HyNet Industrial Cluster against three time horizons:

- Short-term future: 2030
- Mid-term future: 2050
- Long-term future: 2080

1.2 Climate change scenarios

The most recent UK Climate Projections (UKCP18) were issued by the Met Office in 2018. UK Climate Projections 2018 includes five different emissions scenarios, namely RCP 2.6, 4.5, 6.0, 8.5 and SRES A1B.

The Environment Agency (EA) would like to assess the future water availability of HyNet NW in the context of the high temperature UKCP18, RCP8.5 (high emissions scenario)[2]. This scenario is characterised by high rates of temperature change, reaching 5°C above pre-industrial temperatures before the end of the 21st Century (Met Office Hadley Centre, 2018). However, it is worth noting that most water resources planning by regional groups and water companies used RCP6.0 (as recommended by planning guidance) for their preferred plans with RCP8.5 consideration in adaptive planning. Within other contexts, only broad statements can generally be made about the impacts of climate change. However, RCP8.5 has been assessed where possible.

1.3 Report structure

To this end, the report is structured as follows, with call out boxes (**Error! Reference source not found.**) used to highlight knowledge gaps:

- Section 2 outlines the methodology used to undertake the literature review.
- Section 3 provides contextual information relating to the HyNet NW Industrial Cluster and the environment within which it sits.
- Section 4 provides an assessment of the likely water requirements of the HyNet NW, including consumption and discharge.
- Section 5 assesses the current state of the water environment, including water availability, resilience, and risks.
- Section 6 appraises the evidence for how the state of the water environment might change in the future.
- Section 7 summarises the findings of the literature review and puts it in the context of the wider project aims.
- Section 8 presents a list of references used in the report and includes appendices providing supplementary information.

[2] Personal communication, November 2023

Figure 1.2 An example call-out box identifying a gap in our knowledge.

Gap
Call-out boxes like this are used to identify gaps in our knowledge following the literature review.

2.Methodology

2.1 Data collection and information gathering

The scope and direction of the literature review was agreed with the EA. A list of identified sources was shared with the EA for feedback. During an iterative and open process, the EA suggested and shared additional sources to be included in the review. The WRc project team was divided into three task groups, so that the literature review could be completed within short timescales. The three task groups and their objectives are listed in Table 2.1.

Table 2.1 Task groups for literature review

Task Group	Research questions
Group 1 Water requirements of the HyNet NW industrial cluster	1. Who will be the significant water users in the HyNet NW area? 2. Where are they located? 3. How much water will they require? 4. What quality of water will they require, and does this vary by use? 5. How much (waste) water will they discharge? 6. Will discharges be direct to environment, on-site treatment or storm or foul sewer, and what will be the quality of these discharges? 7. What water is currently abstracted and discharged by stranded assets outside of the industrial cluster, (and hence may be available for future HyNet NW use)?
Group 2 Water availability in the HyNet NW area	1. Where are the nearest water sources to likely water users in the HyNet NW area? 2. How much water is currently available in these areas? 3. How might this availability change in the future?
Group 3 Water quality and designated sites in the HyNet NW area	1. What is the current quality of water bodies that could be impacted by the HyNet NW industrial cluster?

Task Group	Research questions
	2. What are the primary drivers of water quality in key water bodies and risks faced by the water environment? 3. What conservation areas or areas of special interest are present in the HyNet NW area? 4. How might each of these change in the future?

2.1.1 Group 1 summary

To determine the water requirements of the HyNet NW Industrial cluster, existing reports relating to the water use of hydrogen production and the immediate available information around the extent of HyNet projects was reviewed. These sources are listed in Table 2.2 and were used to identify planned projects across the HyNet network, before targeted literature searches for information around the relevant technologies were carried out. Additionally, the information published by identified projects around timescales for development was reviewed before calculations to produce an estimate of the water impacts of the network were carried out. Information gaps were assessed throughout the process.

Table 2.2 HyNet extent and hydrogen production water use information sources

Title	Publication Year	Author
Environmental Capacity for Industrial Clusters, Phase 1	2022	Environment Agency
Environmental Capacity for Industrial Clusters, Phase 2	2023	Environment Agency
Current known information for water demand and quality at HyNet Projects and location details for projects, 07-12-23	2023	Environment Agency
Application Variation Document FP3139FNV013 – Decision Document – Environment Agency – 2/5/2023	2023	Environment Agency

HyNet North-West Production Plant Environmental Permit Application Supporting Document	2021	HyNet
HyNet Low Carbon Hydrogen Plant, Phase 1	2020	Report for BEIS
Hydrogen Supply Chain Evidence Base	2018	Element Energy for BEIS
Options for a UK low carbon hydrogen standard	2021	E4Tech and Ludwig-Bolkow-Systemtechnik GmbH for BEIS
HICP Water Study	2022	Element Energy
Water for the Hydrogen Economy	2020	WaterSMART Solutions
Projections of Water Use in Electricity and Hydrogen Production to 2050, under the 2020 Future Energy and CCC Scenarios including BEIS 2020 lowest system cost analysis – with a focus on the East of England	2021	RWE Generation UK
Water and Energy Framework Literature Review	2023	AECOM for Environment Agency

2.1.2 Group 2 summary

A list of sources reviewed is shown in Table 2.3. Gaps in knowledge were identified following the review of agreed literature and additional literature found through searching publication databases listed in Table 2.4. This additional literature was partially reviewed to complete missing information or add further context. This approach was taken to fulfil the project scope within the required time.

Table 2.3 Literature agreed with the EA for review

Title	Author (Publication Year)	Comments
Meeting our future water needs: a national framework for water resources	Environment Agency (2020)	Refresh of this document underway, due for sign-off by 2025
WRW Draft Regional Plan 2024	Water Resources West (2022)	

UU Revised Draft Water Resources Management Plan 2024	United Utilities (2023)	
SVT Draft Water Resources Management Plan 2024	Severn Trent Water (2023)	
DCWW Revised Draft Water Resources Management Plan 2024	Dŵr Cymru Welsh Water (2023)	
HD Draft Water Resources Management Plan 2024	Hafren Dyfrdwy (2023)	
Lower Mersey and Alt abstraction licensing strategy	Environment Agency (2013)	New abstraction licensing strategy due relatively soon, but not complete for inclusion in this annex
Northern Manchester abstraction licensing strategy	Environment Agency (2013)	New abstraction licensing strategy due relatively soon, but not complete for inclusion in this annex
Upper Mersey abstraction licensing strategy	Environment Agency (2013)	New abstraction licensing strategy due relatively soon, but not complete for inclusion in this annex
Weaver and Dane abstraction licensing strategy	Environment Agency (2022)	
Dee Abstraction Management Strategy	Natural Resources Wales (2015)	Noted as the current abstraction management strategy with no newer draft available
HCIP Water Study	Element Energy (2022)	
Water Climate Change Impacts Report Card 2016 (and supporting reports)	UKRI (2016)	
The state of the environment: water resources	Environment Agency (2018)	
Updated projections of future water availability for the third UK Climate Change Risk Assessment	UK CCRA / HR Wallingford (2020)	

Table 2.4 Publication databases searched for additional literature

Database	Subject Area
Environment Agency	Catchment descriptions, protected areas, water use, non-public water supply abstraction, observation borehole location, rainfall statistics
Natural England	Catchment descriptions, protected areas
British Geological Survey	Hydrogeology
Groundwater Forum	Hydrogeology
Ofwat	Leakage performance
Natural Resources Wales	Catchment descriptions, protected areas, non-public water supply abstraction
United Utilities publications	Water management planning and water resource zone / supply area characteristics
Severn Trent publications	Water management planning and water resource zone / supply area characteristics
Hafren Dyfrdwy publications	Water management planning and water resource zone / supply area characteristics
Dŵr Cymru Welsh Water publications	Water management planning and water resource zone / supply area characteristics
Water Resources West publications	Water planning and regional characteristics

2.1.3 Group 3 summary

Receiving water quality

Information on current water body WFD classifications, Reasons for Not Achieving 'Good' status (RNAG) and future objectives was taken from the EA Catchment Data Explorer[3] and the NRW Water Watch Wales[4] website. Further details on individual catchment water quality challenges were taken from the

[3] https://environment.data.gov.uk/catchment-planning

[4] https://waterwatchwales.naturalresourceswales.gov.uk/en/

relevant River Basin Management Plans (RBMPs) and appropriate academic literature.

GIS data was also downloaded from the EA catchment data explorer and NRW Water Watch Wales website.

Other environmental risks

A search of grey literature was undertaken relating to designated sites, focusing on regional and local biodiversity and environment plans where available.

GIS layers were obtained via government data repositories to visualise the location of HyNet assets in relation to protected and sensitive sites and habitats.

This annex does not contain a full review of literature relating to other environmental risks which might impact HyNet NW. For example, a full environmental assessment might also consider:

- Contaminated land
- Flood risk
- Coastal erosion
- Air quality
- Natural resources
- Carbon

Where the stakeholder engagement phase of this project identifies other risks that might impact on the water environment, these will be noted in the final report. However, detailed assessments of flood risk, coastal erosion, contaminated land and air quality are not part of the HyNet industrial cluster project scope.

2.2 Analysis and reporting

Each task group produced an internal report documenting their findings and initial conclusions. Care was taken to ensure frequent and open communication across the task groups, sharing relevant information, findings, and analysis, ensuring consistency of approach, and discussing integration of the findings. This annex presents the findings of the three internal reports to achieve the following:

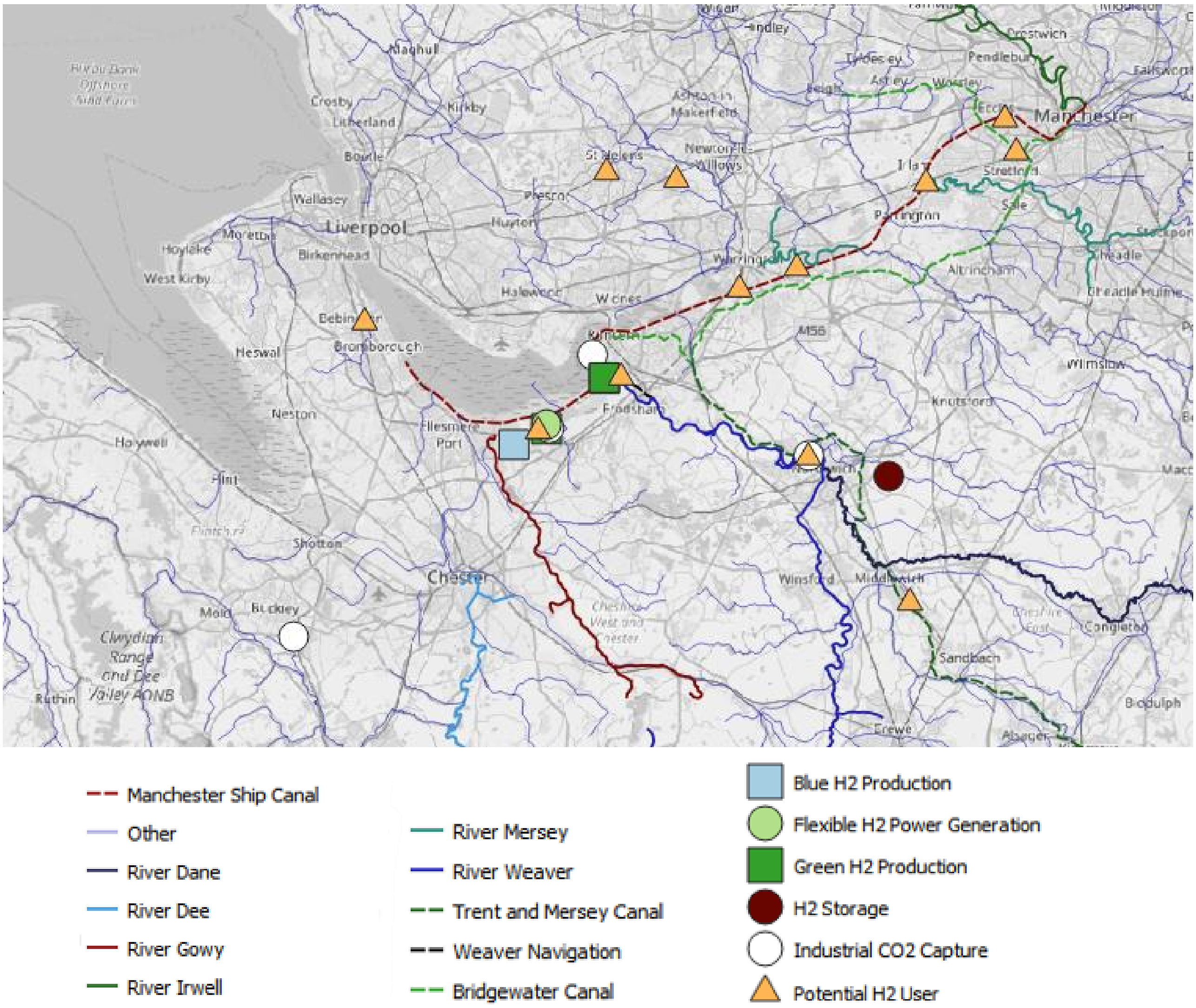
- Present a factual overview of the findings of the literature review, acknowledging data gaps and low confidence areas.
- Present analysis of the relevance of findings to the specific study context, to the proposed HyNet NW assets, local area, and key time horizons.
- Present analysis and initial conclusions which set the basis for the evidence review.
- Identify gaps where more information would be required or beneficial to performing the evidence review and remainder of the project tasks. These will be used to inform stakeholder engagement and further research.

3.Context

3.1 The HyNet NW industrial cluster

The locations of various expected HyNet NW assets are plotted in Figure 3.1 alongside the main watercourses in the area. In the near-term, the most significant assets for consideration with respect to impacts to water are expected to be the blue hydrogen (H_2) production plant, industrial CO_2 capture, and H_2 storage, based on what is currently known about the assets. The blue hydrogen production plant will be located near the south bank of the Mersey Estuary. These are each discussed in the following report sections. There are plans for the blue hydrogen plant to transition towards green hydrogen production, and this has the potential to significantly impact water resources. However, limited details about this transition are available.

Figure 3.1 Main rivers and canals in the HyNet NW area



3.1.1 Hydrogen production

Low Carbon Hydrogen process – blue hydrogen

Blue hydrogen refers to the process of converting fossil fuels or non-renewable hydrocarbons with a low carbon intensity into hydrogen while implementing carbon capture and storage systems. The two principal technologies used to produce blue hydrogen are steam methane reforming and advanced gas reforming. The blue hydrogen technology that will be implemented at the HyNet NW cluster is the advanced gas reforming system, consisting of a Gas-Heated Reformer (GHR) and an Autothermal Reformer (ATR). The GHR/ATR system is named a Low Carbon Hydrogen (LCH) technology developed by Johnson Matthey.

One of the main advantages of using the LCH system is its ability to produce hydrogen while providing a suitable stream for CO_2 capture. The process description of the LCH technology is mentioned below and illustrated in Figure 3.3.

- A feed gas stream will comprise either natural gas or a mixture of up to 55% natural gas and 45% Reactive Organic Gases (ROG). The natural gas will be sourced from the UK national transmission system while the ROG would be piped from the Stanlow refinery.[5]

- The gas stream is pre-heated in the feed-fired heater, and this process allows the removal of any chloride or sulphur compounds present (which could cause deactivation of the catalysts found downstream).[5]

- The purified feed gas is passed to the saturator, where the gas stream meets hot water and steam to saturate the gas streams. A water-saturated gas, known as 'mixed feed', formed during this step is routed to the gas-heated reformer along with the addition of steam from the steam boiler.[5]

- The mixed feed is subsequently directed to the GHR/ATR systems, which incorporate nickel-based catalysts and introduce oxygen through an air separation unit. The GHR/ATR system will help convert the mixed feed into syngas consisting of carbon monoxide, carbon dioxide, hydrogen, and residual methane.[5]

- The syngas leaving the GHR/ATR system will enter an isothermal shift (ITS) converter where the copper-based catalyst present will promote the reaction of carbon monoxide and water to produce hydrogen and CO_2.[5]

[5] Stanlow Manufacturing Complex operated by Essar Oil (UK) Limited - Permitting Decisions - Variation FP3139FNV013

Knockout pots (KO pots) are employed in the system to capture and separate water from the gas stream.

- All the carbon dioxide produced during this process is within the product stream and, therefore, is at a higher temperature and purity, which helps remove the CO_2 using the standard industry removal techniques.[6] The CO_2 removal system will use an amine solution to absorb the CO_2 from syngas.[5]

- The CO_2-free syngas is then passed through to a Pressure Swing Adsorption (PSA) saturation unit where hydrogen is extracted from the gas mixture, removing carbon monoxide, methane, and nitrogen. The final hydrogen product is then compressed, cooled, and exported via the hydrogen pipeline.[5]

The likely water demand and wastewater production at the proposed blue hydrogen plant is presented in Section 4.3.1.

3.1.2 LCH Technology (blue hydrogen)

Location and scale of hydrogen production

The Essar/Vertex hydrogen plant at the Stanlow Refinery in Ellesmere Port is intended to play a central role in the HyNet NW cluster; generating 3 TWh per year of blue hydrogen by 2025 and rising to 30 TWh per year by 2030, the plant will account for more than 1/3 of the Government's ambition for 10 GW (88 TWh per year) of low-carbon hydrogen production capacity by 2030 (HyNet North West, 2021).

Water quality and demand requirements

The influent water streams that will be used for the LCH system are process water streams recovered from the LCH process, harvested rainwater, and river

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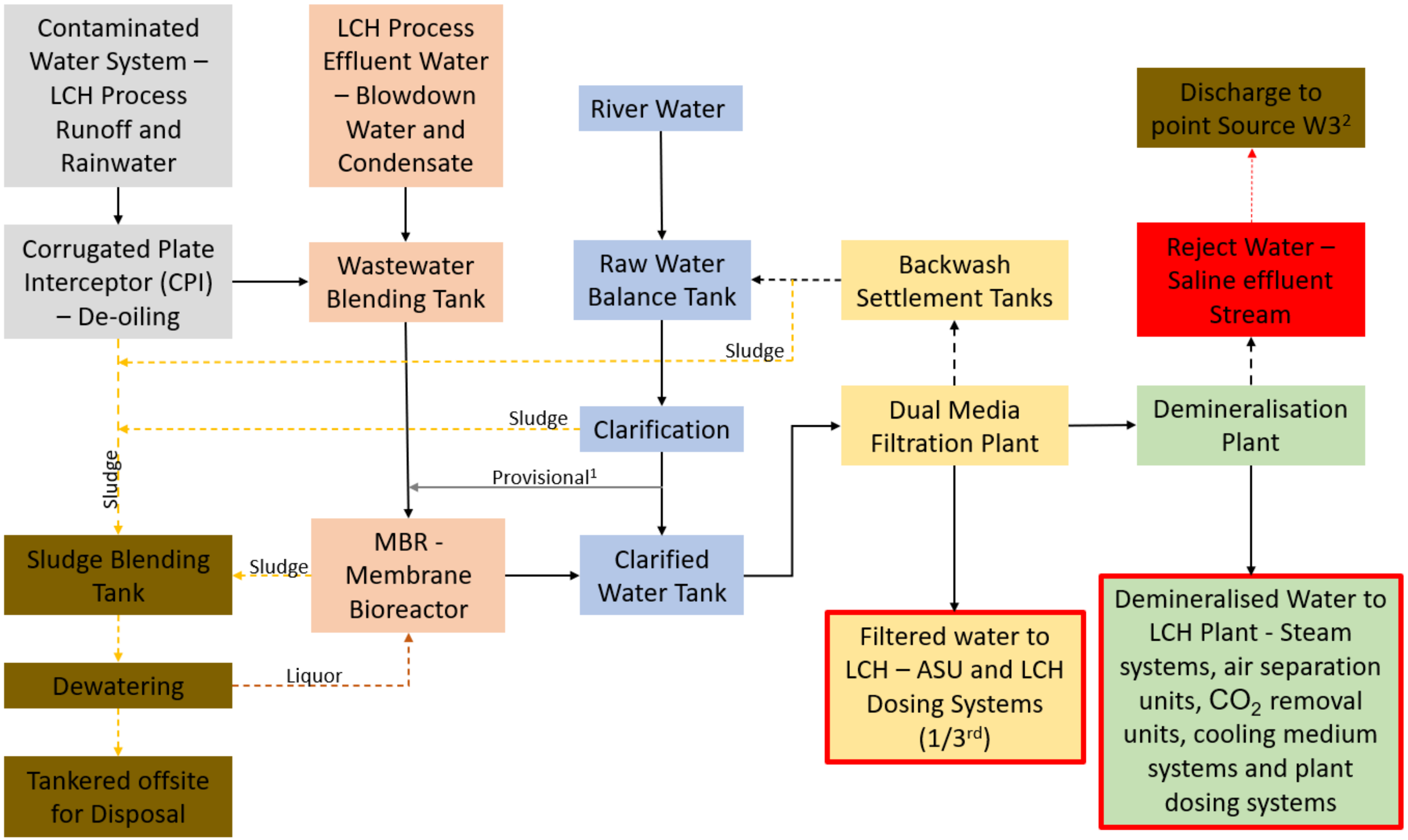
[6] Clean hydrogen. part 1: Hydrogen from natural gas through cost effective CO2 Capture, The Chemical Engineer. Available at: https://www.thechemicalengineer.com/features/clean-Hydrogen-part-1-Hydrogen-from-natural-gas-through-cost-effective-co2-capture/ (Accessed: 01 February 2024).

water supplied from River Dee (United Utilities' supply) (HyNet North West, 2021).

A flow diagram of the wastewater treatment system for the LCH technology is provided in Figure 3.2.

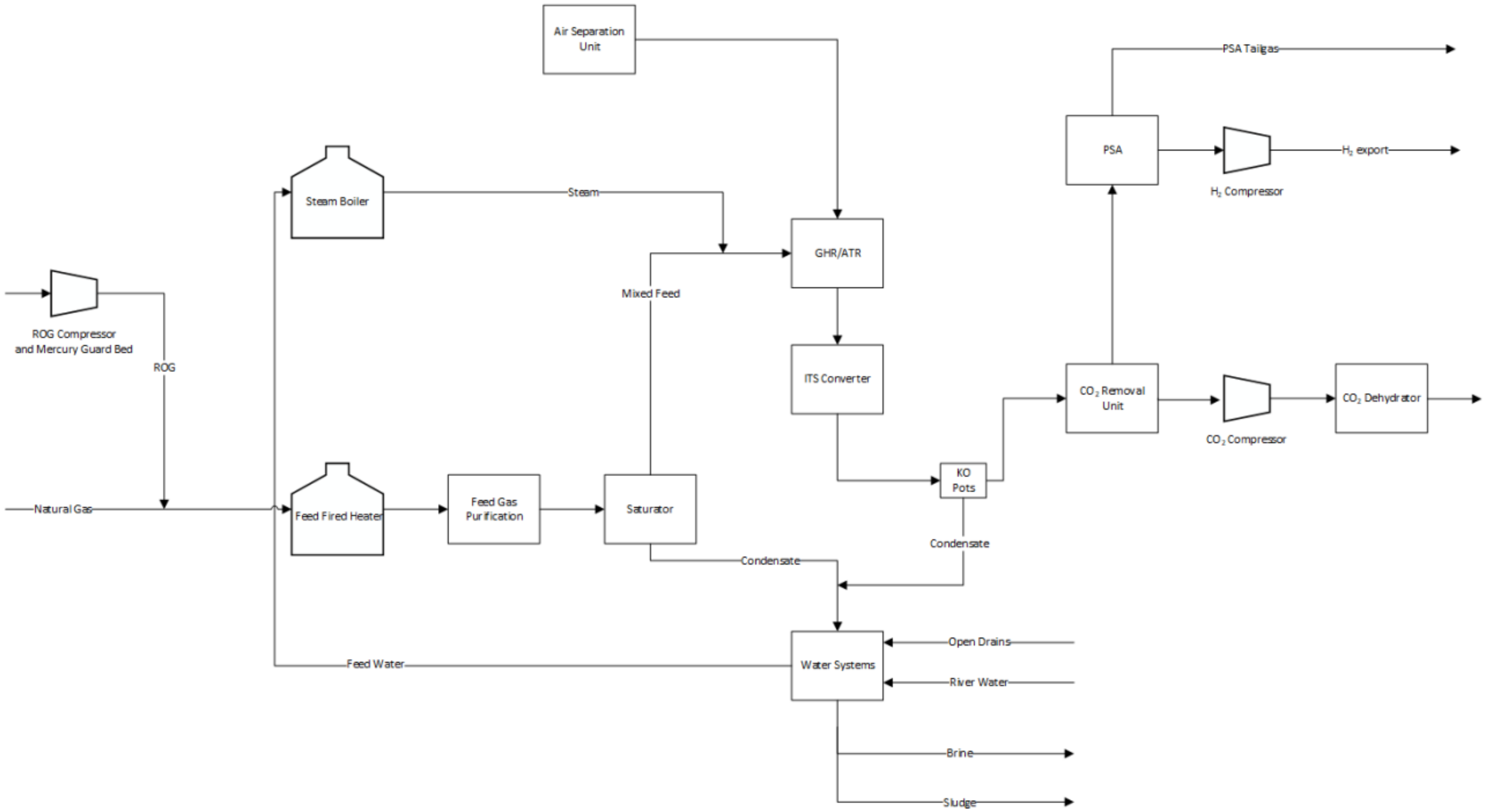
Figure 3.2 Hydrogen Production Plant – Wastewater Treatment Processes



[1]Provisional - If the river water is contaminated, it will require treatment in the MBR following clarification before the treated water is sent to the clarified water tank.

[2]The volume and characteristics of the reject water (saline effluent stream from demineralisation plant) is mentioned in Section 4.3.1

Figure 3.3 Low Carbon Hydrogen Technology – Flow Diagram (HyNet North West, 2021)



Raw water processing

Before the water is used for LCH technology, it must be treated to ensure pollutants are removed and the water quality is fit-for-purpose. Water is necessary for the steam systems, air separation units, CO_2 removal units, cooling systems, and plant dosing systems in the LCH process. The hydrogen production plant will comprise the following wastewater treatment processes: clarification (for raw water only), de-oiling (for rainwater only), a combined biological and filtration treatment utilising a Membrane Bioreactor (MBR), and demineralisation (HyNet North West, 2021).

The main purpose of the clarification treatment step is to remove suspended solids and, hence, reduce the turbidity of the source water. The source water will be initially sent to a raw water balance tank. This tank will also receive the backwash supernatant from the backwash settlement tanks (a reject stream from dual media filtration plant). The supernatant from the backwash settlement tank is the reject stream from the dual media filtration system. The water present in the balance tank will be dosed with aluminium bisulphite and sulphuric acid before being sent to the clarification plant. During the clarification process, a flocculent will be added to the water, which attaches to the suspended solids and form larger and heavier clusters known as flocs. Flocs are settled and removed as sludge from the bottom of the treatment system. The clarified water will be sent to the clarified water tank, which will mix with the treated rainwater and LCH effluent water for further treatment (HyNet North West, 2021).

If the raw water is contaminated, it will require treatment in the MBR following clarification before the treated water is sent to the clarified water tank. If the raw water is uncontaminated, it does not require treatment in the MBR and can be mixed with the combined process water and rain waters after the MBR unit as shown Figure 3.2. Before directing raw water to the clarified tank, a water quality assessment should be carried out to determine the necessary treatment as mentioned above.

Gaps

No information could be found regarding the definition of ‘contaminated’ water and associated water quality parameters.

It is not understood what sort of water quality assessment will be carried out to identify the necessary treatment. This will be identified by authorities later and based on assessments carried out by the EA in the region. However, whether this is an assessment at a single point in time or whether any continuous assessment should be required or appropriate resampling is not clear.

Drainage

There will be two types of drainage networks which will be used as a source of water for the LCH process: a clean system and a potentially contaminated system (HyNet North West, 2021).

The clean system will collect rainwater from areas that are unlikely to contain significant chemical contamination (roads, building roofs etc.) and, according to the application report, will be discharged to United Utilities' (UU) sewerage system. The application report states that the clean water systems will collect the water in four sumps and will have direct access to the Essar site drainage systems from where the water can be discharged to United Utilities sewerage system. The wastewater after treatment will be discharged to the river (and abstracted indirectly for utilisation in the LCH system) (HyNet North West, 2021).

Gaps

This suggests that rainwater from the clean systems will be treated by UU. It is not clear whether this is because a combined sewer system operates in the area. It is also not clear why no attempt is made to collect and use this rainwater.

The area over which rainwater is collected for treatment by UU for utilisation in the LCH system is not known.

The location of the clean system is to be determined / confirmed.

The potentially contaminated systems will collect runoff from LCH process areas and rainwater from individual sumps in the area. The water collected in the contaminated system sumps will be sent to the hydrogen production plant wastewater systems for further treatment prior to being used for the LCH system. The water collected in the contaminated surface water system will be de-oiled using a corrugated plate interceptor (CPI) and will be mixed with the process effluent water stream. The CPI system will have a normal flow of 5 m^3/hr with a maximum design capacity of 10 m^3/hr (HyNet North West, 2021).

Gaps

The CPI system falls short of meeting the production demands and it is not clear how the residual demand will be met.

Process water reuse

The hydrogen production plant will have two tanks for buffer storage: the wastewater blending tank and the clarified water tank. The wastewater blending tank will be placed upstream of the MBR system and will receive the process effluents produced by the LCH technology. The process effluent streams which are recovered and recycled via the closed drains system are:

- Blowdown water from saturator, ITS steam drum, and medium pressure steam drum (steam boiler as shown in Figure 3.3)
- Blowdown from the GHR and ATR water jackets
- Condensate for the reformed gas cooling train and CO_2 compressor
- Blowdown water from the air separation unit

The process effluent streams will be drained to a closed drain drum from where they will be pumped and sent to the wastewater blending tank (HyNet North West, 2021). The incoming water flow from the contaminated systems totals 37.9 m^3/h, comprising recycled water at 36.2 m^3/h and harvested rainwater at 1.7 m^3/h. The gases which will be produced from these closed drain drums will be routed to the flare (HyNet North West, 2021). A flare is provided in the hydrogen production plant to provide a safe disposal route for the hydrogen production plant's flammable gasses under start-up, shut-down, abnormal and emergency conditions. The flare package will consist of a flare knock-out drum, elevated flare stack, flare tip and a flare ignition package.

The liquor produced from sludge dewatering, wastewater from the low pressure flash column reflux drum (which is part of the CO_2 removal unit), and the blowdown water from the cooling medium systems will be directly sent to the wastewater blending tank (HyNet North West, 2021). The water from the wastewater blending tank will be mixed with the de-oiled water from the open drain sumps, dosed with phosphoric acid, nitrogen supplement and micronutrients and routed to the MBR for treatment (HyNet North West, 2021). The quality of MBR feed and treated effluent are presented in Table 4.5 The treated MBR effluent will be sent to the clarified water tank, which is located before the dual filtration media system (Figure 3.2) (HyNet North West, 2021).

Clarification and demineralisation

The clarified water tank will receive the treated water from the MBR system and the treated raw water. The water from this tank will be dosed with sodium hypochlorite and then sent to the dual media filtration plant, which typically consists of a layer of anthracite coal above a layer of fine sand. The main purpose of the dual media filtration system is to remove remaining suspended solids, turbidity, organic matter, and colour. The output of the dual media filtration process will be sent to a filtered water tank. One-third of the water from the filtered water tank will be used in the air separation unit (ASU), the feed-fired heater and the LCH dosing systems. The remaining two-thirds of the water will be dosed with sodium bisulphite and sodium hydroxide and sent to the demineralisation plant (Figure 3.2) (HyNet North West, 2021).

The demineralisation plant will be used as a final polishing step to soften the water. The treated water from the demineralisation plant will be used for the steam systems, air separation units, CO_2 removal units, cooling medium systems, and plant dosing systems (HyNet North West, 2021). In the reviewed document (HyNet North West, 2021), demineralised water was not mentioned to be used in the steam boiler unit. However, depending on the steam boiler type, demineralised water may be required. The feed water for the steam boiler must be softened water for low-pressure boilers and demineralised water for high-pressure boilers. It should be free of hardness constituents and suspended solids (Babcock & Wilcox, n.d.). The medium pressure steam boilers used for the LCH process will require a treatment step to produce deionised or demineralised water to minimise any scale formation or corrosion.

Green hydrogen

Green hydrogen refers to the creation of hydrogen gas via electrolysis of water powered by renewable energy. Ultrapure water is required as the feedstock for the electrolysers. The precise requirements of the system are dependent on the type of electrolyser, electrode material, and system design. Cooling water will also be required. These details are currently unavailable, and, given the time horizons under consideration (up to 2080) and likely timescales for transition to green hydrogen, limited research into likely treatment and site operation has been undertaken. This was agreed with the EA. The likely water demand of the proposed hydrogen plants is presented in Section 4.3.1.

