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Promoting adaptation to changing coasts

T1.4.1 Summary of environmental monitoring & evaluation tools

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Contents

Foreword

The Promoting Adaptation to Changing Coasts (PACCo) project is a cross-border initiative which is financially supported by the INTERREG VA France (Channel) England project co-financed by the European Regional Development Fund.

The broad aim of PACCo is to demonstrate that it is possible to work with stakeholders in estuarine regions to deliver a range of benefits for people and the environment by adapting pre-emptively to climate change. It has a total value of €26m, with €17.8m coming from the European Regional Development Fund (ERDF).

The project focuses on two pilot sites: the lower Otter Valley, East Devon, England and the Saâne Valley in Normandy, France.

A key deliverable of PACCo will be a scalable and replicable PACCo Guide which will highlight successful approaches to adaptation and help impacted communities assess whether adaptation is right for them and how they might best proceed. The PACCo Guide will promote the benefits of adaptive management and provide a resource for over 70 coastal communities and policy makers in England and France.

One element of the guide is a field-tested transferable protocol for monitoring and evaluating flooding, biodiversity, habitats and species. This will help inform environmental monitoring in the planning, construction and legacy phases of projects.

For more information see: [Promoting Adaptation to Changing Coasts (pacco-interreg.com)]

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Executive summary

This document outlines the monitoring and evaluation framework and tools used by each project involved with PACCo – the Lower Otter Restoration Project (LORP) in Devon, England and the Basse Saâne 2050 Project in Normandy, France – to monitor and evaluate environmental elements, including flood risk, water quality, pollution and biodiversity. The findings and data from this monitoring have informed the initial Business Case of each project by highlighting the potential benefits of delivery, as well as project design. It also provides the foundation for evaluating whether the projects have achieved their desired environmental outcomes.

Environmental monitoring during climate adaptation schemes is necessary to demonstrate success, learn from mistakes, know when adaptive management is needed, fill known research gaps and to inform funders, partners and local stakeholders of project environmental benefits and disbenefits.

Monitoring and evaluation items can be divided into those which are *statutory* i.e. a legal obligation and therefore essential, *optional but desirable*, such as the collection of data that demonstrates the value of creating inter-tidal habitat and *managing the environmental risk of scheme delivery* where project works are deemed to have a potential deleterious impact on the environment.

Although every coastal adaptation scheme will be different, they will likely share similar phases. These can be broadly categorised as:

(1) *preparation and project development* i.e. the collation of environmental information during the project development phase to identify any constraints to project delivery and to inform project design,

(2) *construction and delivery* i.e. the monitoring of the environment during works to ensure that the project is legally compliant with environmental legislation, the Environment Statement and any related specified planning conditions, and

(3) *the legacy phase* i.e. the monitoring of environmental change caused by the delivery of the scheme into the future to ensure that the desired outcomes are achieved and potential risks do not become issues.

This document outlines a suite of questions (What? How? Who? When?) that will provide a useful starting point to frame any monitoring plan. It also highlights the key themes and environmental assessments that should be considered when developing a climate adaptation scheme related to an estuary. These include: protected and rare species; biting insects; invasive species; habitats; recreational use; traffic use; ground and surface water pollution; flood risk; archaeology; geomorphology and carbon storage.

It is hoped that the tables supplied within this document will act as a useful framework for other similar schemes to assess what monitoring and evaluation will likely be required and how this might be undertaken.

1. Introduction

This document outlines the monitoring and evaluation framework and tools used by each project – the Lower Otter Restoration Project (LORP) in Devon, England and the Basse Saâne 2050 Project in Normandy, France – to monitor and evaluate the environmental elements of each project, including flood risk, water quality, pollution and biodiversity. The findings and data from this monitoring have informed the initial Business Case of each project by highlighting the potential benefits of delivery, as well as project design. It also provides the foundation for evaluating whether the projects have achieved their desired environmental outcomes.

Monitoring processes and methodologies are common to many large-scale construction projects. For example, in England the use of the Environmental Impact Assessment process is commonplace and a legal obligation for many larger schemes (guidance can be found here: https://cieem.net/wp-content/uploads/2019/02/Combined-EclA-guidelines-2018-compressed.pdf).