Gaps

Technical specification of green hydrogen plants and the cooling requirements of green hydrogen production. If information on these gaps is not available through stakeholder consultation, examples from plants outside the UK may be used to produce assumptions.

Transition date when green hydrogen plants would be commissioned.

Green energy sources for the electrolyser and their water intensity.

3.1.3 HyNet carbon capture sites

Six industrial Carbon Capture and Storage (CCS) or Carbon Capture and Utilisation (CCU) projects are planned as part of the HyNet network, and described below (HyNet North West, 2021).

- The Protos Encyclis Energy Recovery Facility (ERF) at Ince intends to generate up to 49 MW of power from the combustion of 500,000 tonnes of non-recyclable waste annually. The project proposes recirculatory cooling, producing less than 2 tonnes per hour of blowdown and capturing emissions.

- The Runcorn Viridor ERF plans to capture 900,000 tonnes CO_2 per annum, half of which is from biogenic sources.

- Evero Energy from Waste and Mitsubishi Heavy Industries (MHI) plan to retrofit Evero's Ince waste wood to an energy site with Kansai

Mitsubishi's Carbon Dioxide Recovery process, aiming to capture 250,000 tonnes CO_2 per annum once operational in 2029.

- The Ince Low Carbon Power Project plans to develop two units of Combined Cycle Gas Turbine (CCGT), one unit of which may be an 850 MWe natural-gas fired plant with CCS. Plans have not been finalised and this unit may be a second hydrogen fired plant instead.

- The Winnington Combined Heat and Power (CHP) with CCU station is currently operational and producing 40,000 tCO_2 per annum for chemicals manufacture. This plant is amine based and has a return flow of 913.7 m^3/hr to the river.[7] This equates to 200 m^3/tCO_2 of non-consumptive use.

- Padeswood Cement Works aims to capture 800,000 tCO_2/year through an amine-based CCS system and be operational in 2027.

Gaps

Further information on the planned technologies and processes is required before meaningful estimations for water demand and discharge quality can be made. WRc aims to gain this information as part of the stakeholder consultation phase of the project.

3.1.4 Hydrogen storage

Hydrogen storage facility development is planned as part of the HyNet network to hold surplus volumes of hydrogen during periods of lower demand. Salt caverns are artificial cavities created in subsurface salt deposits, and have been identified as a primary option for underground hydrogen storage in several studies (HyNet North West, 2021). (Lemieux, et al., 2019). The construction of a salt cavern is carried out through the process of solution mining, this entails injecting water in a controlled manner to dissolve the salt and then extracting the brine produced (Chen, 2023). Solution mining is a water-intensive process and the resulting brine is either disposed of via outfall or used as raw materials

[7] EA Communication

for manufacturing, for instance of chlorine, sodium bicarbonate or food-grade salt.

Gaps

The water intensity of the proposed hydrogen storage cannot be assessed without knowing whether solution mining has already taken place or will be required in the future to provide the storage.

3.1.5 Industrial hydrogen users

Gaps

Nothing is known about the current potable and raw water demand of current industrial users in the HyNet area, or about changes which will occur following the commissioning of HyNet (such as stranded assets, new, increased or decreased abstractions, or changes to discharges).

3.2 Water in the area

3.2.1 Groundwater

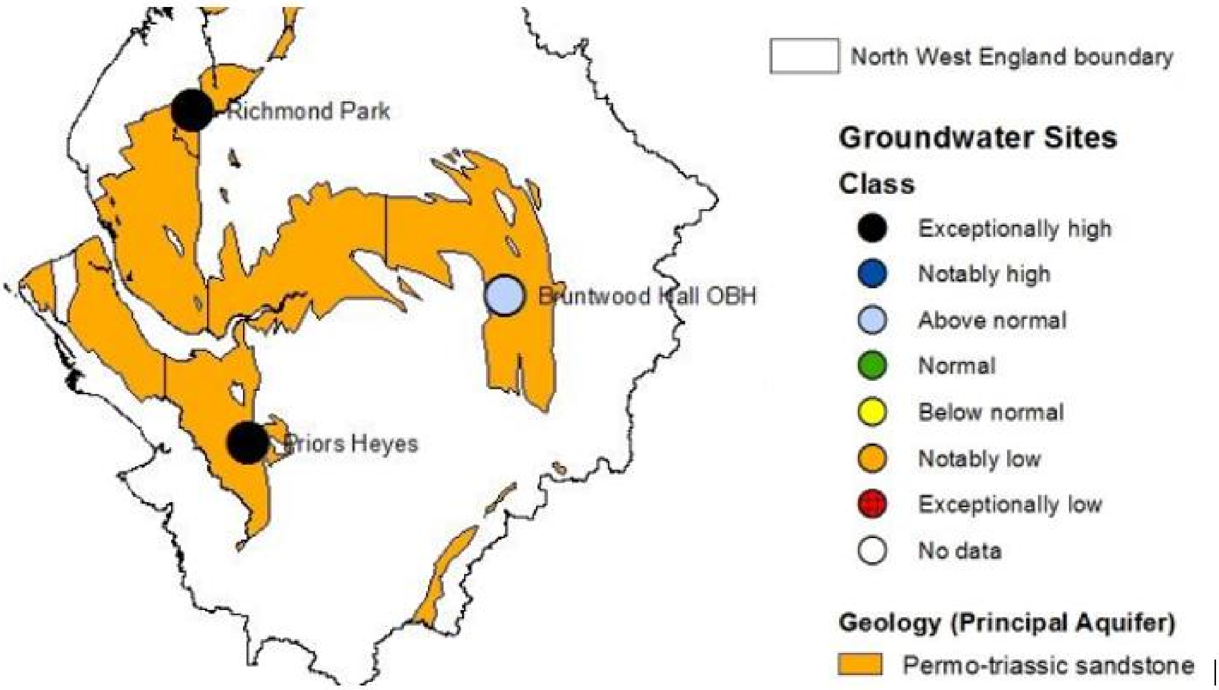
The primary aquifer in the HyNet NW area is the Permo-Triassic Sandstone (Environment Agency, 2013), which is the second most important aquifer in the UK for supporting society and the economy (Griffiths, et al., 2003). The aquifer provides water for both public water supply (PWS) and non-PWS to urban areas, agriculture and industry (Griffiths, et al., 2002). The groundwater quality shows significant spatial variation, and there are a variety of causes for water quality issues including natural reactions with bedrock, pollution and saline intrusion. Inland, saline waters result from the mixing of fresh recharge water and brines from halite dissolution. Despite general control by natural processes, the Mersey Estuary's saline water ingress can be exacerbated by unsustainable abstractions and climate change, significantly impacting groundwater chemistry. Nitrate concentrations can be high from anthropogenic influences, as well as from the aquifer oxidising (Griffiths, et al., 2003).

Common transmissivity values fall within the range of 100 to 400 m^2 per day (Griffiths, et al., 2002). The variability in transmissivities is indicative of the difference between intergranular flow and fracture flow, with the highest values observed in areas where a well-connected fracture network has formed. The specific yield ranges from approximately 6% to 14%, with boreholes in the relevant area tending to be in the unconfined aquifer to the west of the region.

The Mid-Cheshire Ridge serves as the primary recharge area, free of drift cover, while in other catchment areas, recharge water passes through extensive drift before reaching the sandstone (Griffiths, et al., 2002). Recharge estimates differ between unconfined and confined aquifers, with chemical composition changes in the drift. Groundwater levels are high in recharge areas and vary across the basin, influenced by factors like the River Dee which is the primary discharge area for the western part of the aquifer. The groundwater flow regime in the Cheshire basin is influenced by topographic driving forces at the basin margins and density variations in the sandstone by mudstone at the basin centre, impacted by halite dissolution and freshwater mixing.

The observation borehole of Priors Heyes is around the HyNet NW area and provides a view of groundwater levels in Permo-Triassic Sandstone in the area (Environment Agency, 2023).

Figure 3.4 Location of Priors Heyes observation borehole (OBH) with groundwater level observation (Environment Agency, 2023)



The EA provided a series of reports that provide insights into groundwater in the region. These were mainly scanned documents and as such full references are not available. The reports were:

- The Lower Dee Water Resources Study – Final Report. (National Rivers Authority Welsh Region, 1996).
- Wirral and West Cheshire Aquifer Study – Volume 1. (LWRC?, n.d.)
- Lower Mersey and North Merseyside Water Resources Study: Final Report – Volume 1. (Environment Agency, 2009).
- Hydrochemistry of groundwaters in the West Cheshire aquifer of north west England (PA Lucey, n.d.)

Relevant findings in the above reports include the hydrogeological impacts of industrial development in the HyNet region:

- ‘Galligu’, a waste product that can contain arsenic and heavy metals, was used to reclaim marshy areas alongside the Mersey. Chemical waste products were also used to fill landfill sites in hard rock quarries and Weston and in drift sand deposits.
- Transport and service infrastructure, including the docks, rail and road tunnels under the Mersey, provide potential routes for saline water intrusion into freshwater aquifers. Constant dewatering alters local groundwater flow patterns.
- Historic, heavy industry use depleted groundwater levels in the region, since the nineteenth century. In the Widnes - Rainhill - Bold Heath area falls in aquifer water levels of up to 30 to 50 m below sea level occurred. In the Frodsham area falls were even greater.
- Industrial abstraction boreholes in the Stanlow area pumped saline waters. Groundwater abstraction began at Stanlow in the 1920s and increased to reach a volume of 8,200,000 m^3/a by 1969. The supply was obtained from sixteen boreholes and resulted in a composite cone of

depression of groundwater well below sea level around the Stanlow refinery. Data from the 1950s onwards indicated increasing salinity over time. However, groundwater was slightly saline at the start of abstractions in the 1920s.

- The Manchester Ship Canal opened in 1894. At 58 km long, 14 to 24 m wide, and around 9 m deep, it linked Eastham to Manchester. The canal has five locks, and large volumes of lockage water were needed to service those in its most active period, abstracted from the River Mersey. The Ship Canal is unlined and 'in places it is excavated directly into the Permo-Triassic rock.' Leakage from canals is thought to be one of the main hydrogeological impacts, with estimated leakage rates from 300 m_3/day/km to 650 m^3/day/km quoted.

- Groundwater quality is deteriorating because of saline intrusion from the Mersey Estuary.

- Several locations across the Cheshire and north Shropshire Plain have high nitrate concentrations.

- As groundwater levels recover from recent reductions in abstraction, there are potential concerns regarding the mobilisation of pollutants from aging landfills and other contaminated land situated in low-lying areas.

3.2.2 Waterways

The main rivers of the HyNet NW area (as shown in Figure 3.1) are:

- River Mersey
- River Irwell
- River Gowy
- River Weaver
- River Dane
- River Dee

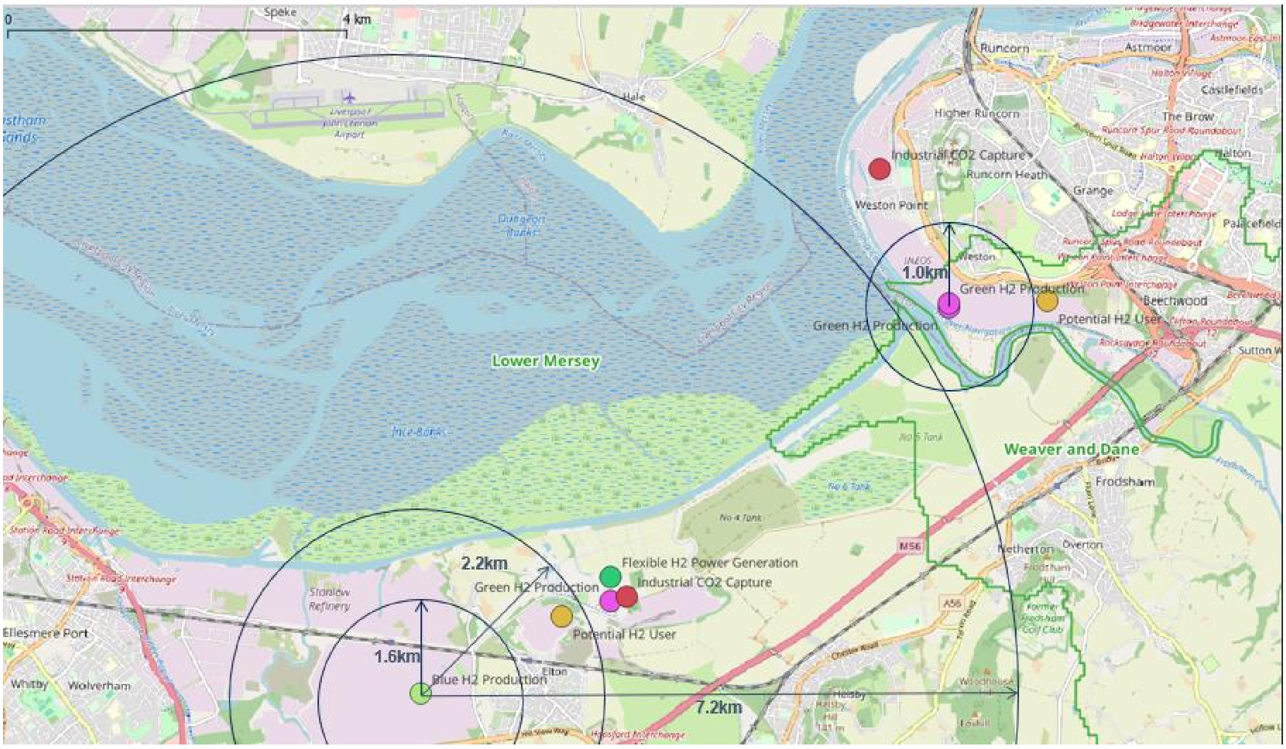
The River Mersey is a tidal river from Warrington, with the Mersey Estuary a designated Special Site of Scientific Interest (SSSI)[8] (Environment Agency, 2013a). The River Irwell is a significant tributary to the River Mersey, as well as significantly contributing to maintaining navigation routes such as the Manchester Ship Canal and the Bridgewater Canal. All the main rivers in the area are mixed-water rivers, meaning they are fed by a combination of groundwater and rainwater (Environment Agency, 2013a). There are many tributaries for the main rivers, with a range of source locations including the Pennines, Peak District, North Wales (Environment Agency, 2013a; Environment Agency, 2020a; Natural Resources Wales, 2015)

The River Dee is a significant river in northern Wales for Public Water Supply (PWS), as well as for the environment. Due to its significance, it has flow compensation from Llyn Celyn, Llyn Tegid and Llyn Brenig to support flow during dry periods (Natural Resources Wales, 2015). This compensation supports water company abstractions between Llangollen and Chester Weir.

The nearest water source to the blue hydrogen production plant would be Manchester ship canal, for example, abstraction from near Ellesmere Port. The nearest point on the River Mersey sits around 2km away from the site, and the end of the River Weaver is around 7km away. The green hydrogen plants to the east are within 1km of the Mersey, Weaver, and end of the Manchester ship canal (Figure 3.5).

[8] See Section 5.3.1.

Figure 3.5 Closest surface water sources to hydrogen production plants



3.2.3 Lakes, reservoirs and meres

There are approximately 14 lakes, reservoirs and meres within the HyNet NW area, (determined from Water Framework Directive (WFD) data). These are predominantly concentrated to the east of the area.

Gaps

The local significance of these water bodies was not identified in the literature reviewed, neither was the potential for these water bodies to provide water for HyNet NW.

3.2.4 Estuaries

The Mersey Estuary is a site of national and international importance for both heritage and environmental reasons (Environment Agency, 2023a). It has multiple designations including Ramsar and SSSI (Natural England, 2023). It is an expansive, sheltered estuary characterised by wide saltmarsh areas and extensive intertidal sand and mudflats (Natural England, 2004). Additionally, there are limited regions of brackish marsh, rocky shoreline, and boulder clay cliffs, all situated in a blend of rural and industrial surroundings. The estuary plays a vital role during the spring and autumn migration periods, especially for wader populations traveling along the west coast of Britain (Natural England, 2014).

The Dee Estuary is within the HyNet NW area and similarly has multiple designations, also including Ramsar and SSSI (Natural England, 2023). It is a large, funnel-shaped estuary with extensive intertidal sand and mudflats, saltmarshes, and transitional brackish areas (Natural England, 2014a). The site encompasses the Hilbre sandstone islands known for their significant cliff vegetation and maritime heathland. The estuary's two shorelines exhibit a stark contrast between industrial use in Wales and residential/recreational use in England. Like the Mersey Estuary, it plays a vital role during migration, particularly for waders along the west coast of Britain and post-breeding Sandwich terns.

3.2.5 Rainfall

Gap

From the literature reviewed, the long-term average rainfall levels and rainfall patterns for the HyNet NW area have not been identified.

The nearest historic Met Office weather data suggests an average of 671 mm per year from 1946-2023 at Shawbury and 810 mm per year at Ringway from 1961-2003 (this station closed in 2004) (Met Office, n.d.). Neither station is considered fully representative of the HyNet area.

3.2.6 Public water supply

There are four water companies that provide the PWS to the HyNet NW area (Figure 3.6)

- United Utilities (UU),
- Severn Trent Water (SVT),
- Hafren Dyfrdwy (HD),
- Dŵr Cymru Welsh Water (DCWW).

There are no other public water companies in the neary area.

Gaps

New Appointment and Variations (NAVs) are limited companies, providing water and/or sewerage services to customers that would otherwise be provided by their local monopoly. These have not been assessed as part of this literature review as their water requirements are already considered by the water companies listed previously. In addition, only the largest water retailer in the region has been investigated.

There are five Water Resource Zones (WRZs) in and near the HyNet NW area that have been focused on within this review:

- Strategic WRZ (UU)
- Chester WRZ (SVT)
- Saltney WRZ (HD)
- Wrexham WRZ (HD)
- Alwen Dee WRZ (DCWW)

Water companies use a range of sources to meet the local demand which includes intercompany transfers to bring water into the area. The main water sources for the WRZs are discussed further in Section 5.1.1.

The local water demand also includes water lost from the system via leakage. According to Ofwat's recent assessment, both SVT and UU are performing at or better than their performance commitment level for leakage, and DCWW and HD are performing poorer than their performance commitment level (Ofwat, 2023). Leakage management is a key part of all four public water companies' dWRMP24s / revised dWRMP24s reviewed for this annex and can significantly impact the amount of water available.

Figure 3.6 Water resource zones and water companies in the Water Resources West region (Water Resources West, 2022)

3.2.7 Regional group - Water Resources West

Water Resource West (WRW) is one of the five regional planning groups across the UK, with the geographical regions shown Figure 3.7. The group's work is aimed at planning the future water needs of the region. The plan includes a summary view of draft plan inter-regional transfer selections and water into supply dates, along with the selection of Strategic Resources Options (SROs) in the region. The group's efforts are part of a larger initiative to ensure sustainable water management.

Figure 3.7 Regional group areas (Environment Agency, 2020)

There are five key water company members of WRW - United Utilities (UU), Severn Trent Water (SVT), Hafren Dyfrdwy (HD), Dŵr Cymru Welsh Water (DCWW), and South Staffs Water (SSW). The region serves approximately 18 million people and numerous businesses across a variety of industries (Water Resources West, 2022). WRW is seeking to develop collaborative water resources solutions in selected catchments, one of which is Weaver Gowy and is relevant for the HyNet NW area.

3.2.8 Non-public water supply

There are also non-PWS abstractions in the HyNet NW area. According to the Water Management Plan (Defra, 2021), there is an aim that all abstractions require a permit by the end of 2022, including previously exempt abstractions. This should allow for the Environment Agency (EA) to more clearly see where water is being used and what for. However, EA guidance on whether an abstraction licence is required stated that there remains exempt abstractions as of the date of this annex (Environment Agency, 2023).

Non-PWS abstractions tend to be local only, relying on water in the area or naturally brought into the area through river or groundwater flow.

Gaps

The split between surface and groundwater abstractions was not found in the literature for the HyNet NW area but could be identified through interrogation of the abstraction licence and actual abstraction data once available. This data has been requested from the EA.

3.2.9 Catchment abstraction management strategies

Natural Water Resources are managed by the Environment Agency (EA) in England and by Natural Resources Wales (NRW) in Wales. The EA and NRW manage water availability primarily through regulation of abstraction (discharges of uncontaminated water are unregulated). While no restrictions are placed on abstractions of less than 20 m^3/d from freshwater sources or any abstractions from open coastal waters or hydraulically isolated water sources, other abstractions are controlled by the EA through the abstraction licensing process[9]. For activities not exempt from these requirements, a license must be granted by the EA to abstract water from freshwater sources. The terms of these licenses include restrictions on the maximum permitted abstraction volumes, and may contain additional restrictions, such as ‘cease to abstract’ clauses related to environmental conditions.

The Catchment Abstraction Management Strategy (CAMS) process is used by the EA to produce abstraction licensing strategies for CAMS boundary areas (catchments). These strategies take into consideration aspects such as natural water flows, trends, permitted and actual abstraction levels, climate trends, national strategies and objectives, and other environmental factors to determine the level of restriction which will be placed on new applications for permits in the catchment. These restrictions are published within ‘abstraction licensing strategies’. Abstraction licenses have a ‘Common End Date’ (CED) after which all abstractors need to re-apply to the Environment Agency should they wish to

[9] It should be noted that conflicting information from EA sources was unable to be resolved. While the 2017 *Water Abstraction Plan* (updated 2021) states from "31 December 2022 – all previously exempt abstractions will be permitted", the guidance named *‘Check if you need an abstraction licence guidance’* (published 2022 updated 2023) still includes the exceptions listed here.

renew their permit(s). The length of these licenses is 12 years. The CED for the catchments relevant to this study are listed below.

- Lower Mersey: March 2028
- Northern Manchester: March 2027
- Upper Mersey: March 2030
- Weaver and Dane: March 2025
- Dee: March 2027

Based on the approximate asset locations shown on Figure 1.1, the blue hydrogen production plant is most likely to be within the Lower Mersey and Alt abstraction licensing strategy catchment, in close proximity to the Weaver and Dane abstraction licensing strategy catchment and Dee abstraction management strategy catchment.

4.Potential impacts of HyNet NW on water

4.1 Technology considerations

This section explores current understanding of the impact of the proposed HyNet NW projects on water in the region.

4.1.1 LCH Technology (blue hydrogen)

The hydrogen production plant will treat and reuse process water and surface runoff which enters the so-called 'contaminated stream'. However, it is understood that rainwater from the rest of the site will be discharged to the sewer network.

Gaps

It is known that combined sewers are present in proximity to at least some HyNet assets. In particular, there are combined sewers feeding Elton in close proximity to the proposed Blue Hydrogen plant at Stanlow. However, it is not known whether the plant would discharge into a separate or combined system.

It is not known how and if surface runoff is currently discharged from the area.

The use of foul sewerage in place of surface water drainage to discharge rainwater and runoff would not be in accordance with correct usage. If additional load is going to be placed on a combined system, the need for investment in UU's infrastructure to avoid additional storm overflow spills, flooding and increased pressure on wastewater treatment works should be considered. Any new development should use separated storm and foul sewerage where possible.

The treated MBR effluent will be sent to the clarified water tank, which is located before the dual filtration media system (HyNet North West, 2021).

Gaps

It is not known to what level of accuracy the numbers in Table 4.1 have been presented. WRc note the presence of zero concentrations which are unlikely to be achievable in practice. The limit of detection/quantification is unknown. The values also contradict the reviewed literature, which states that 'the main purpose of the dual media filtration system (which is situated after the clarification tank) is to remove remaining suspended solids, turbidity, organic matter, and colour'.

Table 4.1 MBR Influent and Treated Effluent Stream Composition (HyNet North West, 2021)

Component	Composition (mg/l)	
	MBR Feed	MBR Treated Effluent
Total Suspended Solids (TSS)	241.7	0
COD	5155.3	33.5
BOD	4055.3	25
Ammonia	182.9	0
Methane	6.5	0
CO_2	1114.2	0
Nitrogen	13.3	0
Methanol	3308.7	0
Amine	18.7	0

A reject water, which is a saline effluent stream, will be produced during demineralisation (HyNet North West, 2021). The reject water will be discharged through Point W3 which is the discharge point to Manchester Ship Canal via N38 (HyNet North West, 2021).

4.2 Carbon Capture & Storage systems

This section details the impact of HyNet Carbon Capture and Storage (CCS) systems on water requirements in the region. The HyNet plans indicate the development and integration of several carbon capture facilities across the Northwest, with storage planned at offshore sites in Liverpool Bay.

4.2.1 CCS Methods

A typical CCS system comprises three main processes: firstly, the capture of CO_2, from the waste gases of combustion (flue gas) or other mixtures of gases; secondly, the compression and transportation of the captured CO_2 to the storage site; and thirdly, the injection of the CO_2 to a geological reservoir for long-term storage. Carbon utilisation is an alternative to storage which aims to reduce carbon emissions by using the captured carbon in manufacturing. The first process is generally the most water and energy-intensive, but the efficiency of these demands and CO_2 capture effectiveness varies according to the chosen system and cooling method for capture. Amine-based CO_2 capture is the most mature and widely-used CCS technology and employs an aqueous amine solvent.[10] Alternative technologies, such as membrane or sorbent systems have been developed, which will require less process water (Global CCS Institute, 2016).

Cooling methods

Post-combustion CO_2 capture systems feed the flue gas of combustion through an absorption column with a solvent, which selectively removes the CO_2. The CO_2-rich solvent is then heated in a desorber column to release CO_2 for storage, after which the regenerated solvent is cooled for reuse (Agbonghae, et al., 2014). The largest driver for water consumption in CO_2 capture systems is the cooling requirement, which can be achieved through three configurations:

Open loop (once-through), 0.20 m^3/t CO_2 average water consumption.[11]

Open loop systems consume relatively little water as they rely on a high volume of raw water abstraction that is discharged back to the source after the heat exchange of the cooling process.

Closed loop (re-circulatory or evaporative), 2.63 m^3/t CO_2 average water consumption.[10]

The higher water consumption (but lower abstraction) cooling technologies employ closed-loop (evaporative) systems. These systems recirculate the cooling water, with cooling occurring as a result of the evaporation of this water. The water consumed is to replace the volume of water lost through evaporation,

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[10] Drax Bioenergy with Carbon Capture and Storage, 2022, Consultation Material

[11] Average water consumption values from HICP Water Study, Element Energy (2022).

and the periodic discharges of blowdown water intended to clear evaporative build-up and sediment from the system.

Air-cooled (dry), 0.01 m^3/t CO_2 average water consumption.[10]

Air-cooled systems do not use cooling water; instead, they use air condenser tubes that are cooled directly by conductive heat transfer from ambient air blown by fans. Whilst these systems significantly reduce water demand, dry cooling systems have relatively higher capital and operating costs and worse performance (Global CCS Institute, 2016).

The water quality requirements of cooling water, and therefore the source, may differ from that of coastal water. Transitional and coastal (TraC) waters with better availability than fresh water may be used in cooling processes.

Gaps
Lifespan or typical leakage of CCS solvents (amine-based)

4.2.2 Secondary water demand impacts

The addition of CCS systems to hydrocarbon-fired power plants has a significant parasitic power load (reported as up to 20% of a plant's generation capacity) (Herzog, 2016). This load reduces the output efficiency of a power plant fitted with CCS, so that in order to produce the same net generation of electricity, a greater volume of water will be consumed.

The EA has indicated that there are no CCS systems currently installed at plants in HyNet that are considering fuel switching to H_2[12], therefore potential reductions in on-site demand resulting from redundant CCS systems do not need to be considered.

[12] EA communication

4.3 Assessment of water requirements for HyNet NW

4.3.1 Hydrogen production

Water demand requirements

The water usage to produce hydrogen utilising LCH depends on the technology's specific design and operating conditions. Currently, LCH technology for producing hydrogen is in the development stage, and the process uses features such as partial oxidation and steam methane reforming (SMR). Extrapolation by WaterSMART Solutions[13] on the LCH process estimated that 31,000 L/hr of demineralised water will be required to produce 6000 kg/hr of hydrogen. The quantity and quality of wastewater produced will be dependent on the source water quality.

Gaps

It has not been considered how appropriate this extrapolation by WaterSMART Solutions is to the HyNet NW situation. Further information regarding this calculation could be valuable, to determine whether the relationship is expected to be linear.

According to a study conducted by Element Energy (Element Energy, 2022), the raw water footprint required for the Carbon Capture and Storage (CCS)-enabled hydrogen technology was estimated to be between 0.57-1.3 m^3/MW (Table 4.2). This study included losses from the raw water feedstock and the water demand required for cooling.

Table 4.2 Water footprint required for the Carbon Capture and Storage (CCS)

Technology	Unit	Low	Central	High
CCS Enabled Hydrogen	M^3/MWh	0.57	0.79	1.30

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13 Saulnier, R., Minnich, K. and Sturgess, P.K. (2020) Water for the hydrogen economy - WaterSMART Solutions. Available at: https://watersmartsolutions.ca/wp-content/uploads/2020/12/Water-for-the-Hydrogen-Economy_WaterSMART-Whitepaper_November-2020.pdf (Accessed: 01 February 2024).

At the HyNet Northwest Cluster, 3 TWh per year of low carbon hydrogen production is expected to be achieved by the year 2025, rising to 30 TWh by 2030.[14] Based on these figures, the total demineralised water required to produce 3 TWh of hydrogen is 53.1 m^3/hr (Table 4.3).

Table 4.3 Demineralised water demand at Stanlow Refinery

Production	Value
Hydrogen production at Stanlow for the year 2030 [14]	30 TWh/year
Demineralised water demand for LCH Technology to produce 6000 kg H_2/hr (WaterSMART Solutions, 2020)	31 m^3/hr (0.7 ML/d)
Total demineralised water demand at Stanlow to produce 3 TWh/year H_2 by 2025	53.1 m^3/hr (1.3 ML/d)
Total demineralised water demand at Stanlow to produce 30 TWh/year H_2 by 2030	530.9 m^3/hr (12.7 ML/d)

If a 70% efficiency coefficient is given for the treatment of water and the production of demineralised water, the total raw water demand would be 7.4 L / kg H_2 which corresponds to 76.6 m^3/hr (1.8 ML/d) in 2025 and 766 m^3/hr (18.3 ML/d) in 2030.

Cooling water requirements for blue hydrogen production

A closed loop cooling medium system will be used for the hydrogen production plant to supply cooling for the LCH system. The hydrogen production plant will supply cooling for the syngas produced upstream of the CO_2 removal unit, steam blowdown from upstream of the closed drains header, blowdown from the saturator, process condensate from the CO_2 removal units, ROG compressor, CO_2 compressor and H_2 compressor (HyNet North West, 2021).

The cooling medium used for this system will consist of demineralised water and propylene glycol. Propylene glycol is being used for the system to reduce the toxicity in the cooling medium. The cooling medium will consist of 66%

[14] HyNet Low Carbon – hydrogen Plant – BEIS Hydrogen Supply Competition – November 2021

demineralised water and 33% propylene glycol. The cooler will be able to reduce the temperature of the coolant from 45˚C to 35°C (HyNet North West, 2021).

Gaps

It is unknown what type of source water is anticipated to be used for cooling and whether any treatment would be required; surface water abstraction has been assumed for calculations.

The characteristics for a closed loop cooling medium system are shown in Table 4.4.

Table 4.4 Characteristics of two types of closed loop cooling medium system for power generation. (Element Energy, 2022)

Cooling System	Abstraction Volumes	Losses (% of abstraction)
Closed loop cooling medium – Wet towers	1 - 5 m^3/MWh [15]	61 – 95 %
Closed loop cooling medium - Pond	22 - 67 m^3/MW	4 – 9 %

Water discharge

Quality of water and wastewater discharged/produced.

Source documents assert that the only discharge flow from the hydrogen production plant will be saline reject water from the demineralisation system. It is important to note that information regarding the salinity of reject water from the demineralisation plant is not available.

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[15] Figures are cooling required per MWh of electricity production from non-renewable combustion. Assumed to be a representative estimate per MWh of H_2 production, or, as a minimum, to demonstrate the relative water intensities.

Gaps

It is not understood whether this implies that all the 'lost' water from the cooling system is evaporation or whether this water is collected as part of the process water.

Information regarding the salinity of and presence of other salts in the reject water from the demineralisation plant is not available.

The composition of this water is shown in Table 4.5 (HyNet North West, 2021).

The process effluent streams produced during the LCH process will be sent back to the hydrogen production plant wastewater treatment plant for further treatment. The treated water will be demineralised and reused for the LCH system as shown in Figure 3.2.