Locally-specific knowledge has developed throughout the delivery of both projects in the Lower Otter and Saâne Valleys which is unique to coastal climate adaptation schemes. Citizen Science has a useful role to play and formed part of monitoring programme as well as serving as a useful community engagement tool. For example, on the lower Otter citizen scientists have been involved with fish monitoring and bird disturbance (See Case Studies).

In addition to guidance related to the Environmental Impact Assess process, other valuable sources of information are available to guide the development of suitable monitoring for river and floodplain restoration projects. One key example is the Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO) (https://www.therrc.co.uk/PRAGMO/PRAGMO_2012-01-24.pdf. This document offers valuable advice on a set of procedures to determine an appropriate monitoring strategy. An associated Monitoring Planner has also been developed to help set up, structure and organise your monitoring strategy: https://www.therrc.co.uk/monitoring-planner

In France too, standardised protocols exist, for example for the minimum scientific monitoring of river restoration operations: https://professionnels.ofb.fr/fr/node/361 . However, in the specific context of climate change adaptation projects in modified low-lying coastal valleys, these guidance protocols cannot always be implemented automatically but must themselves be adapted. However, they can usefully serve as a starting point and basis for reflection.

It is hoped that the tables supplied within this document will act as a useful framework for other similar schemes to assess what monitoring and evaluation will likely be required and how this might be undertaken. These will be disseminated as part of the PACCo Guide to facilitate replication and use at other sites on both sides of the English channel.

Monitoring and evaluation is an important part of any project to ensure that defined outputs of the correct quality are delivered within the time specified, that delivery risks are minimised and that the desired outcomes are achieved.

In programmes to adapt coastal environments to climate change, and in particular nature-based solutions and managed realignment, environmental monitoring and assessment are particularly important to understand the benefits and risks / disbenefits of the project at each stage: design; implementation; post-construction evolution. In intertidal habitat creation projects, the environmental response is not immediate and salt marshes and mudflats will only start to develop once the sea is allowed to reclaim land that has been previously drained. It is therefore important that monitoring is carried out over a sufficient period of time to assess the success of environmental restoration and the associated ecological functionality of created habitats.

Why carry out monitoring?

Monitoring is necessary to:

- demonstrate the added value of an environmental restoration project and evaluate its effectiveness / success;
- learn from mistakes;
- know when adaptive management is needed;
- contribute to research and scientific knowledge, especially regarding new topics like adaptation to transitional environments due to climate change; and fill known research gaps; and
- inform funders, partners and local stakeholders about project objectives reached and environmental benefits and disbenefits.

Monitoring and evaluation items can be divided into three categories:

- **statutory i.e. a legal obligation** and therefore essential – such as not disturbing breeding dormice during the course of works, for example

- **optional but desirable**, such as the collection of data that demonstrates the value of creating inter-tidal habitat. For example, how the scheme stores carbon, functions as a nursery ground for fish species or supports the local economy. This data is valuable for demonstrating the value of the scheme to society.

- **Managing the environmental risk** of scheme delivery where project works are deemed to have a potential deleterious impact on the environment. An example of this might be the intrusion of saltwater within the influence zone of a freshwater abstraction borehole, or the risk of contaminants being released into the environment as a result of the works to be undertaken.

Although every coastal adaptation scheme will be different, they will likely share similar phases. These can be broadly categorised as:

- **Preparation and project development** – the collation of environmental information during the project development phase to identify any constraints to project delivery

and to inform project design. This might include, for example, survey work to understand the presence of protected species on site and how they might be impacted if the scheme is progressed or studies to understand the significance of the level risk of pollution posed by an old tip site.

- **Construction and delivery** – the monitoring of the environment during works to ensure that the project is legally compliant with environmental legislation, the Environment Statement and any related specified planning conditions. This is also important to ensure that works methodology follows best environmental practice. Monitoring in this phase might include, for example, the surveying of breeding birds to ensure they are not impacted during works, or the day-to-day services of an Ecological Clerk of Works ensuring there are no oil spills resulting from the use of machinery.

- **Legacy monitoring phase** – the monitoring of environmental change caused by the delivery of the scheme into the future to ensure that the desired outcomes are achieved and potential risks do not become issues. Planning conditions and statutory obligations related to environmental monitoring may also extend into the project's legacy phase. This might include, for example, the establishment of any new landscape plantings or verifying the anticipated movement of sediment or shingle as a result of changes in the hydrological regime. It is a common fault of many projects to under-resource monitoring and evaluation. A consequence of this is that clarity is never achieved on whether the project has achieved its objectives or not.

For all monitoring there is the need to establish appropriate **governance systems** to track monitoring progress. In the case of LORP this has involved the creation of a **Monitoring Working Group** with an agreed terms of Reference that oversees monitoring objectives, reporting format, reporting timescales and any need for additional actions if the data suggests that either additional monitoring is required or that management interventions are needed. For Basse Saâne 2050, various data collection protocols have already started through local stakeholders (Syndicat de Bassin Versant, Communauté de communes) and a medium to long-term scientific partnership is being formalised with the University of Rouen M2C (Laboratoire Morphodynamique Continentale et Côtière).

2. Setting the objectives

When developing a monitoring plan it is essential to be clear about the objectives and the questions for which answers are being sought.

The following suite of questions will provide a useful starting point to frame the plan:

- **Why** is there a need for the project and **what** are the project objectives?

- **What** is your monitoring objective/**what** are you trying to observe or learn and **why**? **What** purpose will measurements serve?

- **How** will you collect data and **what** assessment methods are you using?
- Do you have any access to pre-project baseline data?
- **When** do you need to collect data and for **how long**?
- **Who** is going to collect the data? **Who** is going to report and evaluate the data?
- **How much** will the monitoring AND its evaluation cost?
- **How confident** are you that the monitoring will show what you are trying to observe?

Using a monitoring planner (see below) at this early stage in the project can help the planning of monitoring and the consideration of these key questions.

There are reference methodologies for the evaluation of hydromorphological restoration projects, which can be adapted to the specific context of coastal areas adapting to climate change. This includer: the CRR monitoring planner (www.therrc.co.uk/monitoringplanner); minimum scientific monitoring of river restoration operations by the Office Français de la Biodiversité (https://professionnels.ofb.fr/fr/node/361); and the Carhyce protocol for monitoring and evaluation of river sections (https://professionnels.ofb.fr/node/386).

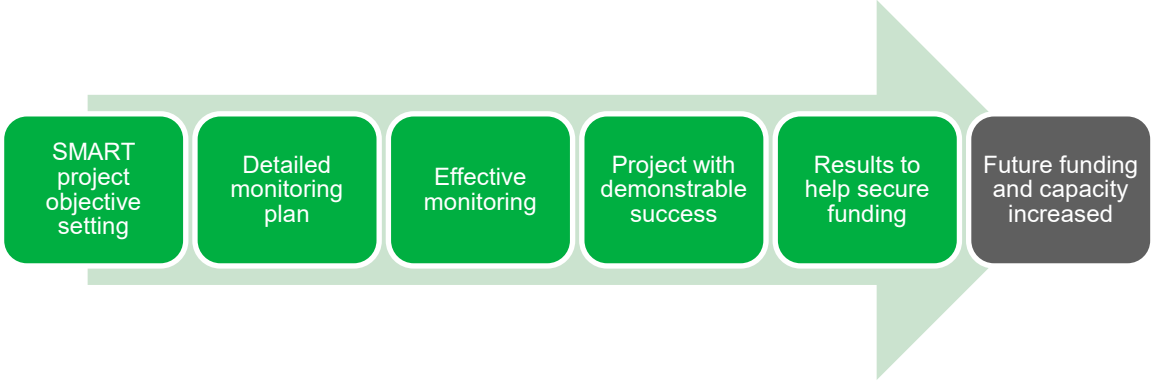
When considering the objectives themselves, the SMART approach can be valuable in making sure these are suitable. Objectives should be:

Specific i.e. are the objectives concise, clear and well defined? Why is the monitoring needed at all?

Measurable i.e. will any measurements be able to successfully track change in a meaningful and reportable way?

Achievable and **Realistic** i.e. is the monitoring possible within the agreed time, within a set budget and with the capacity available.

Time- bound i.e. there is a clear idea of when the objectives will be accomplished by and when monitoring can cease



Planning your monitoring, Source: Adapted from RRC (2017)

For LORP the approach outlined above is summarised in Tables 3.1-3.3.

3. Elements of monitoring and evaluation in the lower Otter valley

3.1. Phase 1. Preparation and project development

During the initial phases of a coastal climate adaptation scheme there will likely be the need to undertake initial bespoke environmental surveying monitoring to provide **baseline data** to help build the initial Business Case for the project. The needs of each project will be unique but a long baseline period (the length depends on the catchment setting) is always preferable to gain a basic understanding of the background hydrological processes, habitats and wildlife in a catchment. A short baseline timeframe is likely to increase the uncertainty in the understanding of how effective the project has been and whether monitoring objectives have been met.