Table 4.5 Demineralisation Plant – Reject Water Composition (HyNet North West, 201)

Parameter	Value
Temperature (˚C)	24.2
pH	7.6
Actual Volume Flow (m^3/h)	14.1
Design Volume Flow (m^3/h)	17
TSS (mg/l)	0
COD (mg/l)	8.03
BOD (mg/l)	5.996

Quantity of water and wastewater discharged/produced

The demineralisation plant can produce a very high volume of reject water (wastewater stream) up to 80% of its input (clarified tank effluent as shown in Figure 3.3) depending on the water quality. To produce 1m^3 of demineralised water for hydrogen production, approximately 1.4 m^3 of raw water is required (subject to water quality).

The blue hydrogen plant is believed to be located at the site of the Stanlow Manufacturing Complex, operated by Essar Oil (UK) Limited. As it has communicated that the site will use the existing natural gas streams, it is assumed that the hydrogen plant would be in place of existing natural gas refinery at the site. This assumption needs to be verified.

Essar Oil (UK) has an existing discharge license from the EA for the site under its current operation. This was most recently amended in 2023[16]. The current permitted discharge flow to point W3 (Point W3 is the discharge point to Manchester Ship Canal via N38 [16]) is 90,000 m^3/day at normal flow and 100,000 m^3/day at abnormal flow (discharge to Essar site drainage systems from where the water can be discharged to United Utilities wastewater treatment works is not available). At a production rate of 100,000 Nm^3/h[17] (3.3 TWh) of hydrogen, the demineralisation plant reject water flow rate at normal flow would be 338.4 m^3/day.[5] This would be discharged at point W3 for phase 1.[18] The discharge at point W3 will consist of the reject water effluent from the demineralisation plant, plant drainage interceptors and any runoffs from the hydrogen production plant (HyNet North West, 2021). As this discharge

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[16] Stanlow Manufacturing Complex operated by Essar Oil (UK) Limited – Notice of variation and consolidation with introductory note – EPR/FP3139FN/V013https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1118694/FP3139FN-V012_-_Variation_Notice.pdf

[17] Normal cubic meter per hour: volumetric flow rate of dry gas at 0 degrees and atmospheric pressure

[18] Stanlow Manufacturing Complex operated by Essar Oil (UK) Limited - Permitting Decisions - Variation FP3139FNV013

corresponds to 0.4% of the currently permitted discharge limits, and the Manchester Ship Canal is not known to be dependent on discharges to maintain ecology or marine life, no issues are foreseen with the quantity of this discharge in line with the current permit. However, the W1 discharge permit does not currently include specific limits for salinity or other dissolved salts.

Gaps

Information on water quality parameters not prescribed in the current permit conditions of the discharge including salinity, presence of other dissolved salts and metals (Copper, Calcium, Magnesium, Sodium, Chloride, Sulphate, Nitrate and Bicarbonate) is unknown.

The reject water discharge flow may be consistent if the plant operates continuously, and the feed water quality remains stable. However, variations in the feed water quality, changes in the operating conditions or maintenance activities can affect the reject water flow rate. Seasonal variations in the reject water discharge flow should be considered in the permit limits.

The existing conditions of the license for discharge to Manchester Ship Canal via N38 at point W3 provides guidance as to what effluent quality from the hydrogen plant might be considered acceptable. A shortened version of these requirements is shown in Table 4.6.[16] The existing license may be subject to a variation to address dissolved salt and metal contents of concern.

All parameters in this permit shall be considered when performing the evidence baseline assessment. A shortlist of key parameters has been presented in the below table.

Table 4.6 Effluent discharge limits for permitted discharge from Stanlow Manufacturing Complex (most recently amended in 2022) – Point source W3[16]

Water emission point	Parameters	Units	Limits
W3 – Discharge to Manchester Ship Canal via N38	Flow	m^3/d	100,000
	Temperature	°C	32.5
	pH		6-9

	Total suspended solids	mg/l	25
	COD	mg/l	125
	Hydrocarbon oil index	mg/l	2.5
	Total nitrogen expressed as N	mg/l	20
	Phenols	mg/l	0.5
	Benzene, toluene, ethyl benzene, xylene	mg/l	0.3
	Cadmium	mg/l	0.002
	Mercury	mg/l	0.0002
	Lead	mg/l	0.002
	Nickel	mg/l	0.02
	Cyanide	ug/l	20
	Sulphide	mg/l	1

Electrolysis technology (green hydrogen)

Green hydrogen describes methods for hydrogen production by electrolysis whose energy demands are met by renewable sources. Where blue hydrogen reforms hydrocarbons to produce H_2 and CO_2, green hydrogen uses electrical power to split water into H_2 and O_2. Potable water, raw water or seawater can all be used as feedstocks for green hydrogen production but need to be purified to ASTM Type II standard water before use in the process. Electrolysis is a water intensive method for generating hydrogen, consuming 9L of ASTM Type ll water to make 1kg of hydrogen (from the stoichiometric relationship).[19] Additional water is required for the water purification system and process cooling.

Various electrolysis methods exist and can be categorised into three types based on electrolytes and operating conditions: Alkaline Water Electrolysis (AWE), Solid Oxide Electrolysis (SOE) and Proton Exchange Membrane (PEM) water electrolysis. These methods have varying energy efficiencies and tolerances for process water quality, and PEM is considered the most mature (Wang, 2022).

Electrolyser manufacturers report a range of water demands from 10.0 to 22.4 L/kg H_2, a range in line with Simões et. al. (2021) asserting that the sum of water needs for the electrolyser is circa 85% on top of the 9 L/kg stoichiometric requirement (Simões, S et al., 2021). A potable water requirement 15.5 L/kg H_2 for PEM (electrolysis, cooling and process water inclusive) has been cited.[20]

There is less evidence around the scale, water sources, demand and operational waste for the planned HyNet green hydrogen production facilities in comparison to the larger Essar/Vertex blue hydrogen plant. The three plants that WRc is aware of have been detailed below.

- Protos' Cheshire green hydrogen project at Ince aims to have a capacity of 12,940 kg H_2 per day (18 MW), requiring 11,280 litres of potable water per hour (10.5 L/kg H_2 or 0.27 ML/d).

- A green hydrogen production plant is planned at Carlton Power in Trafford, for an initial 20 MW phase with an ultimate capacity of 200 MW planned.

[19] EA Environmental Capacity Phase 2 Report

[20] Saulnier, R., Minnich, K. and Sturgess, P.K. (2020) Water for the hydrogen economy – WaterSMART Solutions. Available at: https://watersmartsolutions.ca/wp-content/uploads/2020/12/Water-for-the-Hydrogen-Economy_WaterSMART-Whitepaper_November-2020.pdf (Accessed: 01 February 2024).

An estimate of potable water use for a green hydrogen plant of this scale (using 15.5 L/kg of H_2) is 0.23 ML/d for 20 MW and 2.3 ML/D for 200 MW.

- Project Quill 2, based at the Inovyn site in Runcorn, also plans to develop a green hydrogen site however little information is available about the project's planned capacity.

4.3.2 Carbon Capture & Storage

Gaps

Greater detail around the water sources and cooling methods for the planned projects is required to provide an improved estimate of demand.

The consumptive water use of the proposed projects can be broadly estimated, but limited information has been found to date on water quality requirements and effluent discharge.

Little information found on potential release of nitrosamines to atmosphere, and subsequent impact on water quality through atmospheric fallout.

Based on the available information totalling 2,490,000 tonnes of CO_2 capture per annum, estimations can be made for overall HyNet CCS contribution to water consumption. This amounts to 179 ML/d if each project employs closed loop cooling and 36 ML/d for open loop cooling. It is possible that TraC water may be sourced, which would alleviate concerns around raw or potable water availability.

4.3.3 Hydrogen storage

Gaps

It will be necessary to understand to what extent solution mining will need to be performed to create the proposed hydrogen store. In addition, the water source for this activity will need to be considered. For example, were it possible to utilise TraC water, this could alleviate concerns around raw or potable water availability. The discharge of the resulting brine is a challenge that would also need to be considered.

Research regarding the water quality requirements for solution mining (e.g. how the demand for water is affected by the level of salt saturation already present in the source water) has not been carried out as part of the literature review at this stage.

5.Current status of the water environment

5.1 Review of current water demand and availability

5.1.1 Public water supply

Four supply companies operate within the HyNet network (Figure 3.6); UU, SVT, HD and DCWW. This section focuses on the five WRZs located within the HyNet NW area, noted in Section 3.2.6.

In assessing water availability for public supply, various factors are considered. This includes allowances for both raw and treated water losses, outage considerations, the potential impacts of climate change, and adjustments for sustainability changes to water licenses.

United Utilities

Many HyNet NW assets are within UU's Strategic WRZ, the largest WRZ in the UU region. The average supply is 1794 ML/d, serving a population of approximately 7.17 million (United Utilities, 2023) This WRZ is surface water dominated with some local groundwater sources such as the groundwater abstraction boreholes in Mersey and Bollin catchments. Sources are used in a 'conjunctive' nature. Due to the geographical size of the WRZ, sources come from multiple geographical areas, including Lake District, Peak District, Pennines Lake Vyrnwy and River Dee.

For the entire UU region, in a typical year 94 per cent of the water supplied comes from river or reservoir sources, and only six per cent comes from groundwater; this balance may vary slightly in a dry year.

The total demand for the revised dWRMP24 base year (2019/20) is 1762.6 ML/d, which is comprised of (United Utilities, 2023):

- 52% household (HH) consumption (measured and unmeasured)
- 20% non-household (NHH) consumption (measured and unmeasured)
- 24% leakage

- 4% taken unbilled and operational use

The baseline deployable output (DO) for the year 2025-26 is 2006 ML/d, limited by the 1 in 200 year drought resilience. There are three water companies from which UU import potable water to supply customers within the UU region (United Utilities, 2023a). Less than 0.1 ML/d are taken from both HD and SVT. The import from Northumbrian Water is into the North Eden WRZ not the Strategic WRZ.

UU also exports raw and potable water to seven companies including DCWW, HD, Northumbrian Water, SVT and NAVs. There is a total export of 109.3 non-potable bulk supplies, the largest being up to 28 ML/d raw water to DCWW. All potable exports are less than 1 ML/d each. The current imports and exports are expected to continue over the next AMP period.

Severn Trent Water

Chester WRZ is close to current known locations of HyNet NW assets, with some potentially in the WRZ. It is shown as WRZ 2 in Figure 3.6. The WRZ sources water from both groundwater and River Dee surface water abstractions. Overall groundwater provides approximately a third of SVT's DO, with the remaining supplied largely from surface water abstraction and reservoirs (Severn Trent Water, 2023a). It serves a population of 105.69 thousand, with a distribution input (DI) of 22.59 for the year 2021-22, and dWRMP24 1 in 500 year DO of 28.5 ML/d, constrained by groundwater yield and regulation of River Dee abstraction (Severn Trent Water, 2023a). Leakage in 2021/22 represented 10% of the DI.

SVT's interzonal transfers do not include Chester WRZ. There is one import to Chester WRZ from HD's Wrexham WRZ of 2.08 ML/d, and one export from Chester WRZ to Saltney HD's WRZ of 4.73 ML/d (Hafren Dyfrydwy, 2023a). The amount of the import and export is dependent upon meter data (Severn Trent Water, 2023a). Transfers less than 1 ML/d have not been outlined. There is no indication that there will be any significant changes to the import and export from Chester WRZ.

Hafren Dyfrdwy

HD's Saltney WRZ and Wrexham WRZ are close to current known locations of HyNet NW assets, with some potentially in the WRZ. Saltney WRZ, denoted as WRZ 1 in Figure 3.6, is a small WRZ in the lower Dee catchment with water supplied from an import from Chester WRZ, see above for more information. Given that there is an agreement for SVT to provide sufficient water to meet the Saltney WRZ demand it is encompassed within the SVT dWRMP. Saltney WRZ already has a *per capita* consumption (PCC) below the national target of 110 l/p/d.

Wrexham WRZ is mainly supplied from Llwyn Onn (River Dee) with some groundwater supplies. The River Dee flows are augmented from upstream impounding reservoir to allow abstraction as part of the Dee abstraction (Hafren Dyfrdwy, 2023). As stated above, Wrexham WRZ exports 2.08 ML/d to Chester WRZ (Dŵr Cymru Welsh Water, 2023) (Hafren Dyfrdwy, 2023) HD has noted that the national PCC target of 110 l/p/d is ambitious for Wrexham WRZ, and have stated 118 l/p/d to be a more realistic yet ambitious target (Hafren Dyfrdwy, 2023). Wrexham WRZ was assessed by HD to be 'low vulnerability' to climate change under the 1 In 500-year drought scenario and is expected to remain in surplus in 2030 under RCP8.5 (Hafren Dyfrdwy, 2023).

Further information relevant to this study includes the following:

- According to HD's dWRMP24, there is less than 50 ML/year of unlicenced abstraction in Wrexham WRZ (Hafren Dyfrdwy, 2023).

- As part of the North Wales Growth deal, a large expansion project is planned at the Western Gateway, Wrexham. The new development plan has zoned land for expansion of the Industrial Estate by a third of its existing size. Although at the planning stage, development is expected to start within the next three to five years and continue until around 2035. The water demand required by this new development is uncertain as the type of commercial development is unknown (Hafren Dyfrdwy, 2023).

- NRW has stated that water companies should plan for a net reduction in their River Dee allocations of 26% by the 2070s, due to anticipated reduction in water availability when median climate change scenarios from

UKCP18 Regional Climate Models (RCP) 8.5 were applied to historical inflow data (Hafren Dyfrydwy, 2023a).

Dŵr Cymru Welsh Water

Industrial CO_2 capture is likely to occur within DCWW's Alwen Dee WRZ based on the current known asset locations. The sources for this WRZ are the River Dee supplemented by Llyn Alwen (impounding reservoir), with local groundwater on standby (Dŵr Cymru Welsh Water, 2019). Exports from Alwen Dee WRZ are limited by the infrastructure. There is a small export of 0.16 ML/d to HD in the lower part of the Dee system. In accordance with revised dWRMP24, the DO for Alwen Dee WRZ is 60.5 ML/d as defined by historical data and by a 1 in 200 year drought.

5.1.2 Non-public water supply

Non-PWS abstraction in the area is dominated by navigation requirements, industrial abstraction and, to a lesser extent, agriculture (Environment Agency, 2013). Figure 5.1 shows the Water Resources West (WRW) regional breakdown and Figure 5.2 shows the split of estimated consumptive abstraction from 'industrial' abstraction.

Gaps

Only high-level national breakdowns of water uses from non-PWS abstraction were identified in the literature. Local and more specific data remains a gap. However, WRc have recently received abstraction licenses and actual abstractions data which will be analysed in later stages of this annex.

Both the volume and proportional consumption by industry in the north west are among the highest in England (Environment Agency, 2020). It is noted that the industrial abstraction is currently dominated by chemical and paper industry. Within the WRW area, industry is estimate to account for 62% of 242 ML/d of non-public consumptive water abstraction with power production contributing a further 11%. Water abstraction for navigation is significantly higher in the WRW than any other region in England (larger than the other regions combined), totalling 97 ML/d.

Figure 5.1 Baseline recent actual consumptive abstraction for PWS and Non-PWS estimates, ML/d (Water Resources West, 2022)

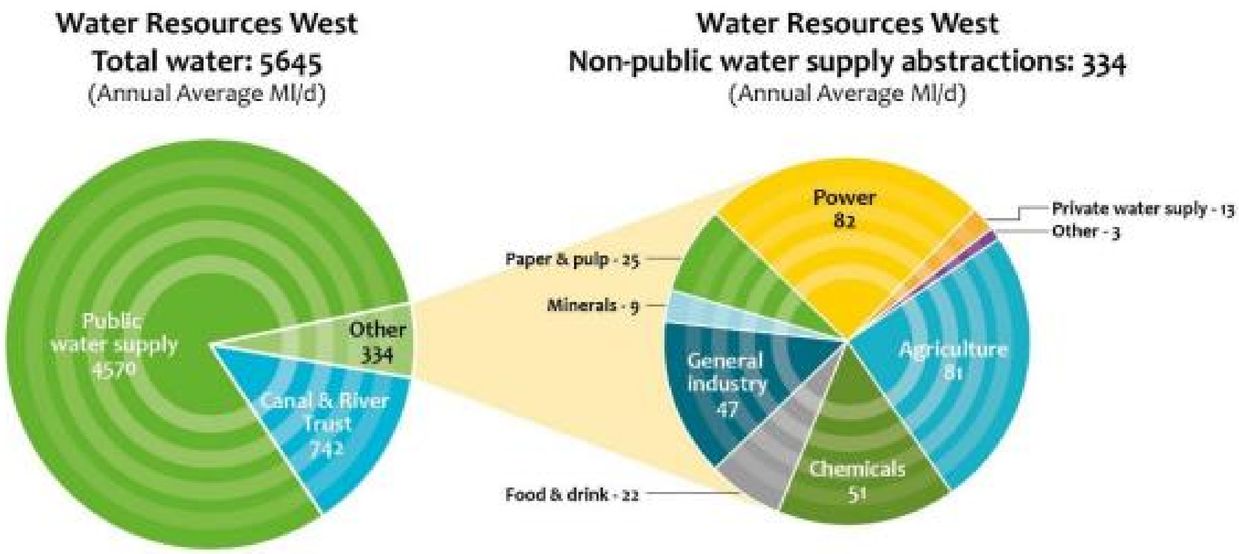
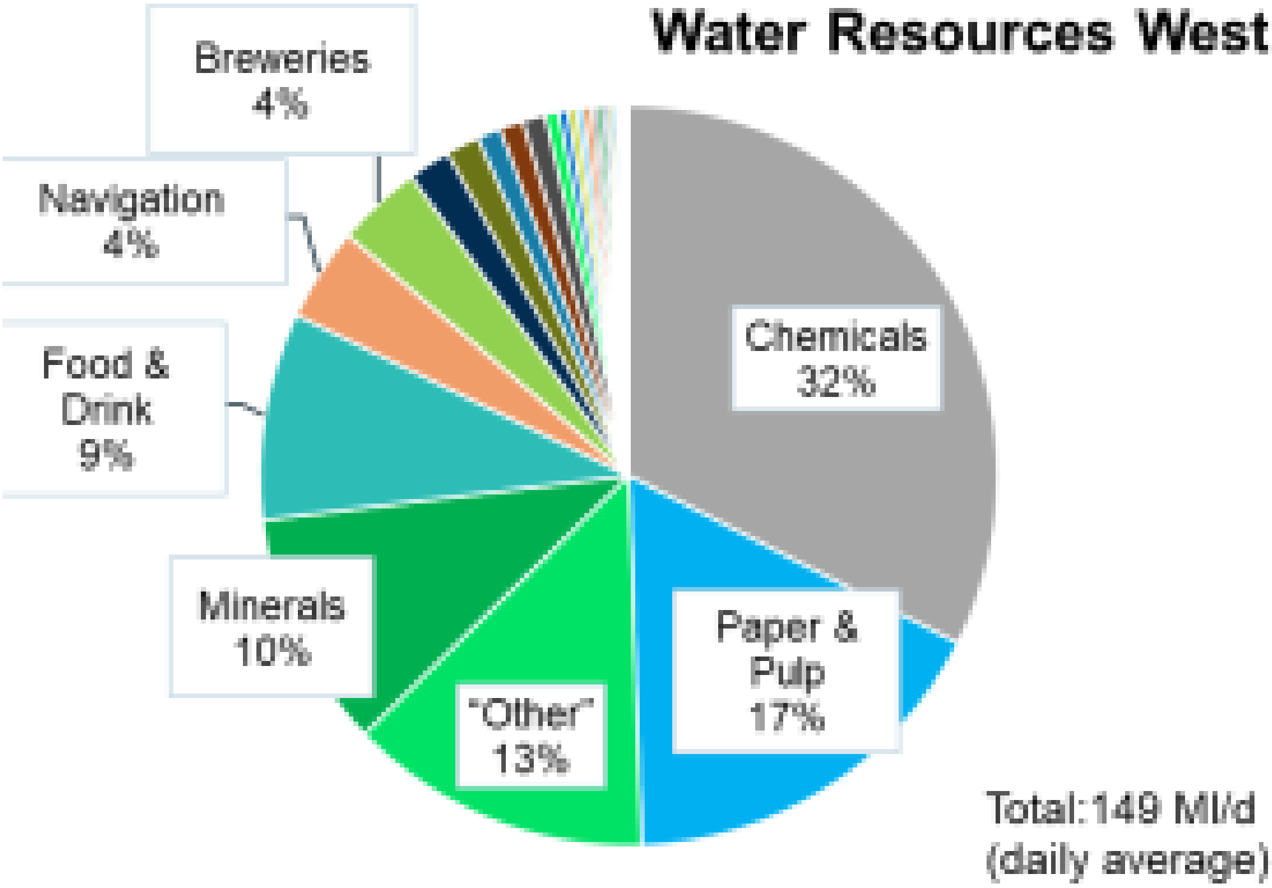


Figure 5.2 Split of estimated consumptive abstraction within WRW from 'industrial' abstraction (Environment Agency, 2020)



5.1.3 Environmental requirements

The abstraction licensing strategies provide hands off flows (HOFs) that are assigned to assessment points with the purpose of protecting the environment. They are put in place to ensure there is sufficient water for the environment and enable abstraction above the HOF (Environment Agency, 2013). A list of applicable HOFs as detailed in the current abstraction strategies can be found in Appendix B.

The HyNet NW area has multiple protected sites such as the Mersey Estuary which is a SSSI, and Oak Mere a SAC. These protected areas are discussed in more detail in Section 5.3. Details of the quantity of water required for these protected areas were not found in the literature review.

5.1.4 Catchment abstraction strategies and current water availability

Current water availability in the HyNet NW area has been assessed using the abstraction licensing strategy assessments. However, please note that these are based on historical data from the time of assessment, and so can quickly become outdated when new abstraction licences are granted, or environmental targets changed. All abstraction licence applications are reviewed based on the information available at the time of application, not based on the information available at the time of the abstraction licensing strategy assessment.

Figure 5.3 shows how the abstraction licensing strategy catchments fit together over the HyNet NW area. There is significant variability in available surface water across the area, as shown by Figure 5.4, Figure 5.5, Figure 5.6, and Figure 5.7. Note that while the Upper Mersey and Lower Mersey abstraction licensing strategies are dated 2013, the literature review found no evidence for significant changes to water availability.

The most notable area of concern regarding water availability is the Lower Mersey abstraction licensing catchment south of the Mersey Estuary. There are significant HyNet NW assets in this location and limited to no water available at low flows (Environment Agency, 2013). It was noted from the literature review however, that there are currently discussions of water trading with UU for the River Dee water they abstract and currently hold a licence for (Environment Agency, 2023c).

Gaps

It is assumed that assets in the HyNet NW network will require abstraction every day of the year. This should be confirmed.

The Weaver and Dane abstraction licensing strategy catchment has the majority of areas designated as ‘water available’ at low flows, with water available across the Weaver and Dane abstraction licensing strategy catchment at high flows.

Figure 5.3 Abstraction licensing strategy catchments

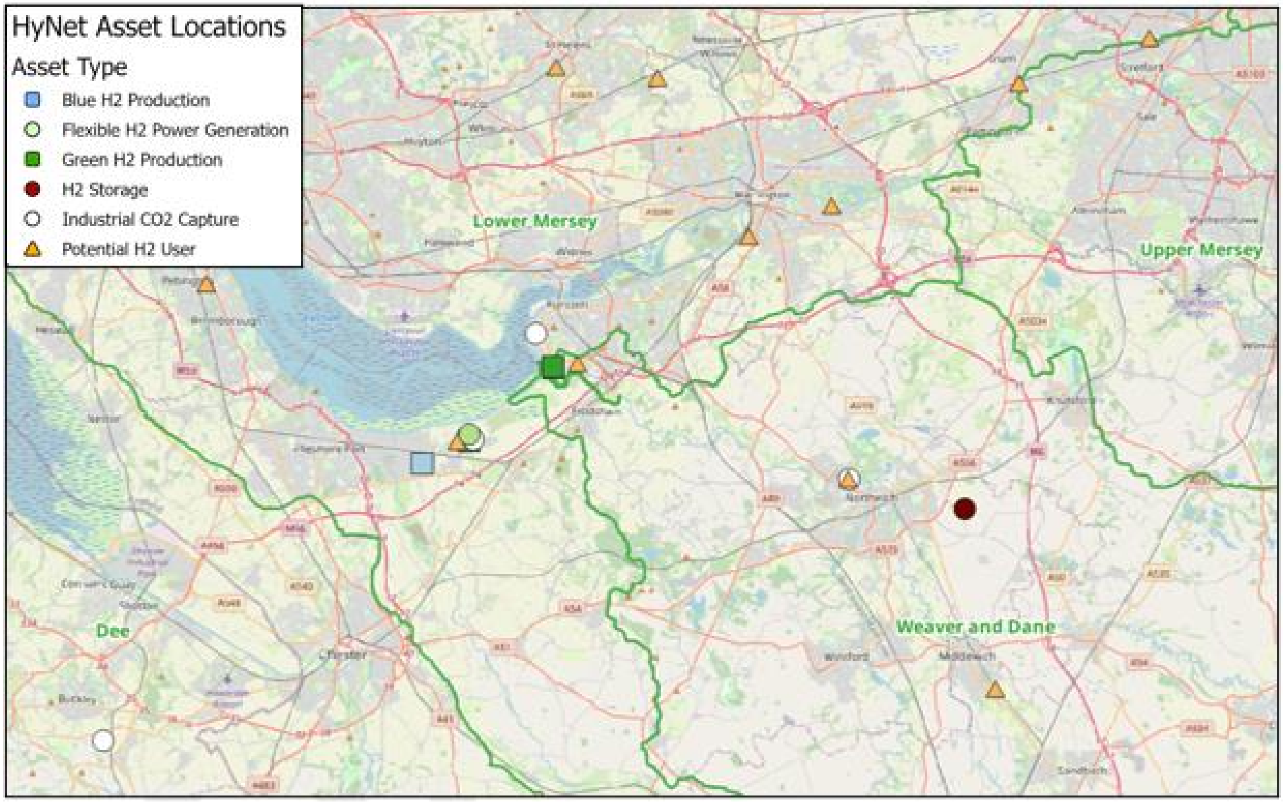


Figure 5.4 Surface water availability in Upper Mersey (Environment Agency, 2013a)

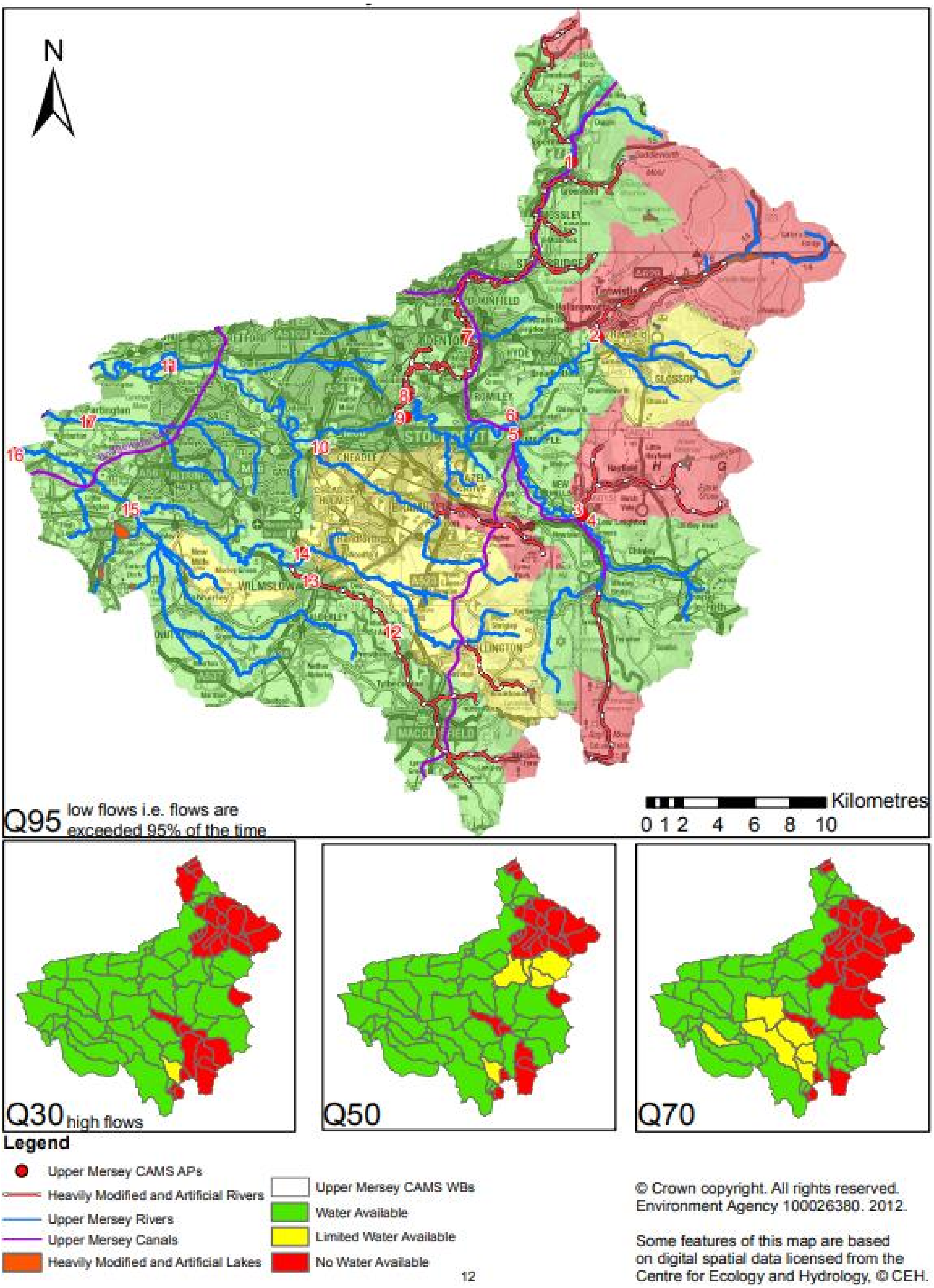


Figure 5.5 Surface water availability in Lower Mersey & Alt (Environment Agency, 2013)

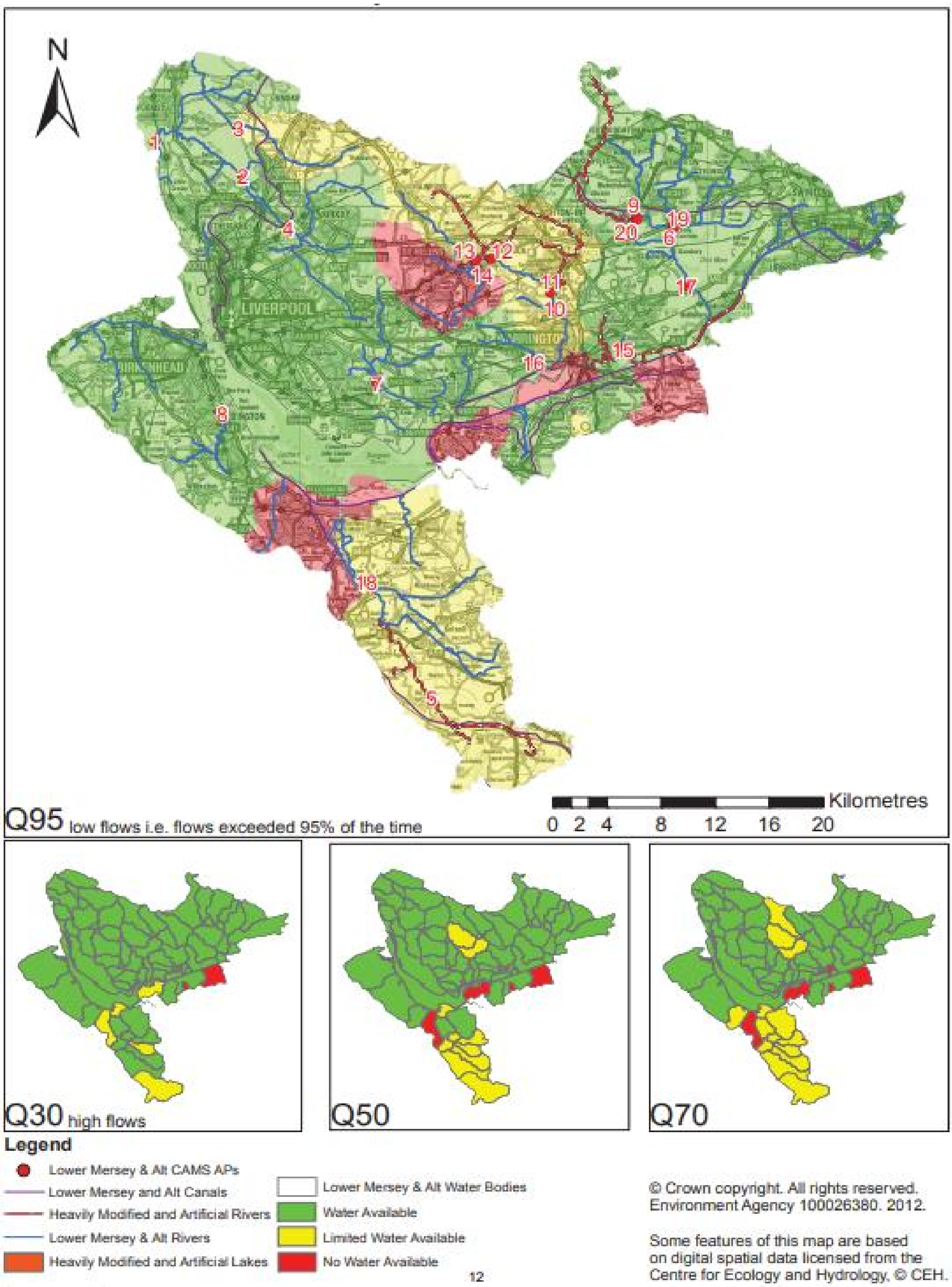


Figure 5.6 Surface water availability in Weaver and Dane catchment (Environment Agency, 2020a)

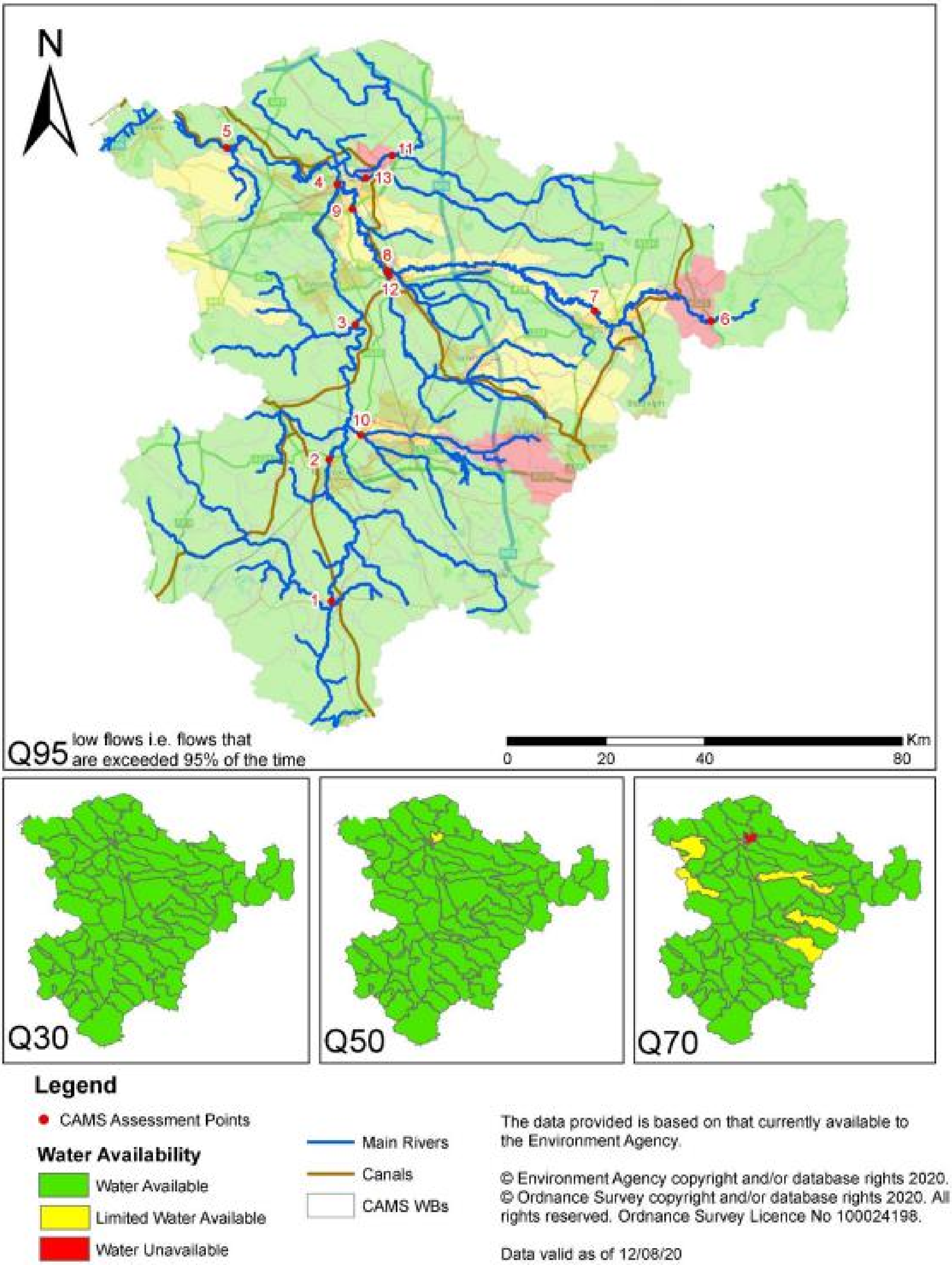
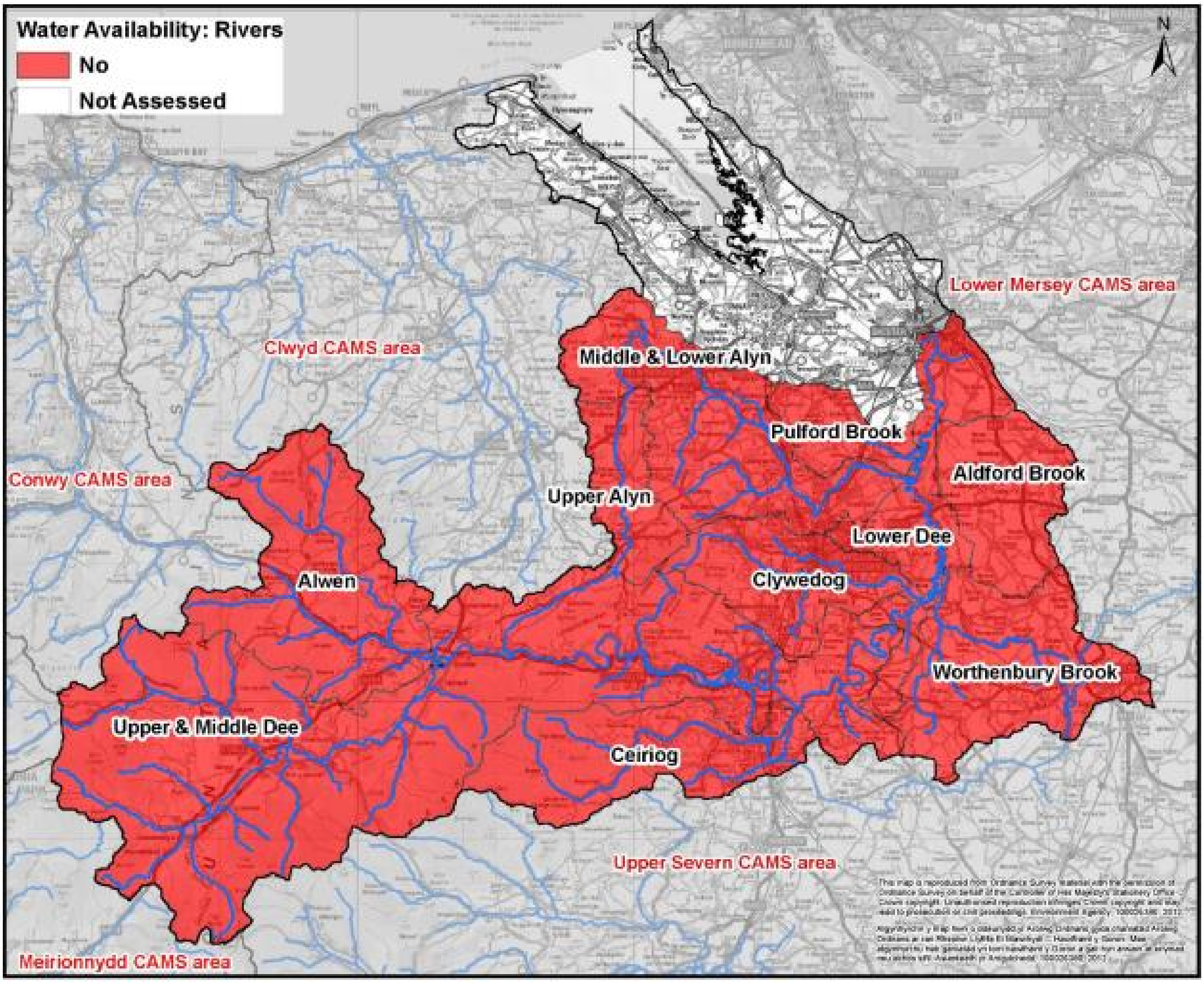


Figure 5.7 Surface water availability in Dee catchment (Natural Resources Wales, 2015)



The Dee Catchment Abstraction Management Strategy Dee (Natural Resources Wales, 2015) indicates that there is no surface water available within the Dee abstraction management catchment (Figure 5.7), with the abstraction strategy suggesting water trading as an option to get surface water from the River Dee.

The abstraction licensing strategies published by the EA provide an indication of how much water was considered ‘available’ at the time of the assessment. These values for selected assessment points (locations shown on Figure 5.4,

Figure 5.5, Figure 5.6, and Figure 5.7) can be seen in Table 5.1. This information was not available for the Dee catchment.

Table 5.1 Indication of water available at time of licensing strategy assessment at selected assessment points

Abstraction licensing strategy catchment	Year of licensing strategy publication	Abstraction Point #	Name	Availability	Number of days per annum abstraction may be available at restriction	Approximate volume available at restriction (ML/d)
Lower Mersey & Alt	2013	7	Ditton Brook (prior to confluence of River Mersey)	Restricted water available	365	15.4
Lower Mersey & Alt	2013	8	Dibbinsdale Brook (prior to confluence of River Mersey)	Water available	365	0.7
Lower Mersey & Alt	2013	17	Glaze Brook at Little Woolden Hall gauging station	Water Available	365	42.4
Lower Mersey & Alt	2013	18	Bridge Trafford gauging station (Lower Gowy)	Water unavailable	Water unavailable	Water unavailable
Weaver & Dane	2020	4	Hayhurst Bridge (River Weaver)	Water available	365	40.9
Weaver & Dane	2020	5	Pickerings Cut GS (River Weaver)	Water available	365	22.8
Weaver & Dane	2020	8	River Dane (prior to confluence of River Wheelock)	Restricted water available	241	1.8
Weaver & Dane	2020	9	Rudheath GS (River Dane)	Restricted water available	285	13.2

Abstraction licensing strategy catchment	Year of licensing strategy publication	Abstraction Point #	Name	Availability	Number of days per annum abstraction may be available at restriction	Approximate volume available at restriction (ML/d)
Weaver & Dane	2020	11	Lostock Graham GS (Wincham Brook)	Water unavailable	Water unavailable	Water unavailable
Weaver & Dane	2020	12	River Wheelock (prior to confluence of River Dane)	Restricted water available	285	7.1
Weaver & Dane	2020	13	Wade Brook (prior to confluence of Wincham Brook)	Restricted water available	365	17

Gaps

These assessment points have been chosen based on their location relative to the HyNet NW area. It is not currently known whether any existing abstraction licenses may be used for the HyNet NW assets and where these abstract from.

The evidence baseline will follow the literature review process which will compare the water availability, water needs, and water and environmental requirements. As such, the analysis below currently remains general and speculative, and refinement may be required to the specific water sources for which availability will need to be assessed.

Groundwater on the south bank of the Lower Mersey is classified as 'limited water available' (Figure 5.8), with the predominant reason for restriction being over licensed on water balance and saline intrusion (Environment Agency, 2013). Where saline intrusion is the only limiting factor it may be possible to implement a managed groundwater scheme, but this would need careful consideration and may not be feasible, particularly considering the additional challenges associated with rising sea levels and storm surges. In the Dee catchment, groundwater availability varies between none and restricted, with the abstraction management strategy noting new groundwater abstractions will only be considered if it is clearly demonstrated that there will be no reduction in the flow in any rivers upstream of Chester Weir, or if 100% of the water abstracted is returned upstream of Chester weir (Natural Resources Wales, 2015). While the Management Strategy was published in 2015, no evidence found indicates changes in water availability.

The nearest groundwater management unit considered to have water available is the East Glaze (Environment Agency, 2013), which could be used to provide water to industrial users but is unlikely to be used for hydrogen production or carbon capture given the location of those assets.

Figure 5.8 Groundwater availability (England) (Environment Agency, 2013)

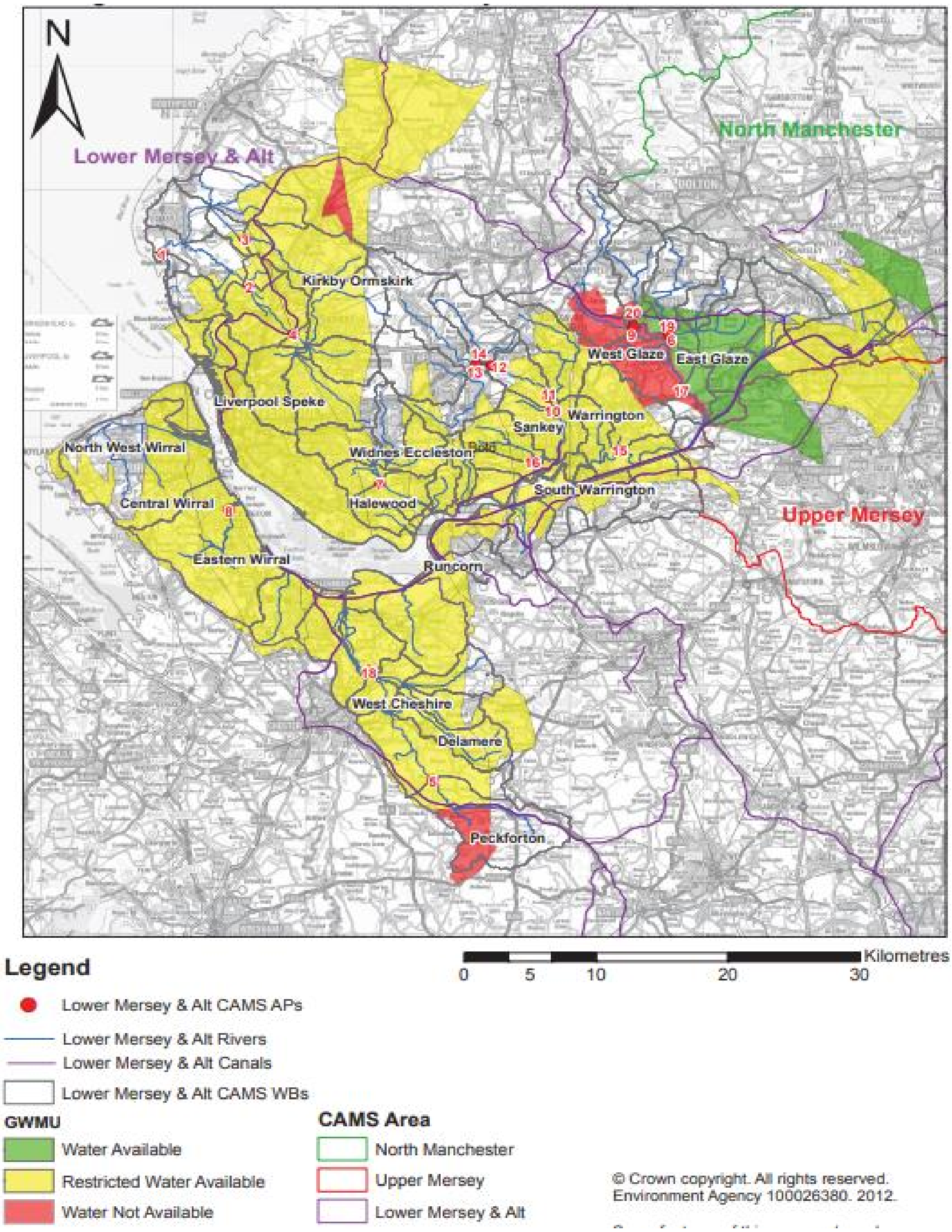
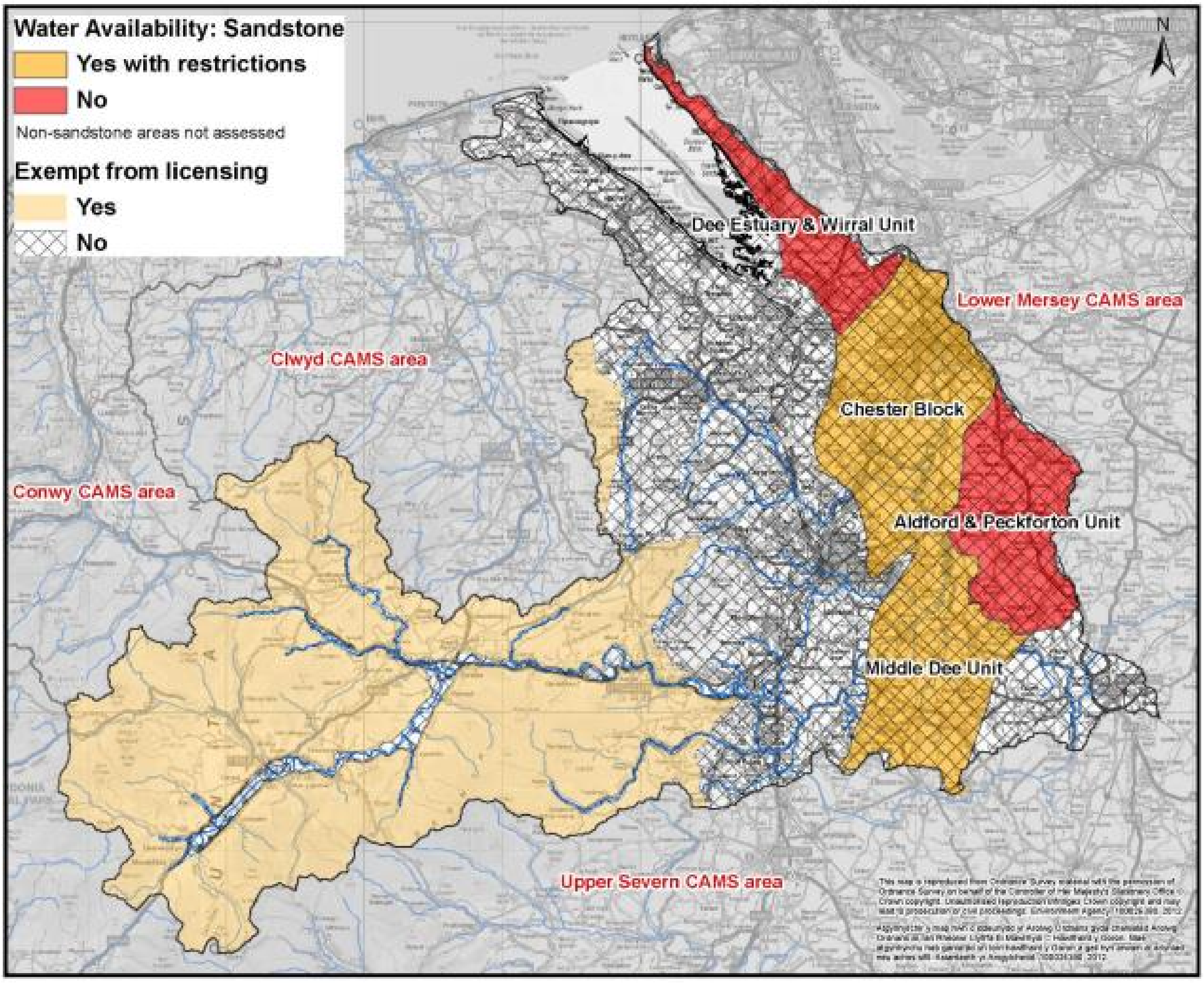


Figure 5.9 Groundwater availability in Dee catchment (Natural Resources Wales, 2015)



5.2 Review of current receiving water quality

To assess the impact and viability of the future HyNet project, it is important to understand the current and future water quality of relevant waterbodies. Changes in water quality near potential abstraction or effluent discharge points could have significant implications for water users and the viability of future developments. Additionally, the impact of possible abstractions or discharges on the hydrological environment must be considered. The following section summarises the current quality of water resources in the HyNet NW region.

Historically the Mersey Estuary has suffered from systemic water quality issues as a result of industry discharges and wastewater effluents from the surrounding urban and industrial centres. Although the Mersey Estuary has experienced substantial improvements in water quality since 1985, thanks to the implementation of the 25-year 'Mersey Basin Campaign') (Source magazine, 2023) and substantial previous investments by UU, the Mersey is still failing to meet the 'Good' ecological and chemical objectives set in the most recent RBMP. Figure 5.10 shows the current WFD classifications for all river water body catchments, transitional water bodies and coastal bodies within the HyNet NW area. The Mersey Estuary and surrounding catchments are all classified as 'Moderate' or worse, although the RNAG WFD status varies between water bodies. The Mersey Estuary transitional water body itself has a current ecological status of 'Moderate', resulting from both ecological and chemical WFD element failures (see Appendix C for a detailed breakdown).

In addition to statutory investigations under the WFD, Per- and polyfluoroalkyl substances (PFAS) concentrations and loads in the River Mersey were investigated in recent research (Byrne, P., et al., 2024). PFAS are a class of thousands of chemical compounds that break down very slowly and therefore persist in the environment. They have been linked to harmful health impacts in humans and animals (US Environmental Protection Agency, 2023). Samples were collected from the River Mersey on 32 occasions from August 2022 to July 2023, and analysed for presence of 17 PFAS. Wastewater treatment works effluent samples were also collected for analysis of two PFAS from 2015 to 2021. River flow data were gathered from an EA gauging station and an Acoustic Doppler Current Profiler. Wastewater treatment works flow data were also obtained.

Although limited data are available for other water bodies, Perfluorooctanesulfonic acid (PFOS) yields (i.e. load divided by catchment area) in the River Mersey were found to be 2-28 times higher than those observed in the Rhone, Seine and Danube rivers. Perfluorooctanoic acid (PFOA) yields were 25 times higher than those observed in the Danube. PFAS yields in the River Mersey were found to be exceeded only by Cape Fear River, USA, and in the Tokyo Basin, Japan (Byrne, P., et al., 2024).

Analysis of river and wastewater treatment works data indicated around 'one-third of PFOA emitted from wastewater treatment works is potentially stored in the catchment and approximately half of PFOS transported by the River Mersey may not originate from wastewater treatment works.' Other potential sources of PFOS suggested include landfill sites, airports, construction activities, chemical and textile manufacture, paper mills, metal fabricators, and contaminated land remediation. The authors recommend catchment-scale monitoring at high temporal resolution to enable development of source control (catchment management) and use restrictions on PFAS.

Figure 5.10 The overall WFD (cycle 3) classifications for river water body catchments, transitional water bodies and coastal water bodies, within the HyNet project area.

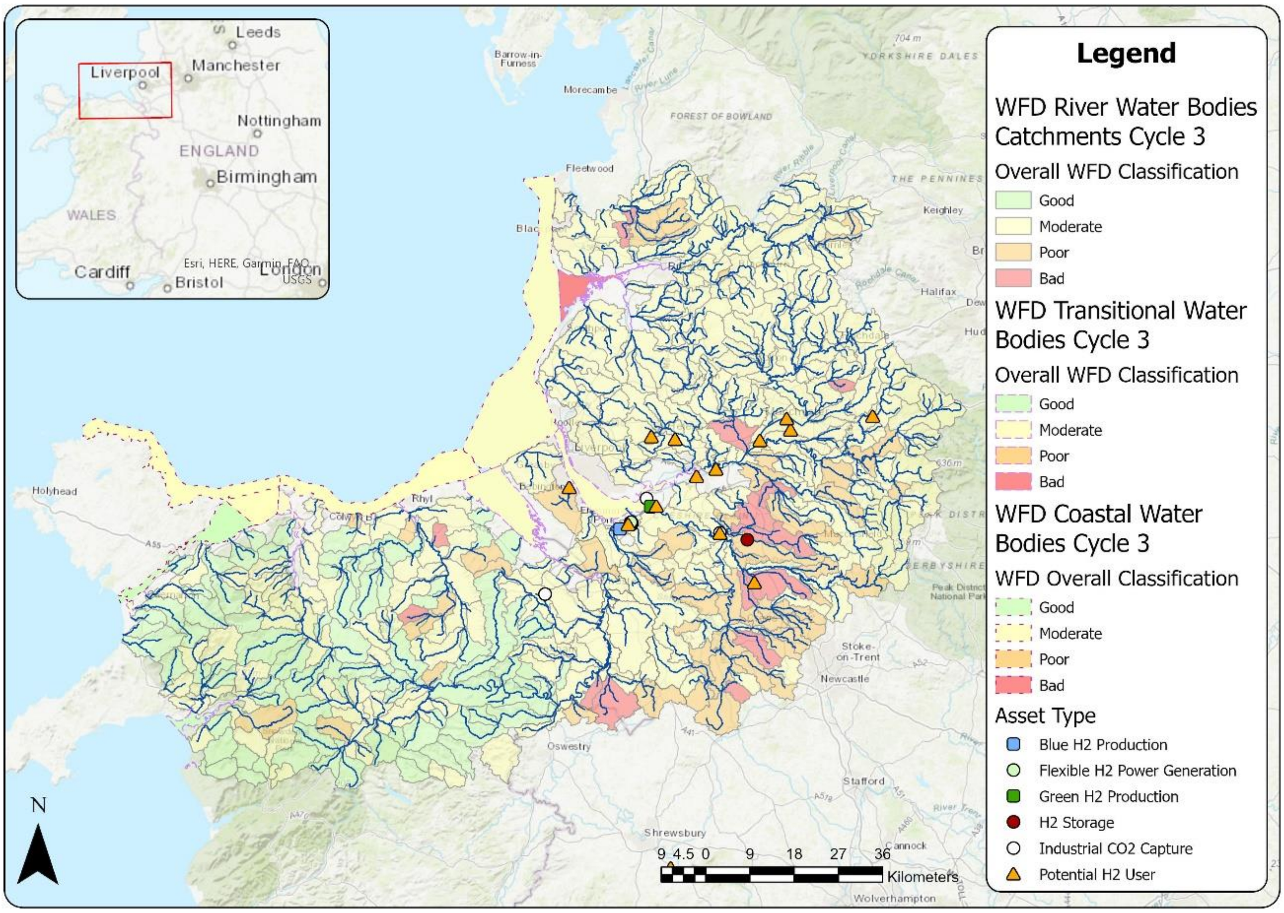
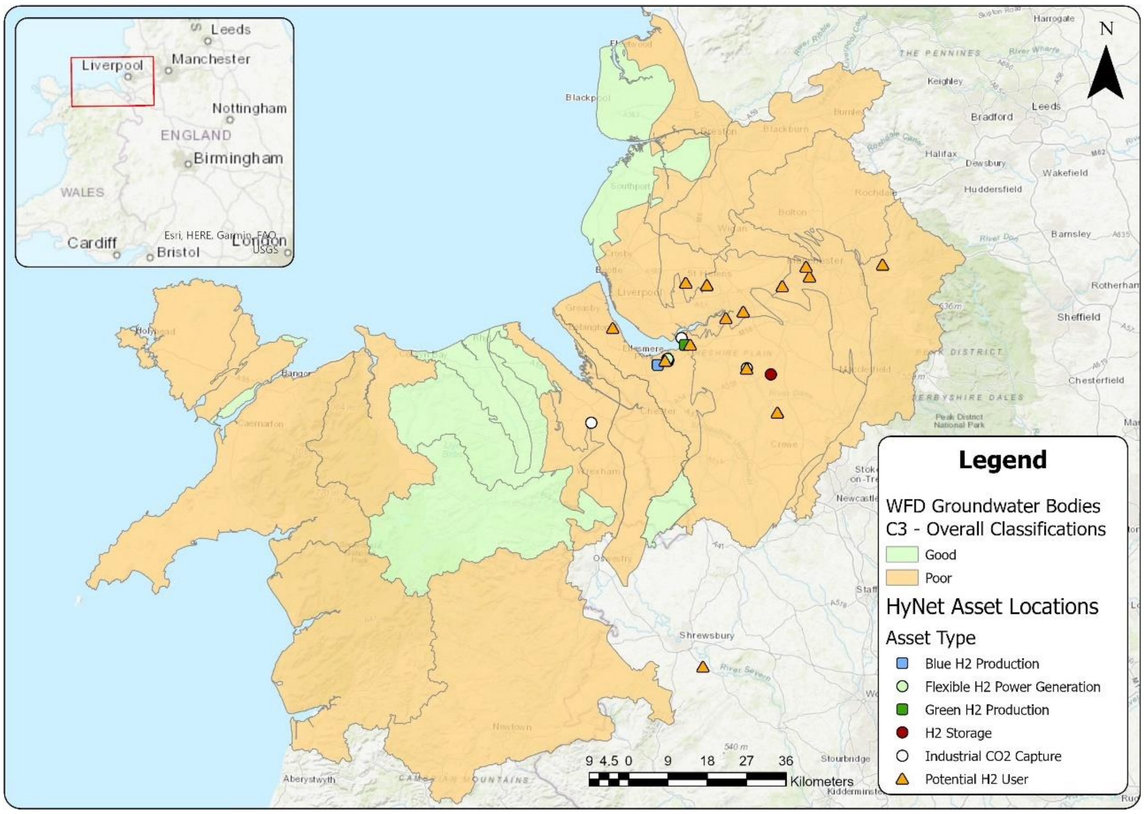


Figure 5.11 shows the current WFD classifications for the groundwater bodies surrounding the HyNet NW region. All the groundwater bodies with future HyNet asset plans are classified as 'poor' due to chemical failures (nitrates, pesticides, and other chemicals) and chemical-dependent surface water bodies. Some of the groundwater contamination can be attributed to surrounding agricultural and rural land management, with further investigations still ongoing. For further

detail on groundwater WFD classifications, RNAG, and objectives, see Appendix C and the ‘evidence baseline’ slides produced for this annex.

Figure 5.11 The overall WFD (cycle 3) classifications for groundwater bodies within the HyNet project area.

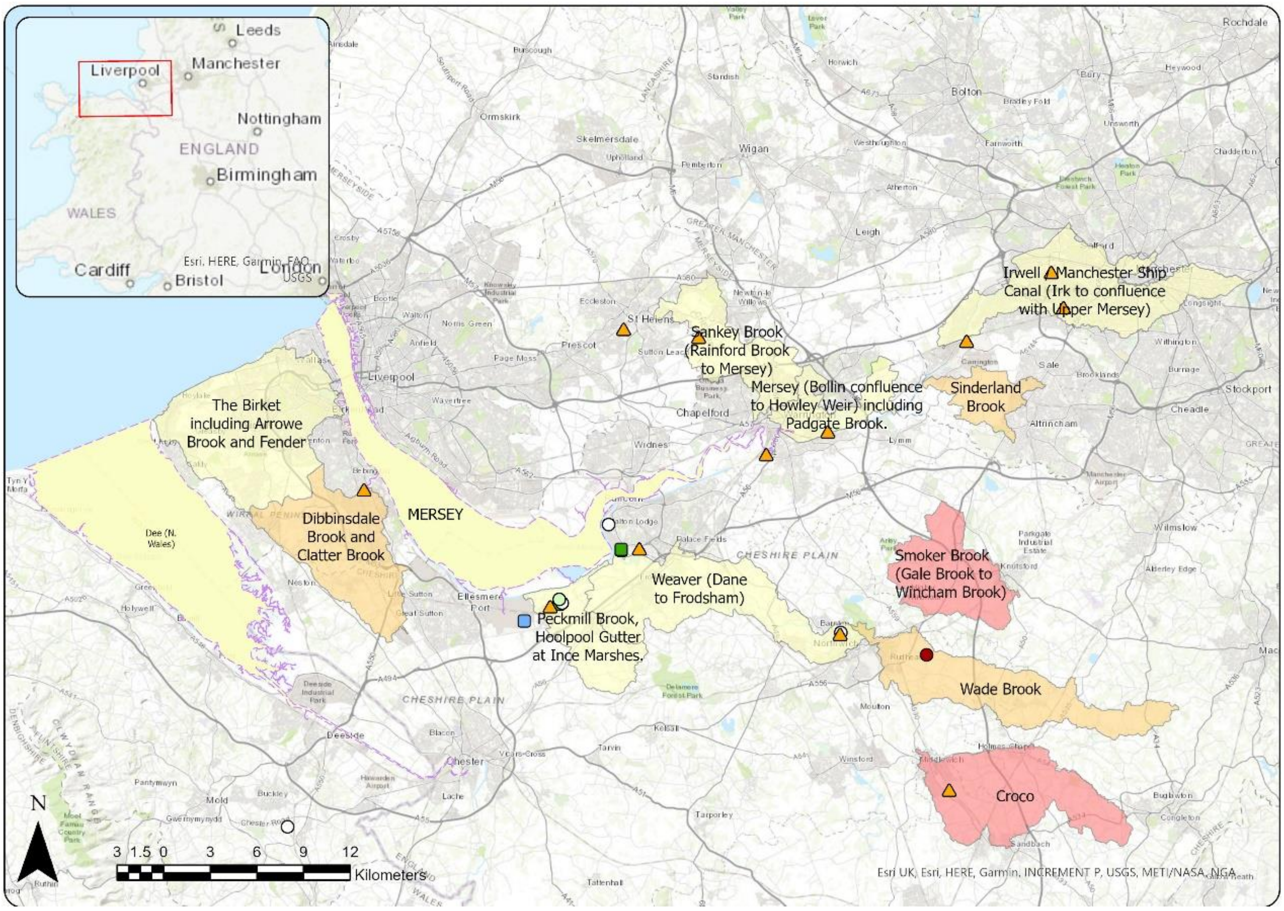


5.2.1 Reasons for WFD failures

A summary of the current water quality challenges for relevant waterbodies in the HyNet NW region are shown in Figure 5.12 and summarised below. For a more detailed breakdown of WFD classifications, RNAG, and objectives for the mentioned waterbodies, please see Appendix C.