In some cases, baseline data may already exist. For example, in England nationally there are:

- more than 3,000 river level and flow gauges in Great Britain managed by the Environment Agency, Natural Resources Wales and SEPA;
- thousands of rain gauges scattered across the UK.

It is essential to consider what monitoring equipment may already be present in the catchment, and the duration and quality of the datasets. Other organisations and landowners within the catchment may also hold or collect monitoring data which could be used.

In the earliest years of LORP, for example, such work undertaken by the landowner included:

- A report on flooding history;
- Baseline studies to understand the conservation value of the existing habitats within the valley through a National Vegetation Classification (NVC) survey;
- Annual bird surveys including a vantage point survey to understand that functional connectivity of the Otter estuary to adjacent estuaries;
- Data from people counters on the main footpaths.

Once the initial Business Case of a project is accepted the monitoring work will likely become more detailed and formalised and with a significantly wider scope. In the case of LORP this included survey work to understanding what protected species were present at the site, the digging of test pits within an old tip site to ascertain the kind of pollutants contained within it, and ground water modelling to determine the risk of future tidal inundation impacting on a freshwater abstraction borehole.

The primary mechanism for undertaking these assessments during the development phase was through undertaking an Environmental Impact Assessment (EIA). For large landscape scale schemes this is required in accordance with the provisions of the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 and the Marine Works (Environmental Impact Assessment) (Amendment) Regulations 2007.

Table 3.1a Key stages of an Environmental Impact Assessment

EIA Stage	What it entails
Screening	Determining whether the effects of a scheme on the environment will be significant. If so, an EIA will be required.
Scoping	Defines which impacts are significant and require study and monitoring
Baseline study	Collects baseline data on the current status of the environment against which change due to project development can be measured.
Impact assessment	Assesses the sensitivity of the receptor at risk (e.g. people, habitats and species) based on a low/medium/high scoring, the likelihood of risk and the magnitude of the impact on the defined receptor on a low/medium/high basis
Mitigation	Measures to alleviate damaging effects upon the environment and assessment of residual effects (after mitigation)

The role of an EIA is to assess all of the likely significant environmental effects of the proposed project together with ways to avoid or reduce any negative environmental effects. The delivery of LORP involved multiple phases over a two-year period with key operations including vegetation clearance, earthworks, the construction of a new road and road bridge, the relocation of a cricket club and the construction of a footbridge.

With regards to the assessment of biodiversity specifically, this followed guidance provided by the Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2018). The resulting EIA comprised multiple chapters amounting to many hundreds of pages. However, the key topics covered, key regulation and guidance documents, the rationale behind the assessments and the studies and monitoring undertaken are summarised in Table 2.1b and can be considered a useful framework to guide similar schemes elsewhere.

The EIA also informed the development of the Landscape and Ecological Management Plan and Habitat Monitoring Plan that will guide environmental monitoring in the legacy phase (see Section 2.3).

Table 3.1b Themes and environmental assessments undertaken as part of the Environmental Impact Assessment

EIA theme	Purpose of assessment	Studies, measurements & monitoring undertaken
Population and Human Health **Key Regulation:** The Countryside and Rights of Way Act 2000	Considers the potential impacts of the scheme on population and human health including local community, access and recreation, and biting insects.	• Assessment of access provision (footpaths and cycle networks); people/car park counters. • Assessment of recreational use • Surveys of biting insects
Biodiversity **Key Regulation:** Conservation of Habitats and Species Regulations 2017; Natural Environment and Rural Communities Act 2006 (Habitats and Species of Principal Importance) Sections 40 and 41; Countryside and Rights of Way Act 2000; The Hedgerow Regulations 1997; Wild Mammals (Protection) Act 1996; The Environment Act 1995; Protection of Badgers Act 1992; The Salmon and Freshwater Fisheries Act 1972; Eel (England and Wales) Regulations 2009; Wildlife and Countryside Act 1981 (as amended); Marine Strategy Regulations; and Weeds Act 1959. **Key Guiding Documents:** Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2018).	Considers the potential impacts of the scheme on biodiversity, marine ecology and fish.	• Desk study of receptors (designated sites/habitats/species) • Phase 1 Habitat Survey (habitats and protected species including dormice, otter, badger, bats and invasive species (Japanese knotweed, Himalayan balsam and water fern).
Geology, soils and contamination	Considers the direct potential impacts of the scheme on geology, soils and contamination.	• Desk study • Ground investigation through drilling of boreholes and excavation of trial pits