Gaps
Following the confirmation of abstraction and discharge points, analysis of additional relevant waterbodies may be included.

Figure 5.12 WFD status of surface water bodies nearest to key developments planned as part of HyNet NW



There are several ongoing water quality challenges contributing to the current 'Moderate' classification of the Mersey Estuary shown in Figure 5.12. Diffuse source contamination from nearby industry continues to exacerbate high concentrations of zinc and tributyltin compounds within the estuarine sediment and associated catchment land. The presence of benzo(g-h-i)perylene, polybrominated diphenyl ethers (PBDE) and mercury compounds within the waterbody also contributes to the failed chemical status. From an ecological perspective, the waterbody remains unsatisfactory for invertebrates and phytoplankton, with high levels of dissolved inorganic nitrogen also reported.

The Manchester Ship Canal is named as a possible saline effluent discharge point for the LCH system. The Manchester Ship Canal has a current WFD classification of 'Moderate'. Sewerage discharge from the water industry, landfill leaching, and pollution from the navigation industry are all contributing to failing levels of tributyltin compounds. Furthermore, mercury compounds and PBDEs are contributing to the chemical failure of the waterbody, although the source of this pollution has not been attributed to any particular industry sector.

As shown in Figure 5.11, the four main groundwater bodies surrounding the Mersey Estuary are:

- Wirral and West Cheshire Permo-Triassic Sandstone Aquifers
- Weaver and Dane Quaternary Sand and Gravel Aquifers
- Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone Aquifers
- Dee Permo-Triassic Sandstone

These are all failing to meet 'Good' WFD standards. The reasons for the 'Poor' groundwater body classifications are generally associated with chemical tests, chemical drinking water protected area legislation, and saline intrusion. The source of these failures has been attributed to poor pesticide and nutrient management in the agricultural industry, along with some failures from the water industry and other stakeholders.

5.3 Designated sites

This section discusses the environmental challenges within the HyNet NW area, including protected and sensitive areas, as well as habitats.

The presence of protected areas/designations may limit what activities can occur in the area. Permits to affect the environment, including abstraction and discharge, may be less likely to be approved, and granted permits will likely be tighter (Environment Agency, 2010), so as not to cause environmental harm (Environment Agency, 2021). Connection to the public sewer network for discharges will likely be encouraged, unless it is unreasonable to do so e.g. too expensive to connect. The Habitats Regulations further require 'competent authorities' to assess and consider the environmental impact of plans and projects on protected habitats sites.

Policy direction appears to be moving towards further protection of designated areas. For example, the UK Government's 25 Year Environment Plan sets out the ambition to restore 75% of terrestrial and freshwater protected sites to favourable condition (Environment Agency, 2021).

5.3.1 Protected sites

Several habitat-specific protection sites exist within the study area. Both the Mersey and Dee estuaries contain SSSI[21], RAMSAR[22] and SPA[23] sites, with the Dee estuary also classed as a SAC[24] (Figure 5.1). These reflect the estuaries' importance to sea birds and wildfowl including little tern, red-throated diver and whooper swan (Environment Agency, 2022) (Defra, 2021). They are also important for smelt, eel, trout and salmon, and are breeding grounds for commercially important fish species.

The assets proximal to the Mersey estuary will likely have tight permits on wastewater discharge quality (if discharged into the Mersey Estuary), or be encouraged to connect to the public sewer network if reasonable to do so.

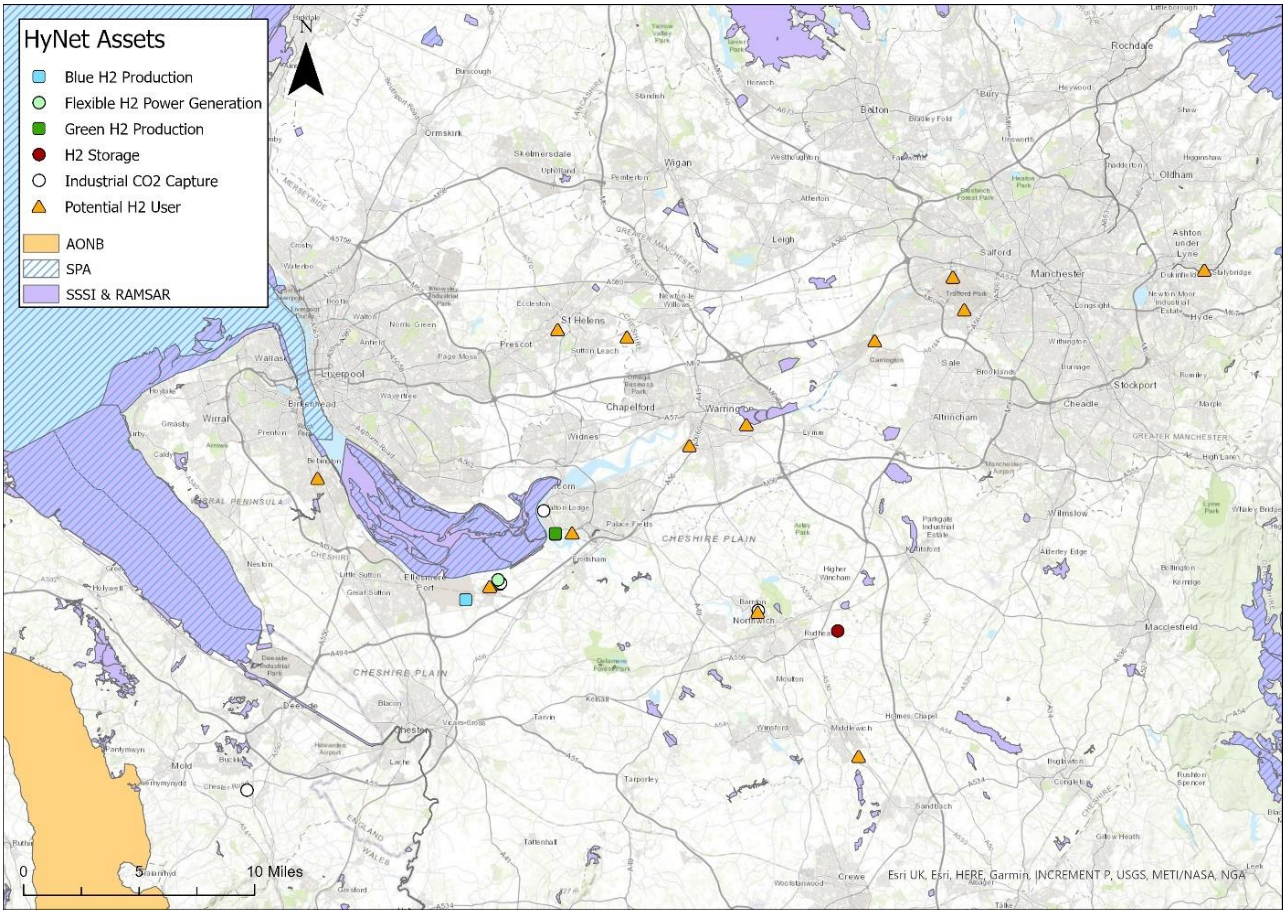
[21] A SSSI is a conservation designation for areas that are considered to represent natural heritage e.g. flora, fauna, geology

[22] RAMSAR is an international designation for wetlands under the Convention on Wetlands, which provides a framework for the conservation and use of wetlands and their resources.

[23] A SPA is a Special Protection Area under the EU's Wild Birds Directive. They are selected to provide protection for one or more rare, threatened, or vulnerable bird species or migratory birds.

[24] A SAC is a Special Area of Conservation under the Conservation of Habitats and Species Regulations 2017 (as amended) in England and Wales and the Conservation of Offshore Marine Habitats and Species Regulations 2017 in the UK offshore area.

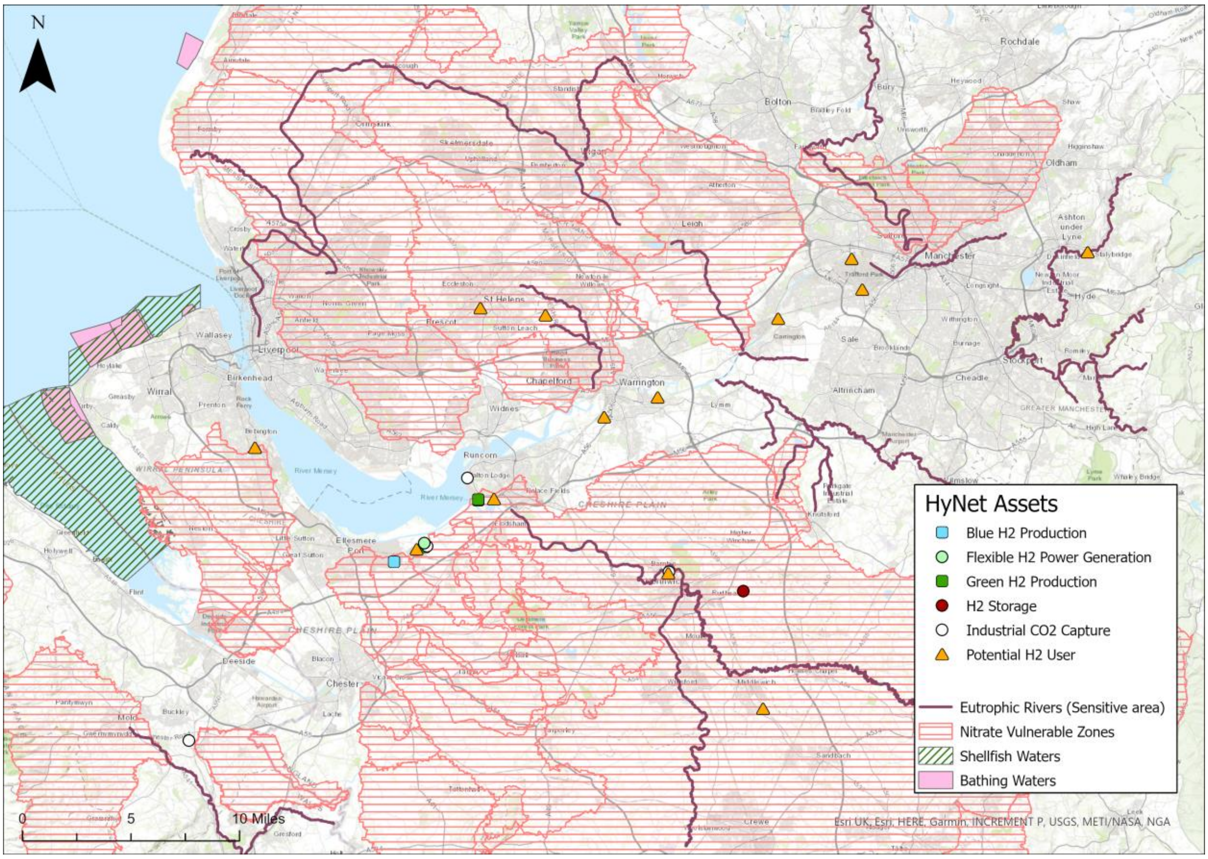
Figure 5.13 AONB, SPA, SSSI, and RAMSAR sites in HyNet NW area



A significant proportion of the study area is within nitrate vulnerable zones (NVZs) (Figure 5.14). These are designated areas that are at risk from agricultural nitrate pollution. Whilst their presence doesn't directly relate to development, HyNet should be mindful of their presence, especially with respect to H_2 production and CO_2 capture that release NO_x in wastewater. Eutrophic rivers are also present within these NVZs. One proposed CO_2 capture location is close to a eutrophic river. Two H_2 users are also close to eutrophic rivers.

Shellfish and bathing waters exist along the northern and western flanks of the Wirral (Figure 5.14). No HyNet assets appear to be in proximity to these areas.

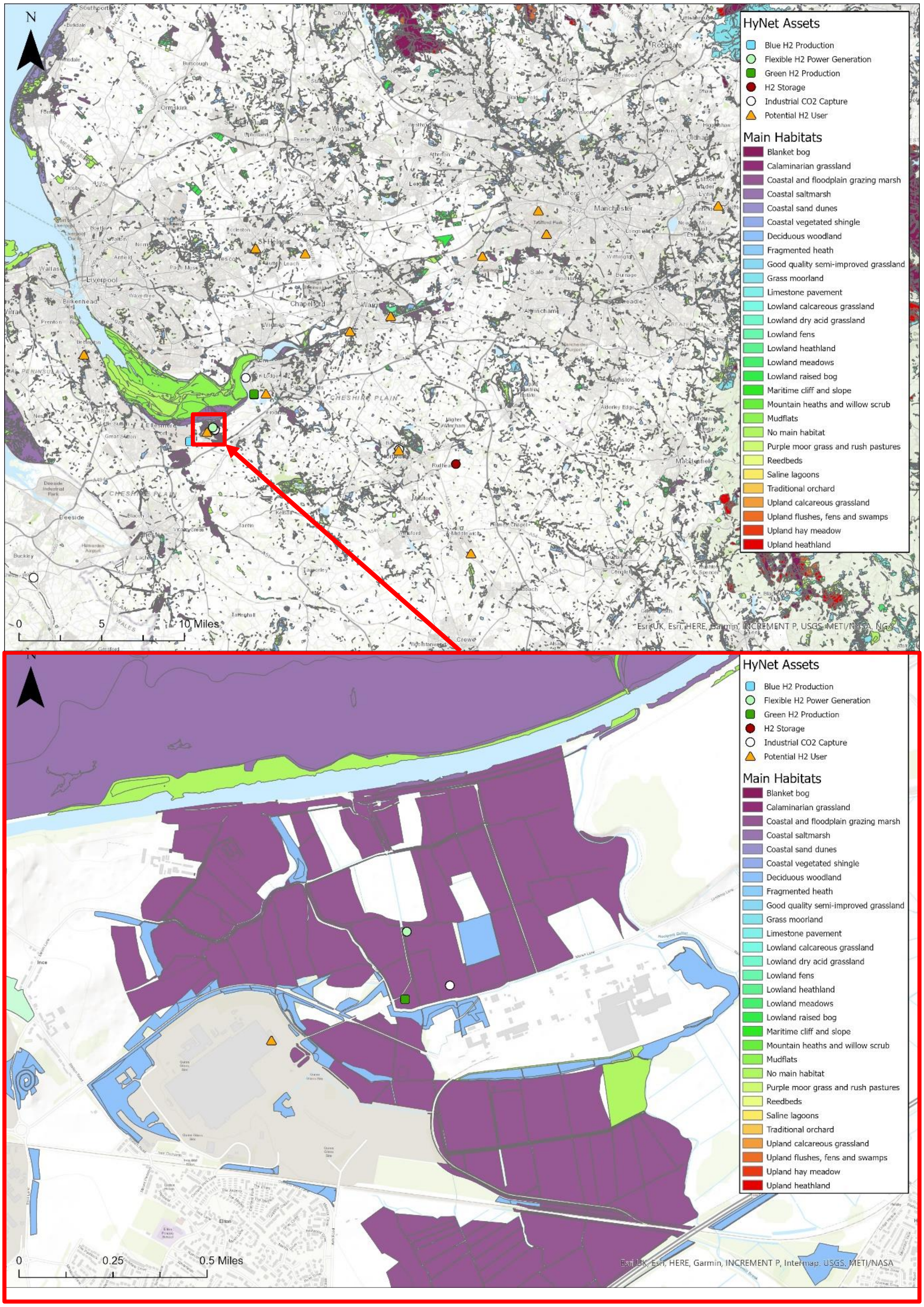
Figure 5.14 Bathing waters, shellfish waters, and NVZ in HyNet NW area



5.3.2 Habitats

Within the Ellesmere Port area, three assets are within coastal and floodplain grazing marsh (Figure 5.15). These are a green H_2 producer, a flexible H_2 producer and an industrial CO_2 capture. All other identified assets appear to be located in developed areas with no identified habitats.

Figure 5.15 Main habitats within the HyNet NW area



5.3.3 Nutrient Pollution

As HyNet could discharge significant volumes of water into neighbouring watercourses or into public sewer networks, it may be necessary to implement measures to control nutrient pollution. Nutrient pollution policy seeks to ensure that new developments do not result in an increase of nutrients entering a waterbody. This is with the aim of reducing the likelihood of deleterious impacts of increased nutrients such as eutrophication and focusses on nitrogen and phosphorus. The nutrient neutrality assessment is to be carried out as part of the Habitat Regulatory Assessment (HRA) in areas where there are unfavourable levels of nitrogen and phosphorus.

Natural England and NRW have indicated that developments near to four Special Areas of Conservation (SAC) in the North-West and North Wales require nutrient assessments (Rankl., F., 2023). The SACs in question are shown in Table 5.2.

Table 5.2 Summary of SACs requiring nutrient assessments near to HyNet NW

Special Area of Conservation (SAC)	Regulator	Neutrality driver
Oak Mere	Natural England	Phosphorus
Rostherne Mere	Natural England	Nitrogen and Phosphorus
West Midlands Mosses	Natural England	Nitrogen and Phosphorus
River Dee and Bala Lake (Wales)	NRW	Phosphorus

6.Future status of the water environment

6.1 Climate change and the HyNet NW area

The most recent UK Climate Projections (UKCP18) were issued by the Met Office in 2018. UK Climate Projections 2018 includes 5 different emissions scenarios, named RCP 2.6, 4.5, 6.0, 8.5 and SRES A1B. WRc have been asked by the EA to concentrate on the RCP8.5 scenario that is characterised by faster rate of temperature change at the end of the 21st Century but slower increases in the near future (Met Office Hadley Centre, 2018).

Gaps

It should be noted that water resources planning focuses upon RCP6.0 with an adaptive pathway for RCP8.5.

The impact of climate change upon PWS has been accounted for by water companies through WRMPs, which were reviewed as part of this annex. UK climate literature and water availability forecasts have been reviewed to further investigate water availability in the HyNet NW area.

Gaps

As future forecasts are uncertain and predictions are generally made at a national level, it was often necessary to consider broad national statements in the local context to assess likely future changes. When interpreting these results it should therefore be noted that while the results below represent the best available knowledge of the likely future, significant deviations from predicted changes and significant local differences to the national picture should not be unexpected.

The Living With Environmental Change (LWEC) Network (since superseded by the Research and Innovation for our Dynamic Environment Forum) has assessed UK climate data in order to assert:

- Likely future weather-related trends.
- The confidence which can be attributed to these assertions.

- The evidence that these trends are caused by man-made climate change (Living With Environmental Change, 2016).

The following confidence level has been associated with statements:

- High (H)
- Medium (M)
- Low (L)

Conclusions from this annex, its supplementary technical reports, the UK Climate Risk Assessment and its supplementary technical reports, and the UK climate projections have been used to assess the potential impacts of climate change in the UK and, where possible, the local HyNet NW area, on environmental water availability in the subsequent subsections. As confidence levels were not reported against statements made in other source documents, this has been indicated by a dash (-).

6.1.1 Precipitation

Precipitation includes any form of water, such as rain, snow, sleet, or hail, that falls to Earth's surface.

National picture

- Under all UKCP18 scenarios, winter precipitation (including rainfall) is expected to increase significantly: over the last fifty years, more winter rainfall has been falling in heavy events, and this will continue (M).
- In contrast, total summer rainfall is expected to decrease, but this rainfall will be more likely to fall as part of storm events (M).
- There is no apparent trend in UK droughts (L). Short droughts may become more frequent (M).

Local picture

- Winter rainfall has increased in the last 50 years in parts of Northern England but this cannot unequivocally be linked to climate change (M). As such, future climate predictions cannot be used to forecast future changes to rainfall.

Impact on water resources at HyNet NW

As overall annual precipitation levels are not expected to change, changes to precipitation may not cause trends in average water availability in the environment. Local patterns and seasonal changes, however, cannot be discounted. The trend towards more precipitation falling within larger events is likely to cause more overland flow resulting in more variability in river levels, particularly in flashy catchments, and could theoretically result in less infiltration and aquifer recharge. The overall result of this could be that water from surface water sources may be available for less of the year as river levels spend more time at low flows before less frequent rainfall events.

6.1.2 Groundwater

National picture

- There are no apparent trends in groundwater levels. (L) suggests an overall decrease in recharge and lower groundwater levels.

- By the 2050s changes in groundwater recharge are projected to range from a 30% reduction to a 20% increase (-). Similarly, seasonal predictions from the UKCEH eFLaG groundwater model (based on UKCP18) indicate that in the near future (2020-2049) there will generally be less groundwater recharge across the UK, particularly in summer, with limited change in winter.

- Seasonal recharge becomes more polarised in the Far Future (2050-2079), with significantly less recharge in summer (-50%) and more recharge in winter (~20%).

Local picture

- Existing studies have focussed on recharge rates on the chalk aquifer in SE England. Other studies included Devonian & Carboniferous limestone in Scotland, but this also is not relevant to the sandstone aquifer under the HyNet NW area. UK studies on Permo-Triassic sandstone are limited in number and restricted to the Midlands.

- Due to the localised behaviour of groundwaters and the low confidence that can be attributed to the case studies, drawing conclusions for the HyNet NW area is challenging. However, it is noted that two of the studies (from 2004 and 2008) predicted annual rechange volumes would decrease by 8-9% by 2020 and 5-21% by 2050 (Jackson, et al., 2016).

- Seasonal predictions for the Near Future (2020-2049) and Far Future (2050-2079) in the HyNet NW area from the UKCEH eFLaG groundwater model are shown in Table 6.1. These predictions are based on UKCP18.

Table 6.1 Short and long-term season predicted changes in the Permo-Triassic Sandstone aquifer below HyNet NW

Season	Near Future (2020-2049)	Far Future (2050-2079)
Spring	-5% to 5%	-5% to 5% -10% to 5%
Summer	-30% to -20%	-50%
Autumn	-5% to 5% -10% to -5% -20% to -10%	-10% to-5% -20% to -10% -30% to-20%
Winter	-5% to 5%	10% to 20%

Impact on water resources at HyNet NW

Gaps

While it was speculated in Section 6.1.1 that the increase in the proportion of precipitation which falls in extreme weather events could affect groundwater recharge, and in Section 6.1.5 that sea-level rises could increase the risk of saline intrusion, resulting in more restrictions being required on groundwater sources to maintain water quality, there is currently no quantitative evidence by which to assert that future groundwater availability at HyNet NW would deviate from current levels (after accounting for current trends).

6.1.3 River flow

National picture

- High river flows and flooding are expected to increase over the century. Changes in UK river flows have not been attributed to anthropogenic climate change; there are periods of high and low flows throughout the UK record (M).

- High winter river flows have increased over the last 30 years (M).

- There is no strong or consistent evidence for decreases in low flows (M).

- Q95 flows in England are forecast to reduce by up to 20% by the mid-century in a 2°C world (-). In a 4°C world, this reduction increases (up to 30% flow reduction) in some areas, such as Wales, the Severn and Tweed river basins (HR Wallingford, 2020).

- Figure 6.1 and Figure 6.2 illustrate potential changes to Q90 flows in the near term (2020-49) and long term (2050 to 79) when using the GR6J model. However, there is variability in these estimates between different models used. For example, the range in Q90 flows from models GR4J, GR6J, G2G and PDM at station Dane at Rudheath in the near term is 0.59 m^3/s to 1.33 m^3/s, and in the long term is 0.35 m^3/s to 1.20 m^3/s (UKCEH, 2023).

Figure 6.1 Transient low flows Q90 2020-2049 (UKCEH, 2023)

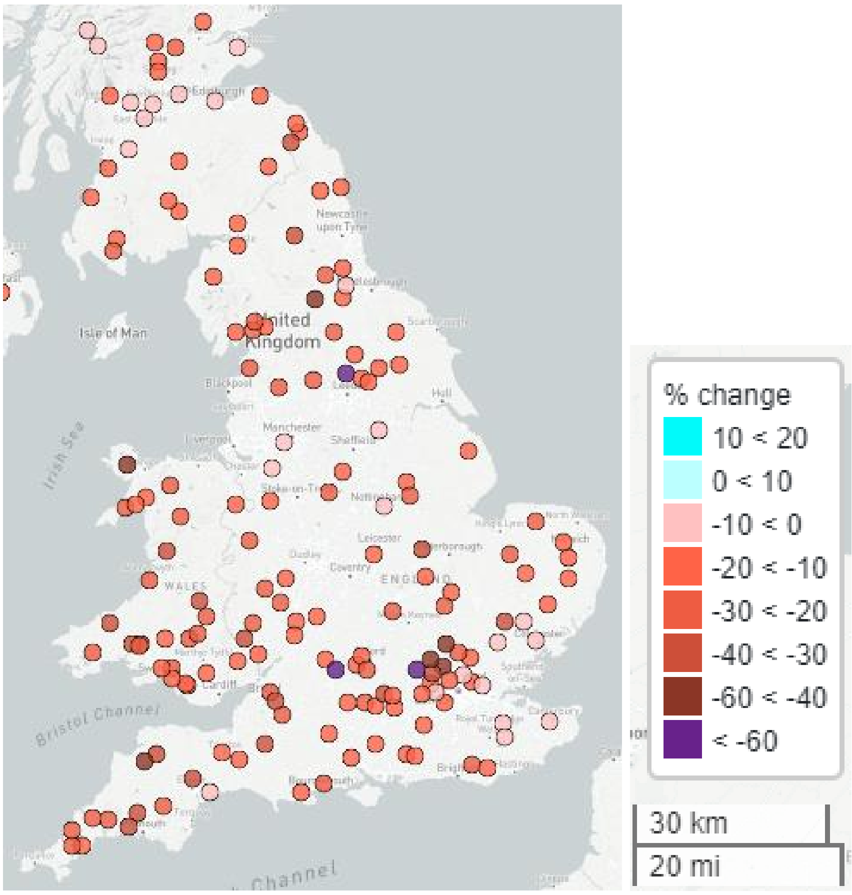
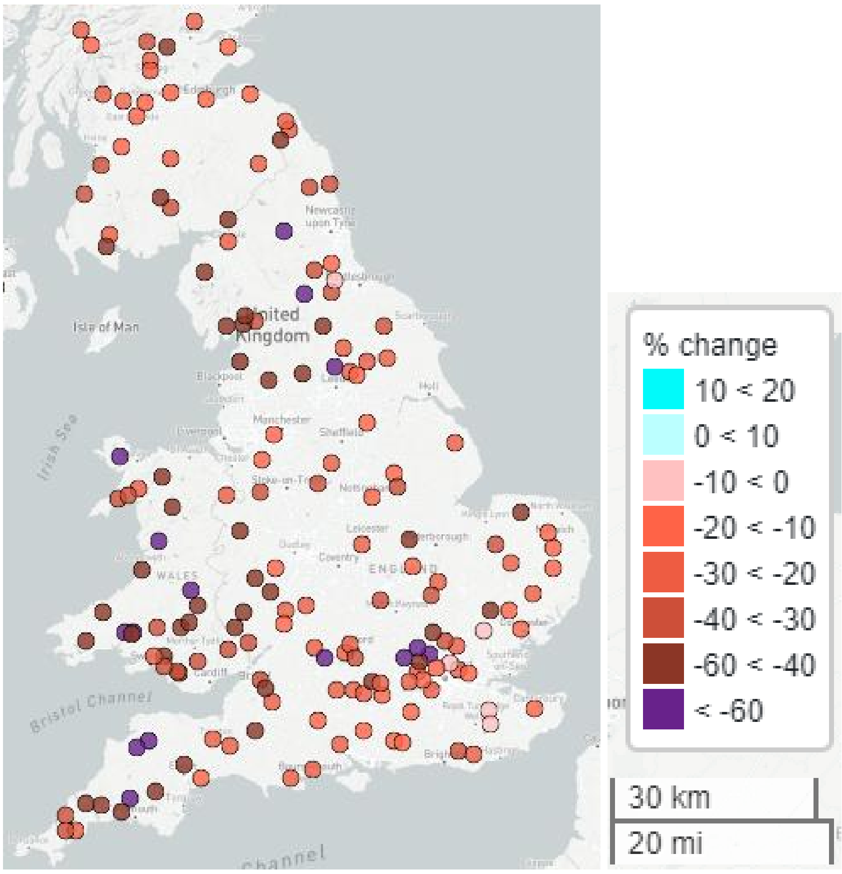


Figure 6.2 Transient low flows Q90 2050-2079 (UKCEH, 2023)



Local picture

- Winter flows have increased in some western catchments, but these have generally been upland areas that are not immediately adjacent to HyNet NW assets (-).

- There has been an increase in the frequency and size of floods in the west and north of the UK (-).

- Winter runoff has increased in 'parts of northern and western England' since the 1960s (Hannaford, 2016), especially in upland, strongly maritime-influenced parts of the UK. While close to the coast, HyNet NW is not in an upland area (-).

- Longer records suggest that winter runoff has increased in some northern and western catchments over the twentieth century, but the trends are generally weaker than for the post-1960 period (-).

- Spring runoff has increased in northern and western areas, and decreased across the English lowlands since the 1960s, but trends were fairly weak. However, the post-1960s decreases are not representative of longer term trends (-).

- In northern and western areas it appears the duration and magnitude of high flows has been increasing since the 1960s. The longer term trend is also upward, but at a lower rate (-).

Impact on water resources

While there is limited evidence linking climate change impacts to low flows, modelling performed by HR Wallingford suggests that overall environmental flows might not be able to be sustained in the future in many of the catchments across England without additional discharges to the river network (HR Wallingford, 2020). Based on the above local trends, it might be speculated that this statement would apply to the HyNet NW area. Overall, the river flow trends are consistent with the precipitation trends in Section 6.1.1 whereby winter runoff is increasing leading to higher and more prolonged high flows. While there is limited evidence for reductions in low flows, the potential impact of droughts and less frequent rainfall should be considered in future planning, in addition to any potential decreases in river discharges.

6.1.4 Evapotranspiration

Evapotranspiration is the combined processes of evaporation, transpiration and – rarely – sublimation of water from the Earth's surface into the atmosphere. It is therefore a function of air temperature, water temperature, water surface area, and humidity.

National picture

- There is no trend in evapotranspiration (L).

- However, it is likely to increase over next 75 years (M).

- All of the UK’s ten warmest years have occurred since 1990 (H).

- Temperatures will increase across the UK over next 75 years, with greatest changes in summer (H).

Local picture

Gaps

No local knowledge has been identified.

Impact on water resources

Gaps

Knowledge in this area seems to be limited.

Increases in evapotranspiration would decrease surface water availability, particularly exacerbating low flows during summer droughts. As the lack of current trend is only known to low confidence, and future temperatures are expected to increase, particularly at a higher rate towards the 2080 time horizon under RCP8.5, the potential future impacts of increases in evapotranspiration should be considered then assessing future water availability.

6.1.5 Other

Demand

National picture

- The demand for water has changed little over the last decade, but demand for water will increase over the next 75 years (H).

Local picture

The most relevant, although somewhat dated, assessment of weather-demand relationships was found to be a 2013 UKWIR report (RPS Environmental Management Limited, 2013). The study combined case studies with UKCP09 climate projections to derive estimate of impact of climate change on water demand by UK region. The study utilised *per capita* consumption data from Thames Water and Severn Trent Water's household consumption monitors to fit two models. This is shown for the areas most relevant to HyNet NW, and for the whole of England, in Table 6.2. Severn Trent Water used these relationships to estimate that across the SVT region there will be an increase in demand by up to 24% when temperatures get over 26°C. With climate change the frequency, intensity and duration of hot weather periods is likely to increase (Severn Trent Water, 2023).

Table 6.2. shows median percentage increases in demand at annual average levels, Minimum Deployable Output[25] (MDO) and Critical Period[26] (CP) demand. The average across the two models is shown in bold.

Table 6.2 Range of percentage change in household demand metrics as a result of climate change in 2040 relative to a 2012 baseline

River basin	Median percentage change at annual average demand relative to 2012	Median percentage change at MDO demand relative to 2012	Median percentage change at CP demand relative to 2012
North West England	0.47-0.74 **0.61**	0.91-1.43 **1.17**	1.56-2.02 **1.79**
Dee	0.50-0.79 **0.65**	0.97-1.53 **1.25**	1.40-1.96 **1.68**
England	0.5-0.8 **0.65**	1.1-1.6 **1.35**	1.7-2.1 **1.9**

A rough indication of impacts by 2030, 2050 and 2070 have been calculated by linear extrapolation of these results in. It should be noted that there is no reason to believe that the behaviour will be linear.

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[25] the period of prolonged dry weather when the deployable output of water resources is at its minimum

[26] average water demand in a 'critical period' as defined within a water company's water resource planning

Regarding non-household demand, the study concluded that, with the exception of agriculture and horticulture in Kent, there is insufficient evidence to demonstrate a link between climate change and demand.

Table 6.3 Estimated percentage change in household demand metrics as a result of climate change in 2030, 2050, and 2080 relative to a 2012 baseline

Basin	Median percentile change at annual average percentage increase relative to 2012	Median percentage change at MDO demand relative to 2012	Median percentage change at CP demand relative to 2012
2030			
North West England	0.39	0.75	1.15
Dee	0.41	0.80	1.08
England	0.4	0.9	1.2
2050			
North West England	0.82	1.59	2.43
Dee	0.88	1.70	2.28
England	0.9	1.8	2.6
2080			
North West England	1.47	2.84	4.35
Dee	1.57	3.04	4.08
England	1.6	3.3	4.6

Predicted increases in household demand are therefore small and are likely to be insignificant when compared to likely increases in non-household use and changes in water availability. As a limited time period was used to train these models, and due to other factors causing year-to-year variations, the models did not identify an annual reduction in PCC driven by demand-side factors, leakage, or other non-weather related variables. It could be argued that there will be greater impetus in the future, and has been in the years following these studies, on leakage reduction and demand reduction which may act to counteract these effects. However, a key recommendation of the study was also that further research should be performed on how customer demand would change under a climate change scenario. It should be noted that some behaviour, such as outdoor water use, could increase under a changed climate.

Impact on water resources

The volume of water in the environment is the balance between supply (precipitation and environmental flows, discharges, and transfers) and demand (abstractions, environmental water use, and evapotranspiration). The majority of water which is abstracted will also be discharged (although not necessarily to the same source or location). As such, it should also be considered how discharges might change under future demand changes. This is particularly important for surface waters where discharges are important to supplement environmental flows. While the reliance of rivers in the study catchments on discharges is unknown, we do know that many of the rivers are discharge rich.

Gaps

We currently have limited knowledge regarding the reliance of key water bodies on discharges. We also do not know how much water is currently being used by the industrial users in the HyNet area and how this might change in the future.

Sea level rises

National picture

- Sea-level rise is predicted at all locations around the UK but will generally be greater in the South of the UK. This increase in mean levels is also expected to drive changes in extreme low and high levels (-).

- Sea level around the UK rose by 1 to 2 mm per year during the 20th century, and by 3 mm per year in the last decade. (H)

- Sea level rise is already affecting UK estuaries. Estuaries will (high confidence) be at increasing risk from floods. Sea level will (high confidence) rise by between 0.4 and 1 m by 2100 (H).

Local picture

The HyNet NW is not coastal but is sufficiently close to the Irish Sea that it may be affected by rising sea levels.

Impact on water resources

While sea levels do not affect water availability from surface and groundwaters directly, they do have indirect impacts through the mitigating measures which may need to be imposed. These include addressing the increased risk of saline intrusion into aquifers (increased head and surface area) and flood prevention measures which may alter the environment in ways that affect environmental flows.

6.2 Assessment of future water requirements and availability

6.2.1 Public water supply

Water companies account for the impact of climate change in their Water Resources Management Plan (WRMP) process. Preferred plans for companies in the HyNet NW region have based these on RCP 6.0 with the exception of HD whose preferred plan is based on RCP8.5 (planned adaptive pathways do however include RCP6.0).

Table 6.4 shows forecasted surplus for the five WRZs this annex has focused upon, although these values are largely dependent upon demand management options.

Abstraction reductions and actions required to protect the environment impact the public water companies. The water available for use (WAFU) impacts of these actions are summarised in Table 6.5. UU and SVT have applied the BAU+ environmental destination scenario (i.e. regulatory approach remains unchanged and European protected sites get sufficient water) to their supply demand balance (results shown in

Table 6.4). The environmental destination reductions are not applicable to HD or DCWW as these supply areas of Wales rather than England. Further impact of abstraction reductions cannot be determined by these tables given the different spatial extents.

Table 6.4 Dry Year Annual Average (DYAA) surplus/deficit in WRZs relevant for the HyNet NW network based on (revised) dWRMP24 final plans

WRZ	Company	Surplus/deficit in 2030/31 (ML/d)	Surplus/deficit in 2050/51 (ML/d)	Surplus/deficit in 2080/81 (ML/d)
Strategic	UU	24.8	129.8	36.5
Chester	SVT	2.8	3.9	1.21
Saltney	HD	1.81	2.17	2.28
Wrexham	HD	4.34	10.18	8.63
Alwen Dee	DCWW	9.39	17.55	16.74

Table 6.5 Total impact on water available for use as a result of combined licenced abstraction reductions due to shorter term regulatory needs and longer term environmental destination needs (Water Resources West, 2022)

Scenario	Reduction in water available for use by the end of 2050 (Ml/d)					
	United Utilities	Severn Trent	Welsh Water	South Staffs	Hafren Dyfrdwy	Total
Low	131	338	n/a	48	n/a	517
BAU+	131	442	n/a	48	n/a	621
Enhanced	133	471	n/a	60	n/a	664

United Utilities

A deficit has been forecast for UU's Strategic WRZ across the short, medium, and long terms, as per the baseline dry year annual average (DYAA) scenario caused by the requirement for increased drought resilience (United Utilities, 2023). UU will resolve this deficit primarily through demand management options, halving leakage and reducing customer consumption to 110 l/p/d by 2050. In addition, their preferred plan includes the development of 3 new groundwater sources by 2030 in the Strategic WRZ, providing an additional 22 ML/d. The preferred plan is based on RCP6.0, with an adaptive plan for RCP 8.5.

Additional new supplies from surface and groundwater are proposed after 2040 as part of the adaptive pathways summarised in Figure 6.3, including new surface water abstractions from the River Irwell, a major tributary of the River

Mersey, which supplies water to the Manchester Ship Canal. The Water Resources Wales (WRW) draft regional plan outlines a new surface water abstraction from the River Irwell, known as WAFU, with an operational date set for 2031. Additionally, the WRW draft regional plan specifies transfers from United Utilities shown in Table 6.6.

UU sponsors the North West Transfer (NWT) Strategic Resource Option (SRO) which supports the Severn to Thames Transfer (STT) SRO, a potential transfer of up to 180 ML/d of raw water from Lake Vyrnwy into the River Severn and to the South East. Notably, the STT SRO is not part of the preferred plan in revised draft WRMP24s and the revised draft Water Resources South East (WRSE) regional plan.

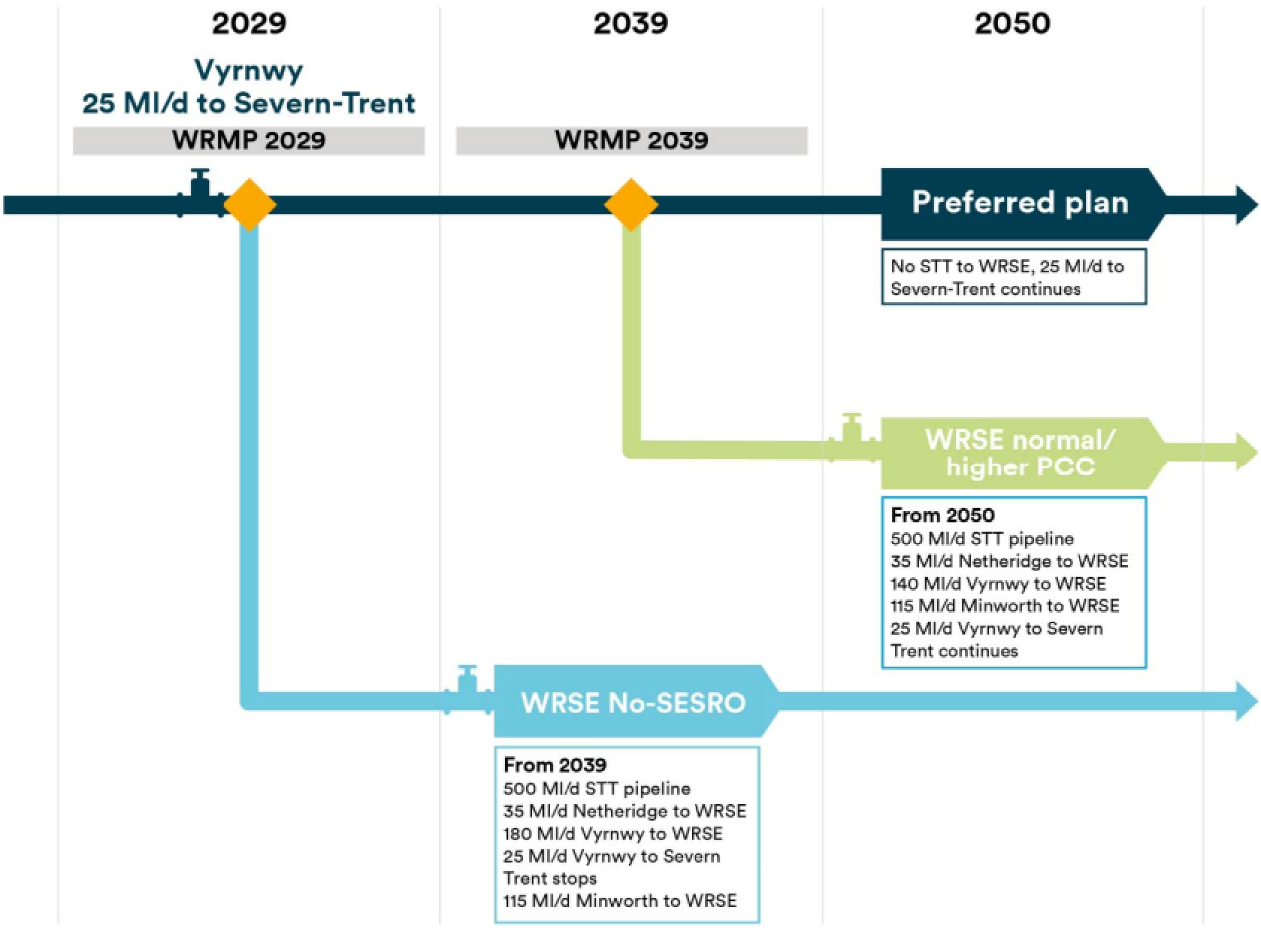
A 25 ML/d transfer from Lake Vyrnwy to Severn Trent Water remains in the preferred plan, and there are substantial uncertainties surrounding WRSE's regional plan, suggesting that water from STT SRO, and consequently NWT SRO, may still be necessary. Figure 6.3 illustrates adaptive planning based on WRSE regional plan decisions, where the "No SESRO" adaptive plan pathway includes a total United Utilities export of 180 ML/d from Vyrnwy, and the higher demand pathway has a total export of 165 ML/d from Vyrnwy.

Table 6.6 UU exports selected in WRW's draft best value plan (Water Resources West, 2022)

Receiving WRZ	Option name	Maximum WAFU (ML/d)	Operational Year
Kinsall	Kinsall additional resource (United Utilities import)	1	2062
Strategic Grid	North West Transfer: Vyrnwy	68	2030
Shelton	Import from United Utilities from Llanforda to Shelton (large)	25	2040
North Staffs	United Utilities Mow Cop borehole treated	2	2050

Receiving WRZ	Option name	Maximum WAFU (ML/d)	Operational Year
	water export		
North Staffs	United Utilities Bearstone treated water export	1	2050

Figure 6.3 High-level overview of WRW-WRSE regional reconciliation outcome and our adaptive pathways (United Utilities, 2023)



Severn Trent Water

According to the dWRMP24 forecast, the Chester Water Resource Zone (WRZ) has a surplus in the short and mid-term, but it is projected to enter a deficit in the long term under the baseline DYAA scenario without any demand management or supply side options (Severn Trent Water, 2023). This deficit is primarily attributed to abstraction license capping and the sustained environmental pressure on groundwater resources. The resolution of this deficit is achievable through demand management measures including halving leakage by 2045 and reducing PCC. However, there are some supply options in other WRZs that may have an impact on the HyNet area. The supply options for SVT's preferred plan, outlined in Figure 6.4, includes a new surface water abstraction (20 ML/d) from the River Weaver near Nantwich.

Strategic Resource Options (SROs) that STV are involved with are the Grand Union Canal transfer (up to 100 ML/d, selected for first utilization in 2031), the Severn to Thames Transfer (no longer part of WRSE preferred plan), and the Upper Derwent Valley Reservoir Expansion (up to 60 ML/d additional WAFU, operational date 2050). These SROs interact with the water resources plans for Water Resources South East and Water Resources North, but their impact on water availability for HyNet NW remains unclear.

SVT's preferred water resources program is based on the RCP6.0, with the adaptive pathway AP4 accounting for climate adjustments in consideration of RCP 8.5. AP4 is triggered by the scale and pace of climate impacts, with the potential trigger year set at 2028. Adjustments to the plan may require an additional 300 ML/d.

Gaps

From the literature, is has not been possible clearly identify impacts to HyNet NW.

Figure 6.4 SVT's preferred water resources programme (Severn Trent Water, 2023b)

AMP 8		AMP 9		AMP 10		AMP 11		AMP 12 and beyond	
Trimpley DO recovery	4Ml/d	Import to Mardy	1Ml/d	UU import to Shelton WTW	25Ml/d	West Midlands Quarry	-	West Midlands Quarry	33Ml/d
Whitacre DO recovery	4Ml/d	Terminate DV export to YKS	35Ml/d	Raise Tittesworth	-	Raise Tittesworth	-	Raise Tittesworth	14Ml/d
Expand Shelton	12Ml/d	Derwent Valley Storage Increase	-	Derwent Valley Storage Increase	-	Derwent Valley Storage Increase	-	Derwent Valley Storage Increase	60Ml/d
Carsington to Tittesworth	30Ml/d*	New WTW near Stafford	-	New WTW near Stafford	-	New WTW near Stafford	23Ml/d	Milton groundwater source	5Ml/d
Transfers from Grid to Notts (Heathy Lea)	37Ml/d*					Third Party Reservoir and new WTW's	-	Third Party Reservoir and new WTW's	18Ml/d
Homesford expansion	5Ml/d					River Weaver new WTW	-	River Weaver new WTW	20Ml/d
Expand Strensham WTW	15Ml/d					New River Trent WTW at Notts	-	New River Trent WTW at Notts	30Ml/d
Little Eaton DO recovery	5Ml/d					East Midlands Quarry	-	East Midlands Quarry	24Ml/d
Draycote Reservoir expansion	9Ml/d					New groundwater near Soar	-	New groundwater near Soar	5Ml/d
UU Vyrnwy release to River Severn	23Ml/d					Ogston expansion	15Ml/d	Hampton Loade to Nurton	12Ml/d*
								Imports from UU to North Staffs	8Ml/d
								Draycote DO recovery	4Ml/d
								Elmhurst new borehole	2Ml/d
								Transfers from Grid to Notts (Ambergate)	30Ml/d
								Bham to Wolves link	32Ml/d*
								Dam extensions at Whitacre, Stanford, Shustoke	9Ml/d
								Ruyton support link main	1Ml/d
								Oldbury to Meriden	15Ml/d
								UU import to Kinsall	1Ml/d
								Blackbrook Reservoir	8Ml/d
								Campion Hills DO recovery	2Ml/d
								East Midlands Quarry	45Ml/d
								Carsington expansion	110Ml/d
								Carsington to Tittesworth phase 2	16Ml/d*
Total	144Ml/d	Total	36Ml/d	Total	25Ml/d	Total	38Ml/d	Total	504Ml/d

(These are internal transfers and the Ml/d shows the maximum expected utilisation in the planning period)*

Hafren Dyfrdwy

In the dWRMP24 baseline DYAA scenario, both the Saltney Water Resource Zone (WRZ) and the Wrexham WRZ are projected to have surplus water in the short, mid, and long term future, assuming no implementation of demand management or supply-side options (Hafren Dyfrdwy, 2023). HD intends to apply demand management targets across the supply area, leading to a further increase in surplus water that gradually diminishes in the long term due to the influence of climate change.

HD has set ambitious leakage reduction goals, targeting a 10% reduction by 2030 and an extensive 50% reduction from 2019/20 levels by 2050. Additionally, the company aims to assist customers in minimizing water usage, and specify that while they will aim to comply with national targets, they have identified 118 l/p/d by 2050 as a more realistic yet ambitious aim. Notably, Saltney WRZ already falls below the PCC target (Hafren Dyfrdwy, 2023).

Given that Saltney imports water, the existing agreement is expected to be honoured, resulting in a minimal assessment conducted by HD. There is a small supply surplus in all zones under the most extreme climate change scenario. Following discussions with neighbouring companies (Dŵr Cymru Welsh Water, United Utilities, and Severn Trent), it has been determined that these small surpluses are insufficient to facilitate a viable water transfer. A reassessment of the position is planned in five years as part of the water resources management plan cycle.

Furthermore, Hafren Dyfrdwy owns and operates two large dams at Clywedog reservoir and Lake Vyrnwy, whose abstraction licenses are controlled by the Environment Agency and United Utilities, respectively, to supply large areas of the Midlands and northern England. Lake Vyrnwy is already part of the United Utilities-driven Strategic Resource Option. As a key member of the River Severn Working Group, the company is actively involved in ensuring that any new releases from the bottom of the dam do not cause environmental harm.

Presently, there are no planned abstraction reductions by Natural Resources Wales (NRW), and water companies are expected to collaborate with stakeholders to ensure sufficient water availability. However, this remains an area of uncertainty, as NRW may implement reductions in the future.

It is noted in the revised dWRMP24 that Saltney WRZ is assessed as having low vulnerability to climate change and resilience to a 1 in 500-year drought by 2030. Similarly, Wrexham WRZ is assessed as having low vulnerability to climate change, remaining in surplus even under a 1 in 500-year drought scenario by 2030. However, by 2070, Wrexham's water supply could potentially be reduced by around 20% under the most severe climate change-impacted drought scenario.

Dŵr Cymru Welsh Water

DCWW have three WRRZs that go into deficit under the dWRMP24's baseline DYAA scenario (Dŵr Cymru Welsh Water, 2023). Alwen Dee WRZ is not one of these WRZs nor is it clear how it would be impacted. DCWW is committed to 10% reduction in leakage by 2030 and 50% reduction by 2050, as well as a reduction in PCC to 110 l/p/d. These demand management measures increase the amount of surplus in the Alwen Dee WRZ.

There are currently no planned water trading activities for Alwen Dee WRZ, but there is a potential for water transfer to Clwyd Coastal Water Resource Zone (WRZ) of up to 1.5 ML/d as part of the high emissions adaptive pathway. Notably, Natural Resources Wales (NRW) has not proposed specific abstraction reduction targets for this planning round, emphasizing a holistic approach to catchments across the country.

In 2021, Dŵr Cymru Welsh Water decided not to promote trading water with neighbouring companies due to an inability to demonstrate a significant benefit to their customers. This decision was based on a scalable water trading option (50–100 ML/d) utilising existing, disused, or under-used sources in the SEWCUS water resource zone in South Wales. This would enable the water currently abstracted from the River Wye to be transferred to either Severn Trent Water (STW) or to South-east England via a proposed Severn to Thames Transfer (STT) link main, which is not currently planned until 2040. Although this trading option is not being considered in the current planning cycle, Dŵr Cymru Welsh Water commits to ongoing collaboration with the Water Resources West regional group and neighbouring companies to reassess this position in the future.

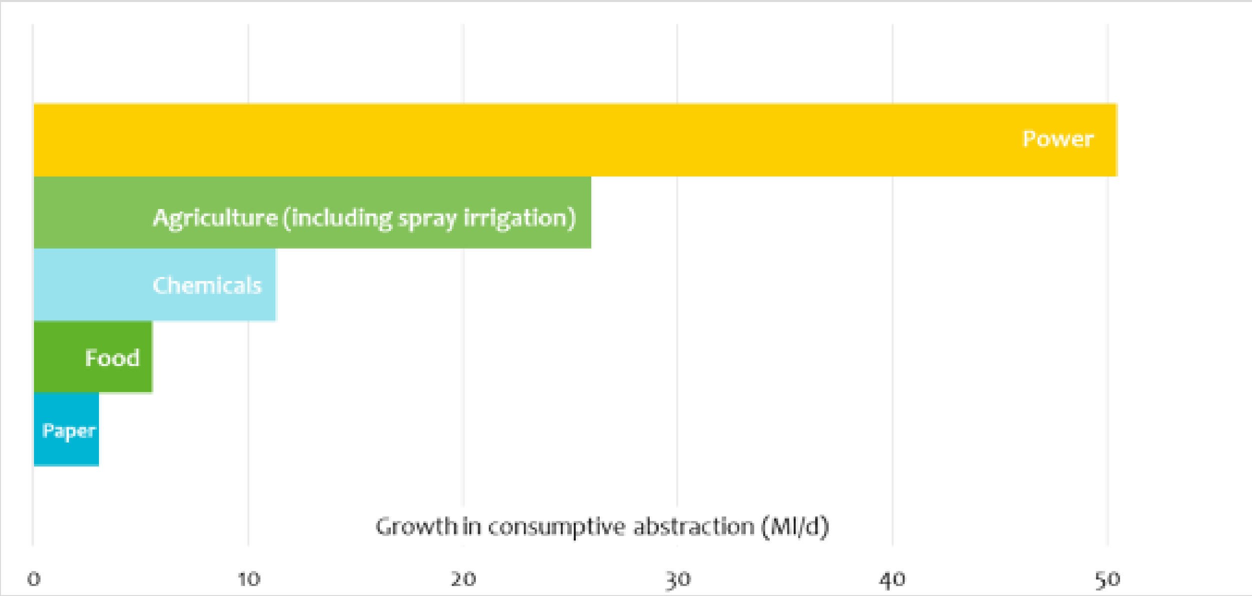
6.2.2 Non-public water supply

Overall, the National Framework for Water Resources (Environment Agency, 2020) concludes that current resilience to drought of sectors outside public water supply is far less well understood than the resilience of public water supply. There are significant regional variations in terms of water usage for non-public water supply due to differences in land use and the local economy.

Modelling future changes in sector productivity, location and water demand is highly complex meaning that producing forecasts and estimates is challenging. Across all the examined in detail in the National Framework for Water Resources, the potential increase in demand from non-PWS sectors appears to remain less than the overall volume currently licensed for abstraction on a national level. This implies that there is sufficient water to meet future demands, but it does not necessarily mean that sufficient water is available when and where it is required. Consumptive water use associated with carbon capture and storage (CCS) is likely to be between 1.45 and 1.9 times higher than thermoelectric generation without it. In particular, it notes that under high adoption of CCS, demand for water could exceed the volume licensed for abstraction at existing sites in the north west.

WRW's non-PWS consumptive use forecast indicates a necessity for approximately 97 ML/d of additional water, distributed across different sectors as shown in Figure 6.5. The increase from current needs (334 ML/d) to the projected demands by 2050 (430 ML/d) is influenced by anticipated growth, calculated using national (EA/Defra) factors for most sectors.

Figure 6.5 Projected growth to 2050 in non-public water supply abstraction by sector for WRW region (Water Resources West, 2022)



Gaps

There is a lack of information available for future water requirements for navigations, posing a significant risk to interpretation of future water availability in the WRW region where there are significant navigation requirements.

Within the WRW area, a potential reduction in abstraction of 16 ML/d will be required from industry (in addition to 259 ML/d from water used for public supply) by 2050 relative to business as usual. Under the 'enhanced' scenario which sees greater environmental protection for protected areas, the requirement for public supply increases to 296 ML/d (Environment Agency, 2020).

6.2.3 Environment

A key consideration when evaluating environmental water needs is the policy adopted and objectives to be met. For example, there are significant differences between a policy of 'no further deterioration', 'net environmental gain', or environmental improvement such as increased protection of special areas and meeting 'Good' WFD status. The National Framework for Water Resources (Environment Agency, 2020) presents three scenarios:

- **Business as usual**: regulatory approach remains unchanged, such as percentages of natural flows.

- **Enhanced**: greater environmental protection for protected areas.

- **Adapt**: reducing the level of protection in less sensitive or modified water bodies.

In cases where the policy is to keep the environmental flows fixed at the same absolute volume, numerous catchments throughout England and Wales face challenges in fulfilling their environmental flow needs unless additional discharges are introduced to the river network (HR Wallingford, 2020). Catchments particularly susceptible to inadequate available resources, meaning they cannot meet the stipulated fixed volume environmental flow requirement, are predominantly situated along the west coast of Great Britain. This is where the most significant reductions in low flows are typically observed.

The EA is enforcing abstraction reductions to increase sustainability and improve the environment, these are planned to come into force in the short-term future. NRW has not stated that they plan to enforce abstraction reductions, instead they expect stakeholders to work together to promote the environmental health of an area (Dŵr Cymru Welsh Water, 2023). However, this does not mean that NRW will not introduce abstraction reductions in the future, instead it is an additional uncertainty. The English approach to environmental destination is also very different, focussing primarily on reductions in abstraction, whereas the Welsh approach is more holistic, looking for opportunities to improve ecosystems and catchment-level biodiversity on the ground (Hafren Dyfrdwy, 2023).

Gaps

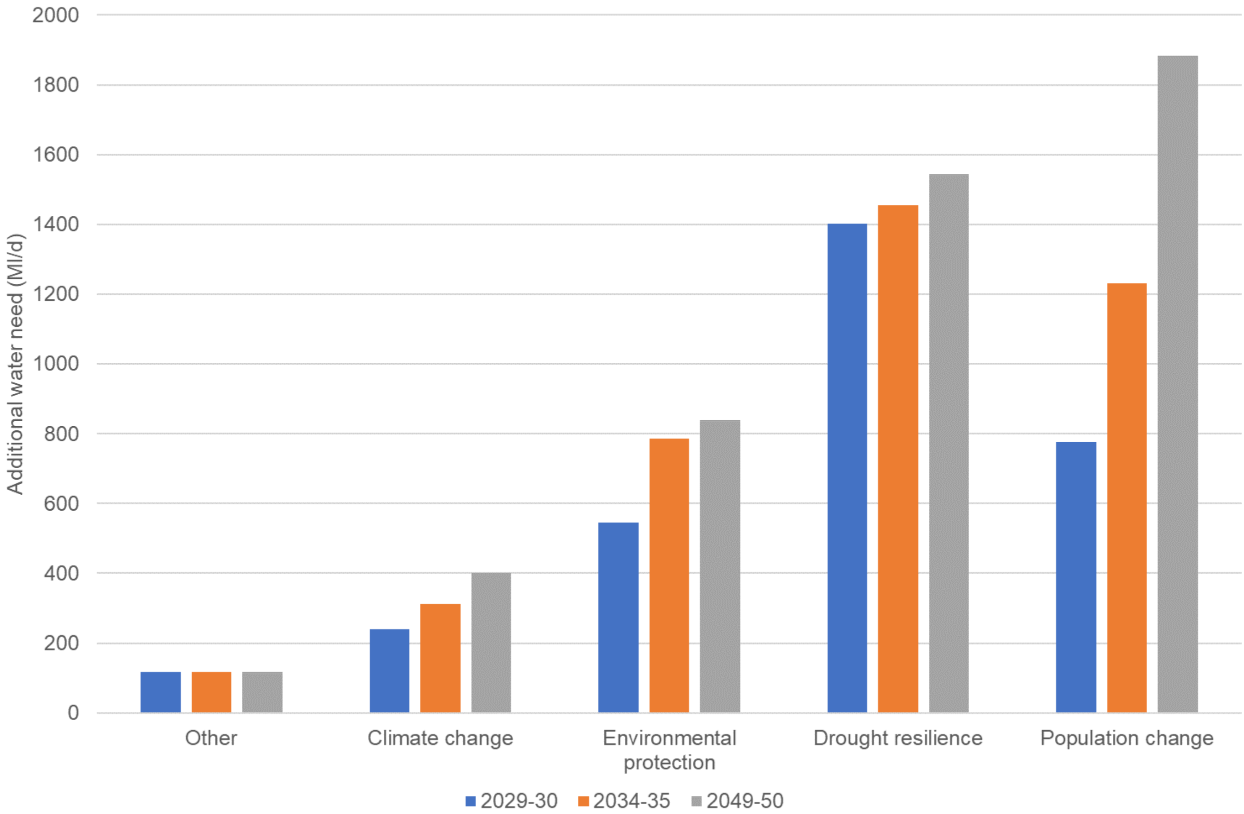
Future water requirements of protected sites in the HyNet NW area were not identified from the literature reviewed.

There is uncertainty regarding future abstraction reductions in Wales, and in the longer-term in England.

6.2.4 National and regional drivers

The analysis at national level shows the greatest increase in water requirements due to population change, drought resilience and environmental protection in the next 10 years. After 2034-35, comparatively minimal additional water is anticipated to be required for drought resilience and climate change, significantly reducing the overall trend. Approximations of these values are presented in Figure 6.6. As such, more focus should be given to the water availability in the 2030 scenario, and limited weight should also be given to current water needs which may be significantly lower than those seen in 2030 when the HyNet NW area will be operational.

Figure 6.6 Approximate future water needs for England by purpose, inferred from (Environment Agency, 2020)[27]



In the Water Resources West region, increase in consumptive use driven by population growth emerges as the primary driver of additional water needs by 2050 (Environment Agency, 2020), as seen in Table 6.7. Moreover, increased public water supply drought resilience and heightened protection for the environment contribute significantly to the pressures on water resources. Although climate change has a smaller impact, it remains noteworthy by reducing the water availability of existing supplies. Care should be taken not to focus unduly on higher profile issues over the more influential issues.

Gaps

The actual future scenario, especially in the short term (2030), remains quite unclear due to uncertainties around public water supply WRMP demand options reaching targets and the

[27] This scenario assumes no further action taken from 2025, high population scenario, 1 in 500 drought resilience, high sustainability change and existing surpluses cannot offset the need.

potential for NRW to implement environmental protection reductions. Post-2030, uncertainties persist regarding sustainability reductions, discharge permitting, and the abstraction approval process as part of EPR.

Table 6.7 Projected additional water needs in the (North) West of England in 2050 and rough estimates in 2030 and 2080

Category	Water need in 2050 (ML/d)	*Approximate extrapolation to 2030*	*Approximate extrapolation to 2080*
Climate change	68	*52*	*87*
Environmental protection	167	*116*	*178*
Population change	237	*149*	*362*
Drought resilience	167	*161*	*177*
Other	0	*0*	*0*

6.3 Assessment of future receiving water quality

6.3.1 Environmental impacts on future (2030-2080) receiving water quality

Although it is likely that climate change will have a significant impact on the water quality of UK riverine, estuarine and coastal environments during the next century, it is difficult to accurately and reliably quantify these changes. The complex, multi-dimensional biogeochemical processes governing water quality variables, along with the heterogeneity of different catchment areas, means it can be challenging to attribute a water quality trend to climate change, and future water quality projections can vary significantly across relatively small spatial areas and periods of time. To accurately identify the impact of climate change on water quality, factors such as catchment runoff (both rural, agricultural, industrial and urban) and variability in river flows need to be accounted for. Consequently, it is important that the appropriate level of uncertainty is accounted for when appraising the future impact of climate change on water quality within the HyNet NW region.