Key Regulation: Environmental Protection Act 1990 and by the Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance 2012 **Key Guiding Documents:** Environment Agency Publication CLR11 Model Procedures for the Management of Land Contamination (Environment Agency, 2004); CIRIA 552, Contaminated land risk assessment: a guide to good practice (CIRIA, 2001).		• Analysis of soils, groundwater and surface waters for likely contaminants, including metals, oils, poly-aromatic hydrocarbons, cyanide, poly-chlorinated bi-phenyls, herbicides, pesticides and asbestos. • Leachate analysis from the tip
Water Environment **Key Regulations:** Water Framework Directive (2000/60/EC); Groundwater Directive (2006/118/EC); Environmental Protection Act 1990, the Water Resources Act 1991, the Water Act 2003, the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 and the Environmental Permitting (England and Wales) Regulations 2016.	Considers the impact of the scheme on the water environment including hydraulically linked surface water and groundwater features.	• Desk Study • Monitoring of groundwater quality within boreholes and piezometers installed over the project area • Creation of conceptual groundwater model. • Flood Risk Assessment
Landscape & Visual **Key Regulation:** European Landscape Convention (ELC), ratified by the UK in 2006; National Parks and Access to the Countryside Act 1949; Water and Sewerage (Conservation, Access and Recreation) (Code of Practice) Order 2000 **Key Guiding Documents:** Landscape Institute and Institute of Environmental Management and Assessment Guidelines for Landscape and Visual Impact Assessment (GLVIA) (3rd Edition).	Considers the landscape and visual impacts from the Scheme.	• Desk Study • Photographs of the site illustrating the local landscape character and landscape descriptions • Baseline Visual Amenity Survey including analysis of viewpoints • Preparation of *Landscape and Ecological Management Plan*
Historic Environment **Key Regulation:** Ancient Monuments and Archaeological Areas Act 1979; Planning (Listed Buildings and Conservation Areas) Act 1990; Enterprise and Regulatory Reform Act 2013; Hedgerows Regulations 1997 (amended 2002); Environment Act 1995.	Assessment of impacts from the scheme on the historic environment including archaeology, built heritage and the historic landscape.	• Desk Study • Archaeological watching brief during the Ground Investigation works. • Geophysical surveys (magnetometer survey)

Key Guiding Documents: Volume 11, Section 3, Part 2 'Cultural Heritage' (HA 208/07) of the Design Manual for Roads and Bridges (DMRB).		
Traffic and Transport **Key Guiding Documents:** Guidelines for the Environmental Assessment of Road Traffic Institute of Environmental Management and Assessment (IEMA), 1993).	Assesses the potential construction impacts of the scheme on traffic and transport.	• Desk Study • Traffic survey • Car park use analysis • Use of priority traffic systems during construction • Designation of specific HGC routes

3.2 Phase 2. Construction and Delivery

The environmental monitoring and evaluation undertaken during the construction and delivery phase of the project is largely guided by the recommendations of the Environment Impact Assessment with the work undertaken by suitably qualified specialists. The importance of this work throughout the delivery phase should not be under-estimated. For example, if the necessary surveys and monitoring are not undertaken this can result in a project being delayed due to works having to halt because of the presence of an overlooked protected species. It can even result in the project not being compliant with the law. In the case of LORP, at key project periods during early vegetation clearance a team of at least eight ecologists were employed for a period of months to oversee work method statements to ensure that the scheme was fully compliant with all protected species licenses. In addition, an Ecological Clerk of Works (ECoW) undertook site visits weekly reporting back to the project team with this including checking on measures to ensure no pollution resulted from works.

Although the monitoring and evaluation will largely be defined by the findings of the EIA there is a need to adopt a flexible approach and to add new environmental monitoring as the need arises. For example, with the LORP scheme beaver welfare suddenly became an issue when a family group took up residence close to an area of intense engineering. Although now a protected species they were not at the time; in the interests of beaver welfare this then required the creation of a site specific Beaver Management Strategy.