Although the impacts of climate change on water quality are complex, there is a general consensus that changes in water temperature and hydrological regimes are the two most significant issues facing freshwater ecosystems in the UK, as a result of climate change (Watts, et al., 2015). In line with the rest of the UK, the Mersey Estuary and surrounding river catchments can expect to experience a rise in average water temperature, relating primarily to the projected increase in average ambient air temperature. The extent to which water temperature will rise in water bodies within the HyNet project area is difficult to predict at a local level, particularly without any in-depth, catchment-specific research. This makes it challenging to unpack how changes in water quality may affect HyNet development in the future, although some generic outcomes can be suggested.

Relating to temperature, the rate of most biogeochemical processes increases at higher water temperatures, which may lead to changes in the decay rate of certain pollutants or substances (Wade, et al., 2002). Furthermore, increased water temperatures, combined with possible increases in nutrient loads, could encourage the growth of algae and exacerbate risks associated with eutrophication (Moss, 2011).

Changes in flow regimes, particularly in relation to hydrological extremes, also has the potential to impact water quality in receiving water bodies. Reductions in flows may impact the effective dilution of effluent discharges in water bodies and exacerbate the impact of agricultural diffuse pollution (Whitehead, et al., 2006), whilst an increase in extreme rainfall events may result in increased urban runoff pollution from the first flush phenomenon, particularly when extreme rainfall follows drought periods causing erosive conditions.

Gaps

Overall, there is significant uncertainty regarding how water quality will be impacted by climate change. The impacts at a local level will be dominated by local factors such as the sources and types of pollution, ground conditions and response of the catchment, flow regime, parameters of concern, and the local weather conditions.

A more detailed analysis could have seen the reasons for failure at each relevant water body evaluated in light of the body of evidence for likely changes to those water quality parameters as a result of climate change. However, this was not possible as part of this annex, and would likely have been of limited value due to significant uncertainty.

6.3.2 Future impacts of investment on water quality

This section gives an overview of planned actions that could impact future water quality in the HyNet NW region. These include River Basin Management Plans (RBMPs), water company business plans, Local Plans and Highway Asset Management Plans (HAMPs) by local authorities, and Marine Plans developed by the Marine Management Organisation (MMO). Plans to alter agricultural practices are generally documented in less detail but covered to some extent by RBMPs. Whilst climate change may worsen water quality in future (increased temperatures, reduced dissolved oxygen, more extreme flows), these plans mostly aim to improve water quality.

Gaps

Changes in water quality because of these planned actions could also alter environmental capacity and water availability for HyNet NW, though in general it is difficult to link planned actions to specific changes in water quality determinands.

Some of the proposed projects below may present an opportunity to gather more information on water quality in the HyNet region, or to improve water quality in collaboration with the organisations involved.

RBMPs *‘set the legally binding locally specific environmental objectives that underpin water regulation (such as permitting) and planning activities’* (Environment Agency, 2022). They inform water company business plans, water resources management plans, drought plans, local nature recovery strategies, Flood Risk Management Plans and Marine Plans, amongst others. RBMPs are reviewed and updated every six years, with the most recent cycle (cycle 3) completed and published by the Environment Agency in 2022. Previous iterations were published in December 2009 and February 2016. RBMPs include an assessment of the current condition of each water body and, if the water body is not in good condition, the reasons why. The RBMP objectives for key water bodies in the HyNet region are presented in Appendix C. Not all water bodies have a target of good by 2063, with some expected to achieve moderate or poor status only based on data currently available.

The Environment Agency publishes planned measures to meet these targets, available via its Catchment Data Explorer (Environment Agency, 2023) and catchment partnership pages (Environment Agency, 2023). National programmes including the Water Industry National Environment Programme (WINEP), Environmental Land Management Schemes (ELMS) and Invasive Non-Native Species removal are included in the list of measures alongside specific projects for the HyNet NW area:

1. **Chester Wetland Centre** - improving water quality, ecology and mitigation measures creating a 14-hectare wet meadow in Chester. Part of the Green Link Project, establishing a series of unique green corridors across Chester.

2. **Upper Weaver Water Friendly Farming.** Engaging with farmers and landowners in the Ash Brook, Englesea Brook, Wistaton Brook, Valley Brook and Darley Brook catchments. Disseminating farm business advice and funding to undertake prioritised interventions identified in the Farm Water Management Plan this annex aims to produce. Project will seek to reduce the impacts of poor agricultural and rural land management practices that are introducing additional nutrients, sediments, chemicals, and effluent into the waterbodies and are the main reasons for these waterbodies failing to reach good ecological status.

Water companies

Water companies in England and Wales have submitted their draft business plans for the 2025-2030 (PR24) period to Ofwat and the Environment Agency. These plans are in draft, subject to approval by regulators in December 2024 (Ofwat, 2023), therefore there is uncertainty in projects outlined in this section. They are, however, the best indication of potential future changes to receiving water quality because of water company action. The plans incorporate National Environment Programme (NEP, for Wales) and Water Industry National Environment Programme (WINEP, for England) scheduled investment for 2025-2030, and Drainage and Wastewater Management Plan (DWMP) recommendations. Detailed NEP and WINEP proposals were not available for this literature review, as they are still under regulator review, therefore the following is based on publicly available business plan documents.

UU and DCWW are the two wastewater companies that discharge into receiving waters within the HyNet NW region. Both companies plan significant spend to reduce storm overflow spills and improve river health. UU proposes 26.8% fewer spills by 2030 (assumed number of spills per year, 60% reduction in storm overflow spills quoted elsewhere in their plan) (United Utilities, 2023) (Dwr Cymru Welsh Water, 2023). They are targeting no more than 10 spills per year in 2050, in line with the government's Storm Overflow Discharge Reduction Plan for England (Defra, 2022). UU further plans to 'protect and enhance 386km of rivers' (United Utilities, 2023) across its region, though the nature of the improvements isn't clear.

DCWW's business plan headlines include reducing 'harm' caused by 186 storm overflows over 2025-2030 and ensuring no overflow causes 'harm' by 2040. Reductions in phosphorus discharges are planned for Special Areas of Conservation. Whereas English water companies are required to ensure overflows spill no more than 10 times per year under the government's Storm Overflow Discharge Reduction Plan (Defra, 2022), Welsh government is focused on preventing adverse ecological impacts. DCWW has defined 'harm' using the 2016 Storm Overflow Assessment Framework methodology (Environment Agency, 2018), which draws on the Urban Pollution Manual's Fundamental Intermittent Standards[28], setting thresholds for pollutant concentrations that are acceptable for specified periods of time.

Whilst it is difficult to identify specific DCWW projects that will impact on water quality in the HyNet region from its draft PR24 business plan, UU's draft plan provides maps indicating overflows or treatment works that they plan to improve, and sections of river that they expect to 'improve' as a result of their actions. These maps are provided in Figure 6.7,

Figure 6.8, and Figure 6.9. The nature of the improvement expected does not appear to be detailed in the draft business plan but may be available from UU.

Of additional relevance to the HyNet NW region:

1. UU indicates that it will be developing a *'long-term environmental plan for the Merseyside area'*, including extensive investigations in 2025-2030,

[28] http://www.fwr.org/UPM3/

and improvements to storm overflow spills, water quality, coastal bathing waters and shellfish beds in 2030-2035. This may present an opportunity to gather more information for HyNet NW, and/or to co-develop options to improve water quality in the region.

2. £340 million of investment is planned by UU in 2025-2030 at three wastewater treatment works discharging to the Manchester Ship Canal, to reduce biological oxygen demand and increase dissolved oxygen. Further investment is planned in 2030-2035 at Davyhulme wastewater treatment works, also near the Manchester Ship Canal. Phosphorus removal is also planned for the canal at upstream treatment works.

3. An Integrated Water Management Plan for Greater Manchester brings together UU, the Environment Agency and Greater Manchester Combined Authority and includes targets related to reducing nitrogen, phosphorus and sediment pollution from agricultural runoff to the water environment by 40% from the 2018 baseline, 'net zero water' new developments and incorporates parts of UU's plans for storm overflows and wastewater treatment works (Greater Manchester CA, 2023). It may provide a useful forum for discussing HyNet's impacts on the water environment.

Figure 6.7 UU planned projects with potential impact on water quality in Cheshire (United Utilities, 2023). Note that Chester is in DCWW's wastewater operations region, so UU plans do not cover the full area shown in the map.

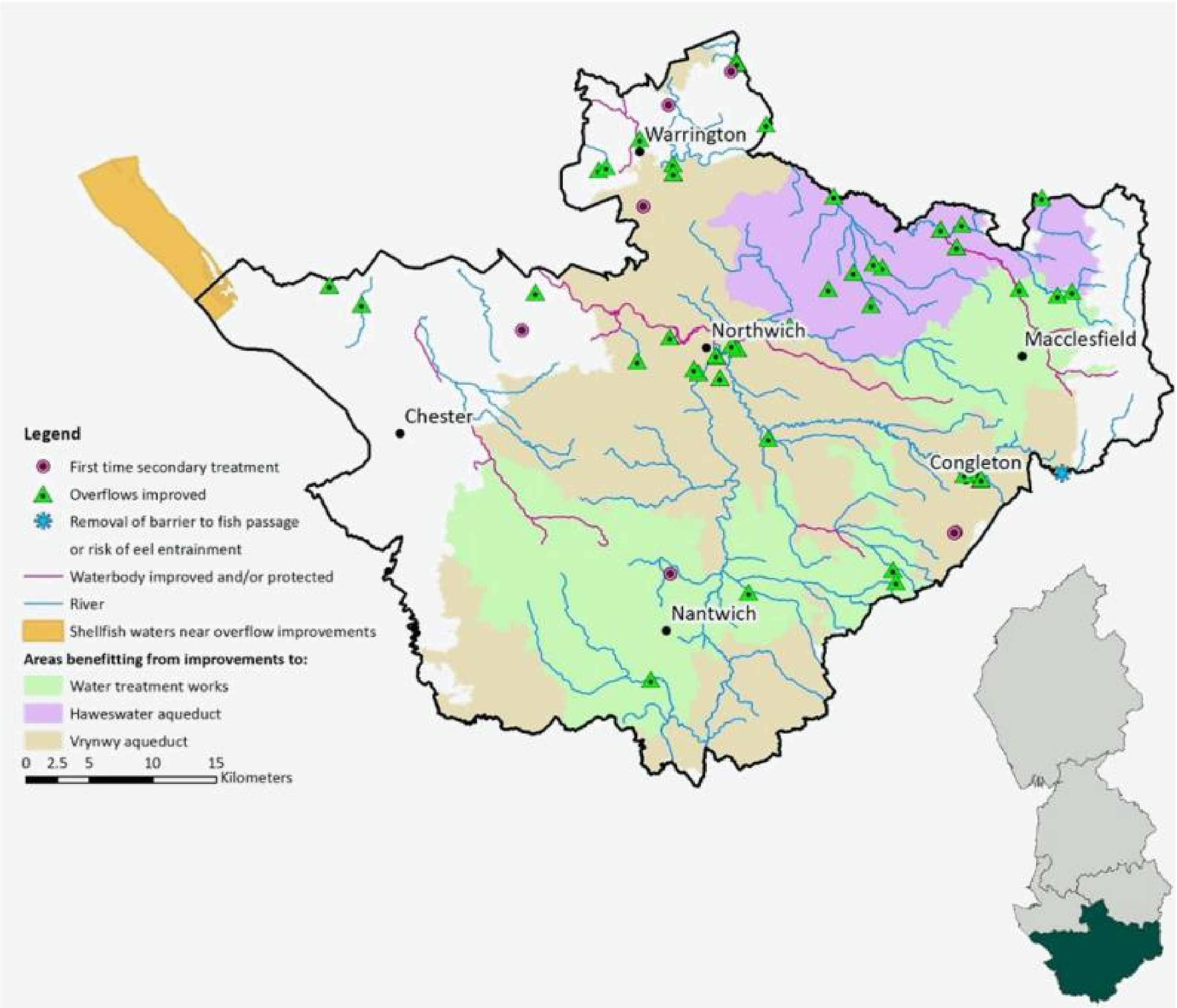


Figure 6.8 UU planned projects with potential impact on water quality in Merseyside (United Utilities, 2023). Note that Chester is in DCWW's wastewater operations region, so UU plans do not cover the full area shown in the map.

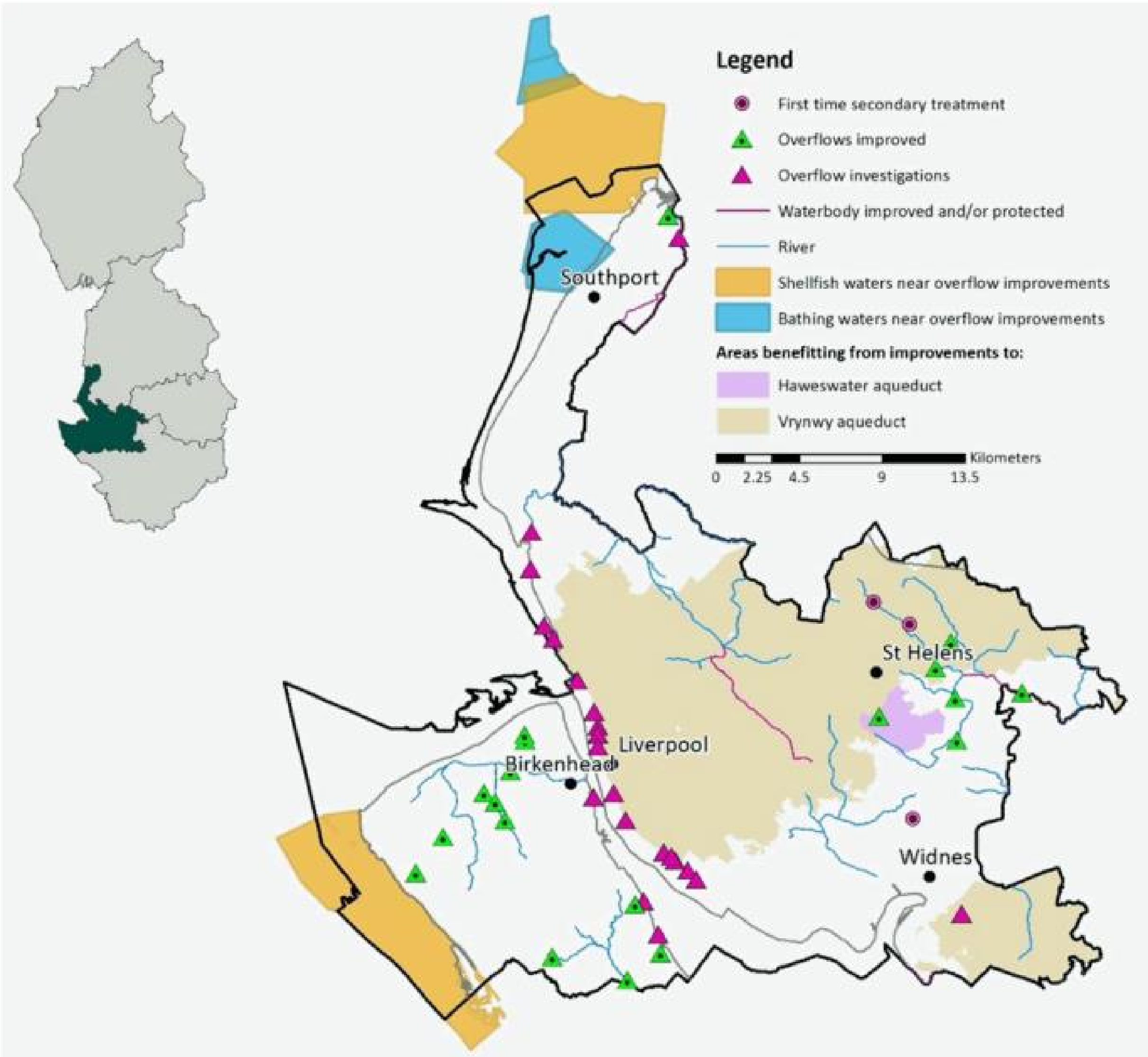
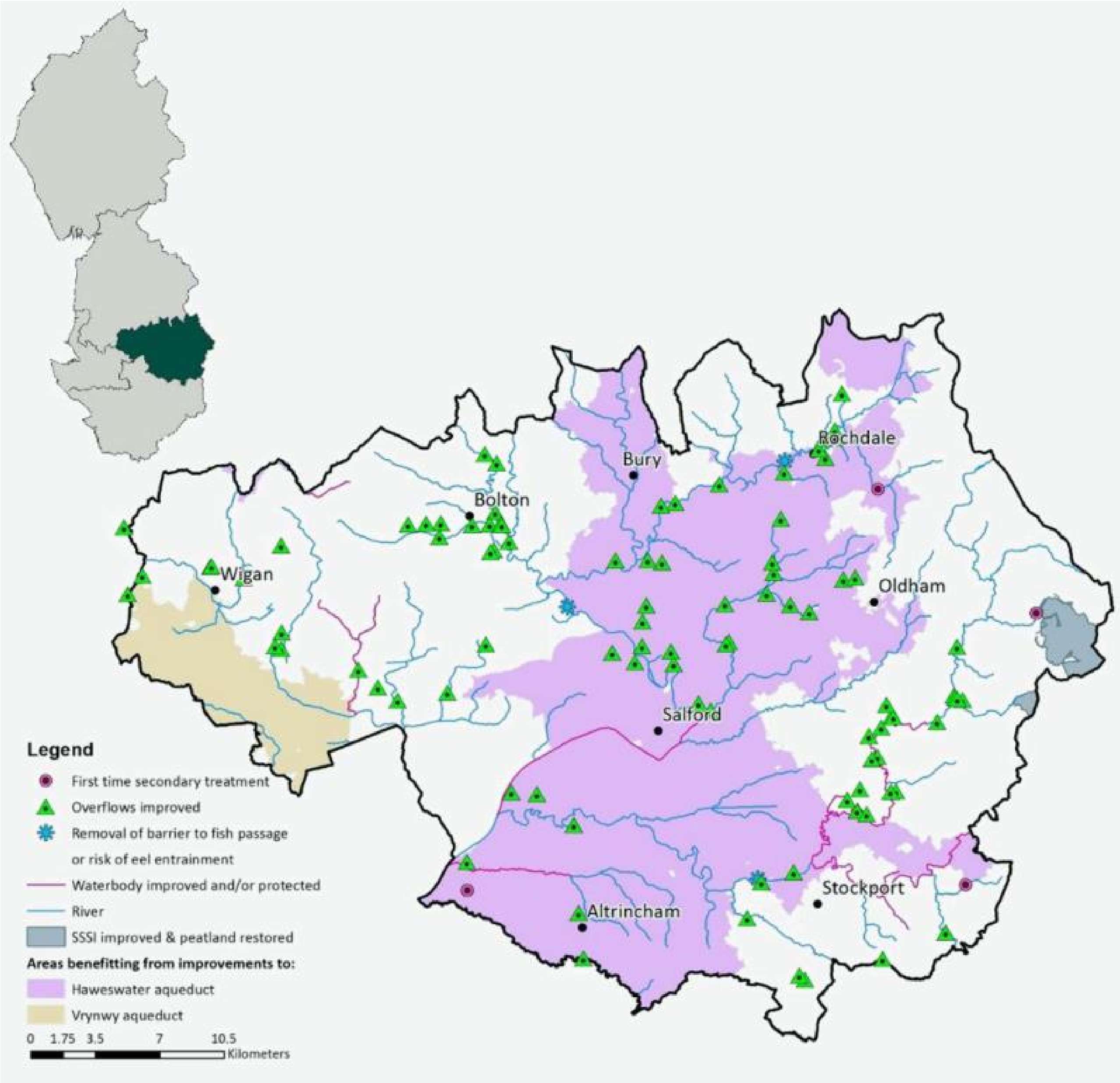


Figure 6.9 UU planned projects with potential impact on water quality in Greater Manchester (United Utilities, 2023).



Agriculture

Beyond RBMPs and information on catchment partnerships, we have not identified specific information on plans for agricultural action to improve water quality in the HyNet NW region. The Environment Agency's Agricultural Regulatory Inspection Officers may have information about potential future changes in agricultural practices.

Local authorities

Local Plans are prepared by local authorities to set a 'vision and a framework for the future development of an area' (Department for Communities & Local Governments, 2017). The four local authorities that manage the areas where most HyNet NW assets will be located are Wirral, Cheshire West and Chester, Halton and Liverpool (Office for National Statistics, 2023). A review of the latest plans for these authorities did not identify specific information on green infrastructure or waterbody impacts. It is likely that any growth or new developments suggested in Local Plans will have been considered by water companies as part of their business plans. Local plans should have regard for the RBMP (Defra, 2021).

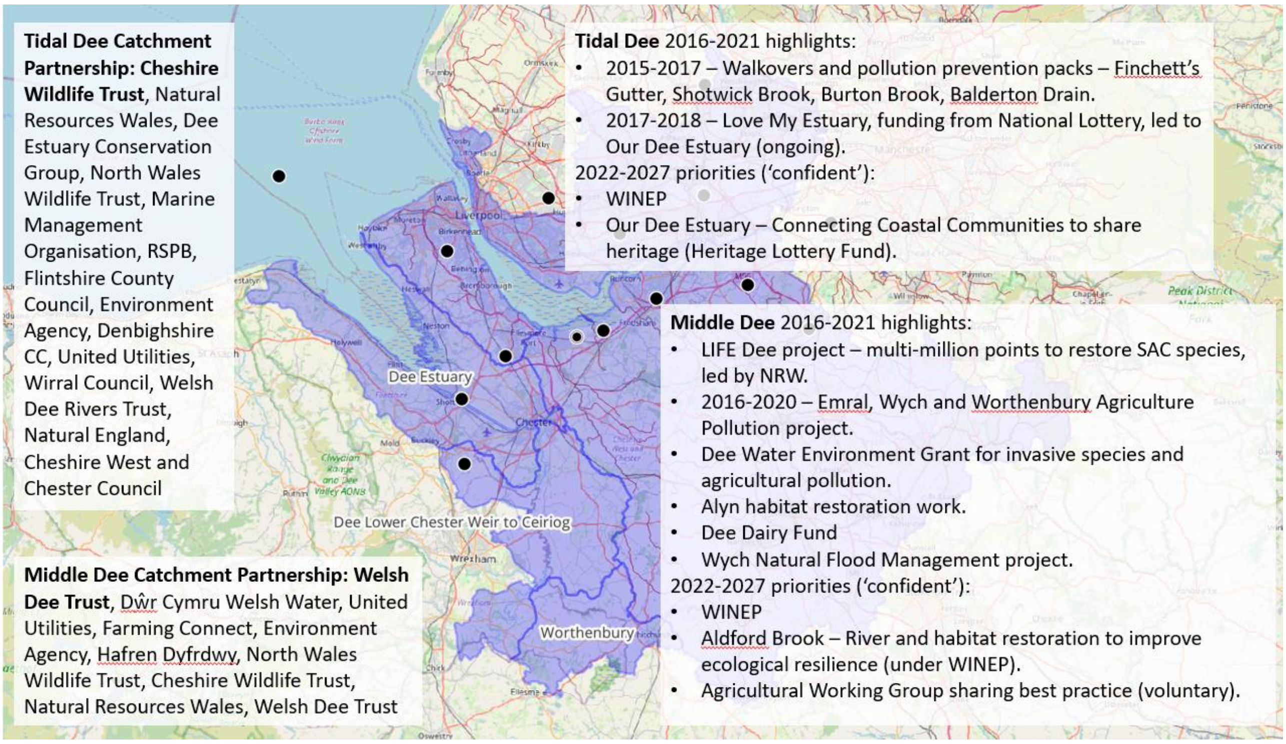
Highway Asset Management Plans (HAMPs) are produced by local councils, however a review of Halton Local Authority's HAMP did not reveal any specific plans to improve highway discharges to the environment.

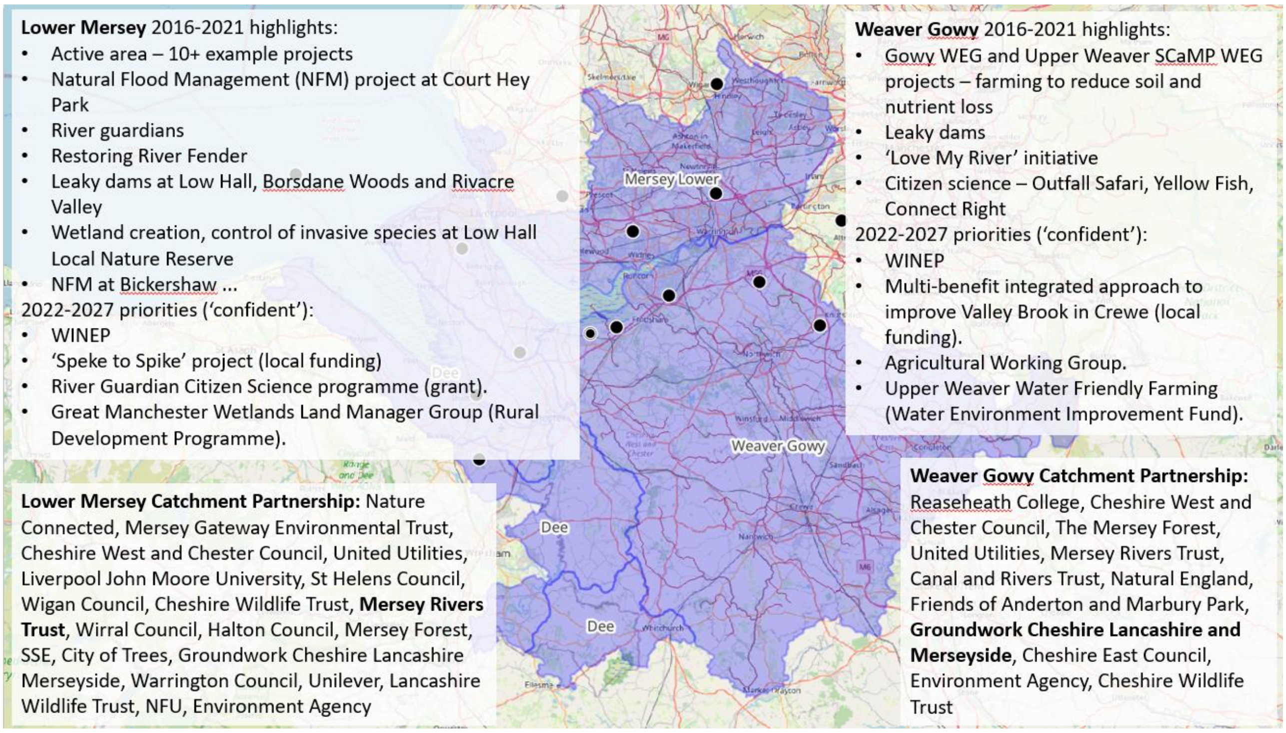
Catchment partnerships

Catchment partnerships bring together local people and groups to set assess the challenges faced by individual waterbodies and develop plans to improve. Partnerships relevant to the HyNet NW area are outlined in Figure 6.10. These stakeholders are likely to be interested in the impacts of HyNet on the water environment. Their planned activities may also improve water quality or availability, with impacts for HyNet. Further details are available via the Environment Agency's Catchment Data Explorer (Environment Agency, 2023).

Natural Course, a European Union funded partnership between United Utilities, the Environment Agency, Natural England, Greater Manchester Combined Authority and The Rivers Trust is another multi-organisational group acting to improve the water environment in the north west (Natural Course, 2023).

Figure 6.10 Key catchment partnerships in the HyNet NW region. List of members in each partnership provided, with lead partner in bold text. Completed projects for 2016 2021, and projects that partnerships are 'confident' will happen in 2022-2027 also shown.





7. Conclusions and next steps

This annex has summarised information available in literature which is relevant to assessing the water demands of HyNet NW, the impacts of effluent discharge, the water availability in the HyNet NW area, and the environmental conditions and constraints which will need to be considered when assessing the impact on water of the HyNet NW Industrial Cluster.

In particular, this annex will be used to identify knowledge gaps which need to be acknowledged or filled during the project, steer stakeholder engagement sessions, and provide the starting point for an evidence baseline for the impacts of HyNet NW on water resources. This annex stops short of assessing how (and whether) the water requirements of HyNet NW can be met by the environment, and the impacts that it would have. Instead, the following conclusions summarise separately the literature with respect to demand, water availability, and the state of the water environment. The evidence baseline annex will approach the situation holistically, considering the compatibility and interdependency of these conclusions to identify possible solutions to provide the water required for HyNet NW while minimising environmental impact and impacts on others.

The following next steps are envisaged for this project, advancing the work presented in this literature review.

- Assimilating the information from this literature review into an evidence baseline annex.
- Stakeholder engagement to fill knowledge gaps (where possible).
- Analysis to determine environmental capacity for the HyNet network and potential strategies to avoid or mitigate potential environmental harm.

7.1 Conclusions: demand

- By the year 2025, 3 TWh per year of hydrogen is expected to be produced at the Stanlow Refinery site, rising to 30 TWh of hydrogen production per year by 2030. The total demineralised water required to produce 3 TWh and 30 TWh of hydrogen is estimated to be 53.1 m^3/hr and 530.9 m^3/hr. This equates to 1.3 ML/d and 12.7 ML/d of raw water consumption.

- The only discharge flow from the hydrogen production plant is thought to be saline reject water from the demineralisation plant. The reject water flow rate for the demineralised plant to produce 3 TWh of hydrogen is estimated to be 338.4 m^3/day at normal flow which contributes to only 0.4% of the current permitted discharge limits at emission point W3.

- For green hydrogen production, total consumptive water use once the two plants with available evidence (excluding Project Quill 2 at Inovyn in Runcorn) are operational is estimated at 2.6 ML/d of potable water for 220 MW of production. Source water for these values is uncertain.

- CCS capacity of 2,490,000 tonnes of CO_2 per annum is expected to be achieved once the planned plants are fully operational, resulting in consumptive water use of 36 ML/d to 180 ML/d dependent on cooling method. Source water for these values is uncertain and may be contributed to by TraC water.

Information gaps

- Any future process efficiency improvements will likely reduce cooling demand and therefore water demand. Blue hydrogen production requires natural gas and is therefore incompatible with a complete transition away from hydrocarbon use, and it is likely to be phased out in favour of green hydrogen in the mid- to long-term future (2050 to 2080). Sufficient information has not been found to produce adjustments to pathways around this phase out, or for potential process efficiency improvements.

- Given the composition of the saline effluent reject water from the demineralisation plant, the parameters mentioned in Table 4.5 align with the discharge condition criteria for discharge point W1 mentioned in Table 4.6. However, it's important to note that information regarding the salinity of the reject water from the demineralization plant is not available. The W1 discharge permit does not include a specific limit for salinity.

- Information gaps around planned cooling methods and sources for water use reduce confidence in water use estimates. Evidence collection should be targeted in these areas during the stakeholder engagement phase.

- The water use of other assets in the HyNet NW area is poorly understood.

- The plans for green hydrogen production are poorly understood. This has the potential to require significant additional water, even compared to the water demands of blue hydrogen. There is a lack of knowledge around the water quality effects resulting from green hydrogen production waste streams.

- The water requirements for hydrogen storage are currently unknown. This has the potential to require a significant one-off use of water.

- There is significant uncertainty regarding the impacts of carbon capture systems on water demand.

7.2 Conclusions: water availability

- A review has been conducted of the current and likely availability of water in the most relevant water bodies to the HyNet NW Industrial Cluster.

- Attempts have been made to assess how this availability might change in the future by giving consideration to climate change, demand trends, trends and future needs of public water supplies and future policy.

- There are a number of water sources within the area, most of which have at least some water availability and are likely to continue to have availability in the future.

Information gaps

- Until the evidence baseline has assessed the availability against the needs and environmental restrictions, it is not possible to indicate whether there is a feasible mechanism by which the required water for HyNet NW can be provided.

- Plans about where users in the HyNet area are planning to abstract and discharge water would allow the evidence baseline to be more robust and a more useful assessment to be made.

7.3 Conclusions: receiving water quality and environmental constraints

- According to the latest WFD investigations, current surface water and groundwater quality is generally ‘Moderate’ or worse in the HyNet project region. The source of waterbody pollution is varied, including industrial discharges, water industry effluent, poor agricultural management, and the navigation industry.

- Suggestions on how water quality in the region may change in the future have been assessed. Changes in agricultural management practices, local council plans and river basin management plans all aim to improve future water quality in the region, whilst climate change is likely to have adverse effects.

- A number of habitat-specific protected sites are present in the HyNet project region, particularly within the Mersey and Dee estuaries. Parts of the HyNet region also fall within nitrate vulnerable zones, shellfish waters and bathing water zones. All these zones and protected sites will limit what activities are allowed and likely result in tighter permit restrictions.

Information gaps

- Abstraction and discharge points for the planned HyNet infrastructure are needed before analysis of the corresponding receiving waterbody quality can be undertaken.

- It is difficult to provide detailed, quantitative statements about the impact of climate change on future water quality, without relevant regional or local studies. The majority of literature focuses on generic, national-level projections and often contains a high level of uncertainty.

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Appendix A Water demand calculation - LCH

Hydrogen production at HyNet North-West is shown in Table 8.1.

Table 8.1 Hydrogen production at HyNet North West

Year	Amount
2025 (TWh / year)	3
2025 (KWh / year)	3,000,000,000
2030 (TWh / year)	30
2030 (KWh / year)	30,000,000,000

1 kg of hydrogen contains approximately 33.33 kWh of usable energy.[29] The conversion of kWh/year hydrogen to Kg/year hydrogen is shown in Table 8.2 and Table 8.3.

Table 8.2 Conversion of kWh/year hydrogen to Kg/year hydrogen for 2025

KWh / year	Tonnes H_2 / year
33	1
3,000,000,000	90,909,090

[29]https://www.idealhy.eu/index.php?page=lh2_outline#:~:text=Hydrogen%20is%20an%20excellent%20energy,www.h2data.de).

Table 8.3 Conversion of kWh/year hydrogen to kg/year hydrogen for 2030

KWh / year	Tonnes H_2 / year
33.33	1
30,000,000,000	909,090,909

The water intensity of hydrogen production for LCH Technology[30] is shown in Table 8.4.

Table 8.4 Hydrogen production for LCH technology

Water (m^3/hr)	Hydrogen Produced (kg H_2 / hr)
31	6,000

Based on Table A.4, total water required for the LCH technology for HyNet Northwest in 2025 and 2030 is calculated and shown in Table 8.5.

Table 8.5 Water demand for HyNet North West LCH technology

Year	Hydrogen (Kg H_2 / hr)	Water (m^3/hr)	Water (ML/d)
2025	10,378	53.1	1.3
2030	103,778	530.9	12.7

[30] WaterSMART Solutions Ltd, 2020, Water for the hydrogen Economy

Appendix B Hands off flows

Table 8.6 Hands off flow at assessment points 4 &5 of Weaver & Dane abstraction licensing strategy catchment and 8 of Lower Mersey & Alt abstraction licensing strategy catchment

Abstraction Licensing Catchment	Assessment Point	Name	HOF restriction (ML/d)	Broad location with respect to HyNet NW	Nearest major conurbation
Lower Mersey & Alt	7	Ditton Brook (prior to confluence of River Mersey)	3.5	North	Liverpool
Lower Mersey & Alt	8	Dibbinsdale Brook (prior to confluence of River Mersey	7.1	West	Chester
Lower Mersey & Alt	17	Glaze Brook at Little Woolden Hall gauging station	13.0	South	Chester
Lower Mersey & Alt	19	Bedford Brook	1.4	East	Salford
Lower Mersey & Alt	20	Westleigh Brook	1.7	East	Salford
Lower Mersey & Alt	6	Moss Brook	3.2	East	Salford
Lower Mersey & Alt	12	Black Brook	7.3	North	St Helens
Lower Mersey & Alt	14	Rainford Brook	10.3	North	St Helens
Northern Manchester	4	River Irwell at Adelphi Weir Gauging Station	114.8	North – East	Prestwich
Northern Manchester	7	River Irk at Collyhurst	11.5	North - East	Manchester
Upper Mersey	11	AP11, Mersey Ashton-on-Mersey Gauging Station	94	North - East	Altrincham

Abstraction Licensing Catchment	Assessment Point	Name	HOF restriction (ML/d)	Broad location with respect to HyNet NW	Nearest major conurbation
Upper Mersey	15	AP15, Birkin Brook (Upstream of River Bollin)	344.4	North - East	Altrincham
Upper Mersey	16	AP16, Bollin (Upstream of Manchester Ship Canal)	678.7	North - East	Altrincham
Upper Mersey	17	AP17, Sinderland Brook at Partington GS	3.4	North - East	Altrincham
Weaver & Dane	3	Ashbrook GS (River Weaver)	53.5	South	Middlewich
Weaver & Dane	4	Hayhurst Bridge (River Weaver)	57.1	South	Middlewich
Weaver & Dane	5	Pickerings Cut GS (River Weaver)	111	South	Middlewich
Weaver & Dane	8	River Dane (prior to confluence of River Wheelock)	99.4	South	Middlewich
Weaver & Dane	9	Rudheath GS (River Dane)	110.6	South	Middlewich
Weaver & Dane	11	Lostock Graham GS (Wincham Brook)	11.4	South	Middlewich
Weaver & Dane	12	River Wheelock (prior to confluence of River Dane)	27.2	South	Middlewich

Abstraction Licensing Catchment	Assessment Point	Name	HOF restriction (ML/d)	Broad location with respect to HyNet NW	Nearest major conurbation
Weaver & Dane	13	Wade Brook (prior to confluence of Wincham Brook)	3.6	South	Middlewich

Appendix C WFD status of relevant water bodies

Table 8.7 Summary of the current WFD status, reasons for not achieving good (RNAG) status, and future WFD objectives, for key water bodies in the HyNet project region.

Water body	Water body ID	Water body type	WFD status (C3)	WFD status objective*	WFD RNAG	
					Classification element	Categories
Mersey	GB531206908100	Transitional	Moderate	Good (2063)	Tributyltin Compounds, PBDEs, Mercury Compounds, Phytoplankton, Dissolved Inorganic Nitrogen, Zinc, Benzo(g-h-i)perylene	Industry, Water Industry, No Sector Responsible + Ongoing Investigations
Dee (N. Wales)**	GB531106708200	Transitional	Moderate	Unknown	Brominated diphenylether (BPDE), polyaromatic hydrocarbons (PAH) and 'PHZ' (not defined).	-
Manchester Ship Canal	GB71210004	Canal	Moderate	Good (2063)	Mitigation Measures Assessment, Mercury Compounds, PBDEs, Tributyltin Compounds	Water Industry, Waste Treatment & Disposal, Navigation, No Sector Responsible + Ongoing Investigations
Wirral and West Cheshire Permo-	GB41101G202600	Groundwater	Poor	Good (2027 – low)	Chemical Drinking Water Protected Area, Trend Assessment	Agricultural & Rural Land Management, Domestic General Public, Water industry

Water body	Water body ID	Water body type	WFD status (C3)	WFD status objective*	WFD RNAG	
					Classification element	Categories
Triassic Sandstone Aquifers						
Weaver and Dane Quaternary Sand and Gravel Aquifers	GB41202G991700	Groundwater	Poor	Good (2027 – low)	Chemical Dependent Surface Water Body Status, Chemical GWDTEs test, Status, General Chemical Test	Agricultural & Rural Land Management, No Sector Responsible + Ongoing Investigations
Lower Mersey Basin and North Merseyside Permo-Triassic Sandstone Aquifers	GB41201G101700	Groundwater	Poor	Good (2027 – low)	Chemical Drinking Water Protected Area, Chemical Saline Intrusion, Trend Assessment, Quantitative Saline Intrusion, Chemical Dependent Surface Water Body Status	Agricultural & Rural Land Management, Water industry, 'Other', No Sector Responsible + Ongoing Investigations
Dee Permo-Triassic Sandstone	GB41101G202400	Groundwater	Poor	Good (2015)	n/a	n/a
Smoker Brook (Gale Brook to Wincham Brook)	GB112068060410	River	Bad	Good (2063)	Ammonia (Phys-Chem), Phosphate, Macrophytes and Phytobenthos Combined, Fish, PBDEs, Mercury Compounds	Agricultural & Rural Land Management, Domestic General Public, No Sector Responsible
Sankey Brook (Rainford Brook to Mersey)	GB112069061200	River	Moderate	Moderate (2027 – low)	PBDEs, PFOS, Macrophytes and Phytobenthos Combined, Phosphate, Mercury Compounds, Invertebrates, Fish	Industry, Water Industry, Agricultural & Rural Land Management, Urban &

Water body	Water body ID	Water body type	WFD status (C3)	WFD status objective*	WFD RNAG	
					Classification element	Categories
						Transport, No Sector Responsible + Ongoing Investigations
The Birket including Arrowe Brook and Fender	GB112068060530	River	Moderate	Good (2063)	Dissolved Oxygen, PFOS, Phosphate, Mitigation Measures Assessment, Fish, Ammonia (Phys-Chem), Invertebrates, Mercury Compounds, PBDEs	Agricultural & Rural Land Management, Urban & Transport, Local and Central Government, No Sector Responsible + Ongoing Investigations
Sinderland Brook	GB112069060980	River	Poor	Poor (2027 – low)	Invertebrates, Dissolved Oxygen, Phosphate, Macrophytes and Phytobenthos Combined, Fish, Mercury Compounds, PBDEs, PFOS	Water Industry, Urban & Transport, Domestic General Public, Local & Central Government, No Sector Responsible + Ongoing Investigations
Wade Brook	GB112068060370	River		2063	Cadmium Compounds, Cyanide, Invertebrates, PBDEs, Macrophytes and Phytobenthos Combined, Temperature, Mercury Compounds,	Industry, Agricultural & Rural Land Management, No Sector Responsible + Ongoing Investigations

Water body	Water body ID	Water body type	WFD status (C3)	WFD status objective*	WFD RNAG	
					Classification element	Categories
					Trichloromethane, Phosphate, Phenol, Ammonia (Phys-Chem)	
Weaver (Dane to Frodsham)	GB112068060500	River		2063	Macrophytes and Phytobenthos Combined, Mercury Compounds, Mitigation Measures Assessment, Invertebrates, Phosphate, PBDEs, Ammonia (Phys-Chem)	Water Industry, Navigation, Agricultural & Rural Land Management, Urban & Transport, No Sector Responsible + Ongoing Investigations
Peckmill Brook, Hoolpool Gutter at Ince Marshes.	GB112068060330	River		2027 (low)	Ammonia (Phys-Chem), Mercury Compounds, Phosphate, Fish, PBDEs, Macrophytes and Phytobenthos Combined	Water Industry, Agricultural & Rural Land Management, Urban & Transport, No Sector Responsible
Irwell / Manchester Ship Canal (Irk to confluence with Upper Mersey)	GB112069061452	River	Poor	2015	Dissolved Oxygen, PBDEs, Phosphate, Ammonia (Phys-Chem), PFOS, Mitigation Measures Assessment, Mercury Compounds	Industry, Water Industry, Navigation, Urban & Transport, Local & Central Government, No Sector Responsible
Dibbinsdale Brook and Clatter Brook	GB112068060270	River	Moderate	2015	Dissolved Oxygen, Mercury Compounds, Phosphate, Invertebrates, Fish, PBDEs, PFOS	Agricultural & Rural Land Management, Urban & Transport, Domestic General Public, No Sector Responsible

Water body	Water body ID	Water body type	WFD status (C3)	WFD status objective*	WFD RNAG	
					Classification element	Categories
						+ Ongoing Investigations
Croco	GB112068055460	River	Moderate	2027 (low)	Macrophytes and Phytobenthos Combined, Copper, Ammonia (Phys-Chem), Phosphate, PBDEs, PFOS, Mercury Compounds, Invertebrates	Water Industry, Agricultural & Rural Land Management, Urban & Transport, No Sector Responsible + Ongoing Investigations
Mersey (Bollin confluence to Howley Weir) including Padgate Brook.	GB112069061012	River	Moderate	2027 (low)	Ammonia (Phys-Chem), Dissolved Oxygen, Phosphate, PBDEs, Benzo(g-h-i)perylene, PFOS, Mercury Compounds, Invertebrates, Mitigation Measures Assessment	Water Industry, Industry, Urban & Transport, Local & Central Government, No Sector Responsible + Ongoing Investigations
Additional relevant water bodies to be added once abstraction and discharge points are confirmed						

Data sourced from the EA 'Catchment Data Explorer' (https://environment.data.gov.uk/catchment-planning) and 'Water Watch Wales' (https://waterwatchwales.naturalresourceswales.gov.uk/en/)

** WFD objective date refers to the overall waterbody classification.*

***Less information available on Water Watch Wales than EA's Catchment Data Explorer, therefore Dee estuary data here are less complete.*

Table 8.8 The reasons for not achieving good (RNAG) WFD classification status for the Mersey Estuary and selected surrounding river water body catchments.

Water body	Classification element	WFD level	Category	Activity
Mersey	Tributyltin Compounds	Good	No sector responsible	'Other'
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	'Other'
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Tributyltin Compounds	Good	Industry	Contaminated water body bed sediments
	Tributyltin Compounds	Good	Water Industry	Contaminated water body bed sediments
	Phytoplankton	Moderate	Sector under investigation	Unknown (pending investigation)
	Dissolved Inorganic Nitrogen	Moderate	Sector under investigation	Unknown (pending investigation)
	Zinc	Moderate	Industry	Contaminated water body bed sediments
	Zinc	Moderate	Industry	Contaminated land
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Benzo(g-h-i)perylene	Fail	Sector under investigation	Unknown (pending investigation)
Dee (N. Wales)	'PHZ'	Moderate	-	Unknown
	Brominated diphenylether (BPDE)	Moderate	Unknown, water industry	Contaminated water body bed sediments, sewage discharge (continuous).

Water body	Classification element	WFD level	Category	Activity
	Polyaromatic hydrocarbons (PAH)	Moderate	-	Unknown
Manchester Ship Canal	Mitigation Measures Assessment	Moderate or less	Sector under investigation	Other (not in list, must add details in comments)
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Tributyltin Compounds	Fail	Navigation	Other (not in list, must add details in comments)
	Tributyltin Compounds	Fail	Water Industry	Sewage discharge (continuous)
	Tributyltin Compounds	Fail	Water Industry	Sewage discharge (intermittent)
	Tributyltin Compounds	Fail	Waste treatment and disposal	Landfill leaching
Smoker Brook (Gale Brook to Wincham Brook)	Ammonia (Phys-Chem)	Good	No sector responsible	Not applicable
	Phosphate	Moderate	Agriculture and rural land management	Poor Livestock Management
	Macrophytes and Phytobenthos Combined	High	No sector responsible	Not applicable
	Macrophytes and Phytobenthos Combined	High	Domestic General Public	Private Sewage Treatment
	Phosphate	Moderate	Agriculture and rural land management	Poor nutrient management
	Phosphate	Moderate	Agriculture and rural land management	Poor nutrient management

Water body	Classification element	WFD level	Category	Activity
	Phosphate	Moderate	Agriculture and rural land management	Poor soil management
	Phosphate	Moderate	Agriculture and rural land management	Poor soil management
	Phosphate	Moderate	Agriculture and rural land management	Farm/site infrastructure
	Fish	Bad	No sector responsible	Not applicable
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
Sankey Brook (Rainford Brook to Mersey) - River	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Macrophytes and Phytobenthos Combined	Moderate	Agriculture and rural land management	Poor soil management
	Macrophytes and Phytobenthos Combined	Moderate	Industry	Trade/Industry discharge
	Macrophytes and Phytobenthos Combined	Moderate	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Moderate	Urban and transport	Urbanisation - urban development
	Macrophytes and	Moderate	Agriculture and rural land management	Poor nutrient management

Water body	Classification element	WFD level	Category	Activity
	Phytobenthos Combined			
	Phosphate	Bad	Water Industry	Sewage discharge (continuous)
	Phosphate	Bad	Urban and transport	Urbanisation - urban development
	Phosphate	Bad	Industry	Trade/Industry discharge
	Phosphate	Bad	Agriculture and rural land management	Poor nutrient management
	Phosphate	Bad	Agriculture and rural land management	Poor soil management
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Invertebrates	Moderate	Industry	Trade/Industry discharge
	Invertebrates	Moderate	Urban and transport	Urbanisation - urban development
	Invertebrates	Moderate	Urban and transport	Flood protection - structures
	Fish	Poor	Urban and transport	Urbanisation - urban development
The Birket including Arrowe Brook and Fender	Dissolved oxygen	Bad	Urban and transport	Contaminated land
	Dissolved oxygen	Bad	Agriculture and rural land management	Poor Livestock Management
	Dissolved oxygen	Bad	Agriculture and rural land management	Poor soil management
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Phosphate	Poor	Urban and transport	Urbanisation - urban development
	Phosphate	Poor	Agriculture and rural land management	Poor nutrient management

Water body	Classification element	WFD level	Category	Activity
	Mitigation Measures Assessment	Moderate or less	Local and Central Government	Other (not in list, must add details in comments)
	Mitigation Measures Assessment	Moderate or less	Urban and transport	Other (not in list, must add details in comments)
	Fish	Poor	Agriculture and rural land management	Poor pesticide management
	Fish	Poor	Agriculture and rural land management	Poor soil management
	Fish	Poor	Agriculture and rural land management	Poor soil management
	Fish	Poor	Sector under investigation	Ports and harbours - structures
	Fish	Poor	No sector responsible	Ecological recovery time - surface waters
	Fish	Poor	Agriculture and rural land management	Poor Livestock Management
	Fish	Poor	Urban and transport	Urbanisation - urban development
	Fish	Poor	Urban and transport	Flood protection - structures
	Fish	Poor	Agriculture and rural land management	Land drainage - structures
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Poor soil management
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Poor Livestock Management
	Ammonia (Phys-Chem)	Moderate	Urban and transport	Urbanisation - urban development
	Ammonia (Phys-Chem)	Moderate	Urban and transport	Contaminated land
	Invertebrates	Poor	Agriculture and rural land management	Poor Livestock Management
	Invertebrates	Poor	Agriculture and rural land management	Poor soil management

Water body	Classification element	WFD level	Category	Activity
	Invertebrates	Poor	Sector under investigation	Flood protection - structures
	Invertebrates	Poor	Urban and transport	Urbanisation - urban development
	Invertebrates	Poor	Agriculture and rural land management	Poor nutrient management
	Phosphate	Poor	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Poor	Agriculture and rural land management	Poor soil management
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Dissolved oxygen	Bad	Urban and transport	Urbanisation - urban development
	Dissolved oxygen	Bad	Agriculture and rural land management	Land drainage
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
Sinderland Brook	Invertebrates	Poor	Urban and transport	Urbanisation - urban development
	Invertebrates	Poor	Domestic General Public	Misconnections
	Invertebrates	Poor	No sector responsible	Not applicable
	Dissolved oxygen	Moderate	Sector under investigation	Unknown (pending investigation)
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Moderate	Water Industry	Sewage discharge (continuous)
	Macrophytes and	Moderate	Domestic General Public	Misconnections

Water body	Classification element	WFD level	Category	Activity
	Phytobenthos Combined			
	Macrophytes and Phytobenthos Combined	Moderate	Urban and transport	Urbanisation - urban development
	Phosphate	Poor	Urban and transport	Urbanisation - urban development
	Phosphate	Poor	Domestic General Public	Misconnections
	Phosphate	Poor	No sector responsible	Not applicable
	Fish	Moderate	Urban and transport	Urbanisation - urban development
	Fish	Moderate	Local and Central Government	Barriers - ecological discontinuity
	Fish	Moderate	Domestic General Public	Misconnections
	Fish	Moderate	Local and Central Government	Flood protection - structures
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
Wirral and West Cheshire Permo-Triassic Sandstone Aquifers	Chemical Drinking Water Protected Area	Poor	Agriculture and rural land management	Forestry
	Chemical Drinking Water	Poor	Domestic General Public	Other (not in list, must add details in comments)

Water body	Classification element	WFD level	Category	Activity
	Protected Area			
	Chemical Drinking Water Protected Area	Poor	Domestic General Public	Private Sewage Treatment
	Chemical Drinking Water Protected Area	Poor	Agriculture and rural land management	Poor nutrient management
	Chemical Drinking Water Protected Area	Poor	Agriculture and rural land management	Poor Livestock Management
	Chemical Drinking Water Protected Area	Poor	Water Industry	Other (not in list, must add details in comments)
	Trend Assessment	Upward trend	Agriculture and rural land management	Poor nutrient management
Weaver and Dane Quaternary Sand and Gravel Aquifers	Chemical GWDTEs test	Poor	Sector under investigation	Unknown (pending investigation)
	Chemical Dependent Surface Water Body Status	Poor	Sector under investigation	Unknown (pending investigation)
	Trend Assessment	Upward trend	No sector responsible	Not applicable
	General Chemical Test	Poor	Agriculture and rural land management	Poor nutrient management
	General Chemical Test	Poor	Agriculture and rural land management	Poor nutrient management
Lower Mersey	Chemical Drinking	Poor	Agriculture and rural land management	Poor pesticide management

Water body	Classification element	WFD level	Category	Activity
Basin and North Merseyside Permo-Triassic Sandstone Aquifers	Water Protected Area			
	Chemical Drinking Water Protected Area	Poor	Water Industry	Other (not in list, must add details in comments)
	Chemical Drinking Water Protected Area	Poor	Other	Unknown (pending investigation)
	Chemical Drinking Water Protected Area	Poor	Agriculture and rural land management	Poor nutrient management
	Chemical Drinking Water Protected Area	Poor	No sector responsible	Private Sewage Treatment
	Chemical Saline Intrusion	Poor	No sector responsible	Saline or other intrusion
	Trend Assessment	Upward trend	Sector under investigation	Unknown (pending investigation)
	Quantitative Saline Intrusion	Poor	No sector responsible	Saline or other intrusion
	Chemical Dependent Surface Water Body Status	Poor	Sector under investigation	Unknown (pending investigation)
Wade Brook	Cadmium and Its Compounds	Fail	Sector under investigation	Unknown (pending investigation)

Water body	Classification element	WFD level	Category	Activity
	Cyanide	Moderate	Industry	Contaminated land
	Invertebrates	Moderate	Industry	Trade/Industry discharge
	Invertebrates	Moderate	No sector responsible	North American signal crayfish
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Poor Livestock Management
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Poor nutrient management
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Poor nutrient management
	Temperature	Good	No sector responsible	Not applicable
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Poor soil management
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Trichloromethane	Fail	Industry	Landfill leaching
	Phosphate	Moderate	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Moderate	Agriculture and rural land management	Poor nutrient management

Water body	Classification element	WFD level	Category	Activity
	Phosphate	Moderate	Agriculture and rural land management	Poor soil management
	Phenol	Moderate	Industry	Trade/Industry discharge
	Ammonia (Phys-Chem)	Bad	No sector responsible	Not applicable
	Ammonia (Phys-Chem)	Bad	Industry	Trade/Industry discharge
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Poor soil management
	Macrophytes and Phytobenthos Combined	Poor	Agriculture and rural land management	Farm/site infrastructure
	Phosphate	Moderate	Agriculture and rural land management	Farm/site infrastructure
	Cyanide	Moderate	Industry	Trade/Industry discharge
Weaver (Dane to Frodsham)	Macrophytes and Phytobenthos Combined	Good	Agriculture and rural land management	Poor Livestock Management
	Macrophytes and Phytobenthos Combined	Good	Navigation	Inland boating and structures
	Macrophytes and Phytobenthos Combined	Good	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Good	Agriculture and rural land management	Poor Livestock Management

Water body	Classification element	WFD level	Category	Activity
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Mitigation Measures Assessment	Moderate or less	Navigation	Other (not in list, must add details in comments)
	Invertebrates	Bad	Sector under investigation	Unknown (pending investigation)
	Phosphate	Poor	Agriculture and rural land management	Poor nutrient management
	Phosphate	Poor	Agriculture and rural land management	Poor soil management
	Phosphate	Poor	Agriculture and rural land management	Farm/site infrastructure
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Poor Livestock Management
	Ammonia (Phys-Chem)	Moderate	Industry	Trade/Industry discharge
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Poor nutrient management
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Farm/site infrastructure
	Ammonia (Phys-Chem)	Moderate	Agriculture and rural land management	Poor soil management
	Phosphate	Poor	Urban and transport	Urbanisation - urban development
	Phosphate	Poor	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
Peckmill Brook,	Ammonia (Phys-Chem)	Poor	Agriculture and rural land management	Poor Livestock Management

Water body	Classification element	WFD level	Category	Activity
Hoolpool Gutter at Ince Marshes.	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Phosphate	Poor	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Poor	Urban and transport	Contaminated land
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Phosphate	Poor	Agriculture and rural land management	Poor soil management
	Phosphate	Poor	Agriculture and rural land management	Farm/site infrastructure
	Fish	Moderate	Water Industry	Sewage discharge (continuous)
	Fish	Moderate	Urban and transport	Urbanisation - urban development
	Fish	Moderate	Agriculture and rural land management	Poor Livestock Management
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Fish	Moderate	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Moderate	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Moderate	Agriculture and rural land management	Poor soil management
	Macrophytes and Phytobenthos Combined	Moderate	Agriculture and rural land management	Farm/site infrastructure

Water body	Classification element	WFD level	Category	Activity
	Macrophytes and Phytobenthos Combined	Moderate	Agriculture and rural land management	Poor Livestock Management
	Ammonia (Phys-Chem)	Poor	Water Industry	Sewage discharge (continuous)
	Ammonia (Phys-Chem)	Poor	Urban and transport	Urbanisation - urban development
Irwell / Manchester Ship Canal (Irk to confluence with Upper Mersey)	Dissolved oxygen	Bad	Industry	Contaminated water body bed sediments
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Dissolved oxygen	Bad	Urban and transport	Contaminated water body bed sediments
	Dissolved oxygen	Bad	Navigation	Inland boating and structures
	Dissolved oxygen	Bad	No sector responsible	Not applicable
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Ammonia (Phys-Chem)	Moderate	Industry	Trade/Industry discharge
	Ammonia (Phys-Chem)	Moderate	Water Industry	Sewage discharge (continuous)
	Ammonia (Phys-Chem)	Moderate	Urban and transport	Contaminated land
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Mitigation Measures Assessment	Moderate or less	Urban and transport	Other (not in list, must add details in comments)
	Mitigation Measures Assessment	Moderate or less	Local and Central Government	Other (not in list, must add details in comments)

Water body	Classification element	WFD level	Category	Activity
	Mitigation Measures Assessment	Moderate or less	Navigation	Other (not in list, must add details in comments)
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Dissolved oxygen	Bad	Water Industry	Contaminated water body bed sediments
	Dissolved oxygen	Bad	Water Industry	Sewage discharge (continuous)
	Dissolved oxygen	Bad	Water Industry	Sewage discharge (intermittent)
Dibbinsdale Brook and Clatter Brook	Dissolved oxygen	Bad	Agriculture and rural land management	Poor Livestock Management
	Dissolved oxygen	Bad	Agriculture and rural land management	Poor soil management
	Dissolved oxygen	Bad	Urban and transport	Urbanisation - urban development
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Phosphate	Poor	Urban and transport	Private Sewage Treatment
	Dissolved oxygen	Bad	Agriculture and rural land management	Poor nutrient management
	Phosphate	Poor	Agriculture and rural land management	Poor nutrient management
	Invertebrates	Poor	Agriculture and rural land management	Poor soil management
	Invertebrates	Poor	Agriculture and rural land management	Poor nutrient management
	Invertebrates	Poor	Domestic General Public	Private Sewage Treatment

Water body	Classification element	WFD level	Category	Activity
	Invertebrates	Poor	Sector under investigation	Unknown (pending investigation)
	Invertebrates	Poor	Urban and transport	Urbanisation - urban development
	Invertebrates	Poor	Agriculture and rural land management	Poor soil management
	Invertebrates	Poor	Agriculture and rural land management	Poor nutrient management
	Phosphate	Poor	Agriculture and rural land management	Poor soil management
	Phosphate	Poor	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Poor	Urban and transport	Urbanisation - urban development
	Fish	Poor	Urban and transport	Urbanisation - urban development
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Fish	Poor	Domestic General Public	Private Sewage Treatment
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Fish	Poor	Agriculture and rural land management	Poor soil management
	Fish	Poor	No sector responsible	Barriers - ecological discontinuity
	Fish	Poor	Agriculture and rural land management	Poor nutrient management
Croco	Macrophytes and Phytobenthos Combined	Bad	Urban and transport	Urbanisation - urban development
	Copper	Moderate	Sector under investigation	Unknown (pending investigation)

Water body	Classification element	WFD level	Category	Activity
	Macrophytes and Phytobenthos Combined	Bad	Agriculture and rural land management	Poor Livestock Management
	Ammonia (Phys-Chem)	Moderate	No sector responsible	Not applicable
	Ammonia (Phys-Chem)	Moderate	Sector under investigation	Unknown (pending investigation)
	Phosphate	Poor	Urban and transport	Urbanisation - urban development
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable
	Phosphate	Poor	Agriculture and rural land management	Poor Livestock Management
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Phosphate	Poor	Agriculture and rural land management	Poor nutrient management
	Phosphate	Poor	Agriculture and rural land management	Poor soil management
	Phosphate	Poor	Agriculture and rural land management	Farm/site infrastructure
	Phosphate	Poor	Agriculture and rural land management	Riparian/in-river activities (inc bankside erosion)
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Macrophytes and Phytobenthos Combined	Bad	Water Industry	Sewage discharge (continuous)
	Macrophytes and Phytobenthos Combined	Bad	Agriculture and rural land management	Poor nutrient management

Water body	Classification element	WFD level	Category	Activity
	Macrophytes and Phytobenthos Combined	Bad	Agriculture and rural land management	Poor soil management
	Macrophytes and Phytobenthos Combined	Bad	Agriculture and rural land management	Farm/site infrastructure
	Macrophytes and Phytobenthos Combined	Bad	Agriculture and rural land management	Riparian/in-river activities (inc bankside erosion)
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Invertebrates	Bad	Water Industry	Sewage discharge (intermittent)
	Invertebrates	Bad	Sector under investigation	Unknown (pending investigation)
Mersey (Bollin confluence to Howley Weir) including Padgate Brook.	Ammonia (Phys-Chem)	Moderate	Water Industry	Sewage discharge (continuous)
	Dissolved oxygen	Moderate	Water Industry	Contaminated water body bed sediments
	Phosphate	Poor	Water Industry	Sewage discharge (continuous)
	Dissolved oxygen	Moderate	Industry	Contaminated water body bed sediments
	Dissolved oxygen	Moderate	Urban and transport	Contaminated water body bed sediments
	Dissolved oxygen	Moderate	Navigation	Inland boating and structures
	Dissolved oxygen	Moderate	No sector responsible	Not applicable
	Polybrominated diphenyl ethers (PBDE)	Fail	No sector responsible	Not applicable

Water body	Classification element	WFD level	Category	Activity
	Benzo(g-h-i)perylene	Fail	Sector under investigation	Unknown (pending investigation)
	Perfluorooctane sulphonate (PFOS)	Fail	Sector under investigation	Unknown (pending investigation)
	Mercury and Its Compounds	Fail	No sector responsible	Not applicable
	Dissolved oxygen	Moderate	Water Industry	Sewage discharge (intermittent)
	Dissolved oxygen	Moderate	Water Industry	Sewage discharge (continuous)
	Invertebrates	Bad	Water Industry	Sewage discharge (continuous)
	Mitigation Measures Assessment	Moderate or less	Navigation	Other (not in list, must add details in comments)
	Invertebrates	Bad	Urban and transport	Urbanisation - urban development
	Mitigation Measures Assessment	Moderate or less	Local and Central Government	Other (not in list, must add details in comments)
	Invertebrates	Bad	Water Industry	Sewage discharge (continuous)
	Invertebrates	Bad	Urban and transport	Flood protection - structures
	Invertebrates	Bad	Water Industry	Sewage discharge (intermittent)
	Mitigation Measures Assessment	Moderate or less	Urban and transport	Other (not in list, must add details in comments)

Table 8.9 The WFD classification status objectives for the Mersey Estuary and selected surrounding river water body catchments.

Water Body	Water Body ID	Water Body Type	Year	Overall WFD Status
Mersey	GB531206908100	Transitional Water	2063	Good
Smoker Brook (Gale Brook to Wincham Brook)	GB112068060410	River	2063	Good
Sankey Brook (Rainford Brook to Mersey)	GB112069061200	River	2027 (low)	Moderate
The Birket including Arrowe Brook and Fender	GB112068060530	River	2063	Good
Sinderland Brook	GB112069060980	River	2027 (low)	Poor
Wade Brook	GB112068060370	River	2063	Good
Weaver (Dane to Frodsham)	GB112068060500	River	2063	Good
Peckmill Brook, Hoolpool Gutter at Ince Marshes.	GB112068060330	River	2027 (low)	Moderate
Irwell / Manchester Ship Canal (Irk to confluence with Upper Mersey)	GB112069061452	River	2015	Moderate
Dibbinsdale Brook and Clatter Brook	GB112068060270	River	2015	Poor
Croco	GB112068055460	River	2027 (low)	Poor
Mersey (Bollin confluence to Howley Weir) including Padgate Brook.	GB112069061012	River	2027 (low)	Moderate