The critical elements of environmental monitoring and evaluation undertaken during the project's construction phase are tabulated in Table 2.2a . Most coastal climate adaptation schemes are likely to have broadly similar needs and Table 2.2a can be taken as a useful initial framework to guide what might be required. As well as the monitoring undertaken, Table 2.2a also highlights some of the primary mitigation measures employed.

Table 3.2 Critical elements of monitoring and surveying during the project's construction phase

EIA theme		Why monitor?	Critical elements of monitoring and surveying during project's construction phase
Biodiversity	**Dormice**	To prevent disturbance, be legally compliant and abide by planning conditions	• European Protected Species (EPS) derogation licence obtained (defined method statement) • Watching brief during vegetation clearance • Directional and progressive vegetation removal • Installation of nest boxes
	Otter	To prevent disturbance, be legally compliant and abide by planning conditions	• A pre-construction survey of all watercourses on site for holts and lying-up sites was undertaken for otter at least 12 weeks in advance of any site clearance works.
	Bats	To prevent disturbance, be legally compliant and abide by planning conditions	• Pre-construction survey of trees that were scored as having moderate or high bat roosting potential and that required felling was undertaken during the main active season (May-September). • EPS derogation licence obtained • New species-rich hedgerow planting/gapping up of existing hedgerows and scrub/woodland planting undertaken • Installation of bat boxes
	Beaver	Although not a protected at the time there was a desire to ensure beaver welfare (now protected as of Oct 2022)	• Beaver surveys and development of a Beaver Management Strategy
	Harvest mouse	Although not a legal obligation there is a desire to ensure harvest mouse welfare	• Vegetation checked for harvest mice before clearance e.
	Birds	To prevent disturbance, be legally compliant and abide by planning conditions	• Clearance of vegetation undertaken outside the bird nesting season (mid-February to August inclusive) as far as possible and when within the breeding season, informed by pre-construction checks for the presence of breeding attempts by birds, which would then need to be avoided.
	Reptiles	To prevent disturbance, be legally compliant	• Habitat manipulation within the site to encourage reptiles out of areas to be impacted. Once vegetation has been cut to ground level it needs to be maintained at this level throughout the construction period.

		and abide by planning conditions	• Staged vegetation clearance timed to avoid the reptile hibernation period (November-February inclusive). • Dismantling potential refugia / hibernacula by hand where they are identified within the construction footprint and/or the footprint to be inundated, and their destruction cannot be avoided.
	Fish	To prevent disturbance, be legally compliant and abide by planning conditions	• Catchment connectivity maintained throughout construction including the fluming or temporary diversion of Budleigh Brook where required to maintain passage of fish during watercourse realignment activities. • Construction activities phased to avoid key migratory periods and thereby avoid significant effects on mobile species. • When dewatering was required pumps fitted with appropriately sized screens to prevent the impingement or entrainment of fish including eel. • Fish rescue undertaken on existing Budleigh Brook channel, upstream of the aqueduct, to be infilled before water is diverted into the new alignment.
Geology, soils and contamination		To prevent pollution and contamination	• Tracking systems; dust suppression; spill prevention; site security • Installation of impermeable barrier between the new main creek channel and the eastern area of the landfill, • Watching brief undertaken by the Environmental Clerk of Works (ECoW) during works to detect if any contamination arose. • Monitoring of groundwater and surface water related to installation of highway embankment • Use of rip rap protection where appropriate
Water Environment		To prevent pollution and contamination	• Construction Management Plan detailing the contractors' control methods, • Surface Water Management Plan which will address the management of drainage and sediment management • Pollution Incident Control Plan. • Piling Risk Assessment
Archaeology		To prevent disturbance, be legally compliant and abide by planning conditions	• Written Scheme of Investigation (WSI) with this to include the activities below: • Fieldwalking and metal detecting to recover prehistoric and later artefacts within the topsoil • Targeted investigation (trial trenching) and watching brief undertaken when necessary. • Recording of sections through Big Bank and Little Bank and at the breach at the southern end of the Scheme. • Archaeological monitoring (watching brief) during ground reduction works • Level 1 Historic Building Record (of aqueduct) • Targeted rotary drilling using a rig to recover sealed, intact, core samples from key locations
Traffic		To safeguard health and safety and minimise scheme delivery impact on local communities	• Use of priority traffic systems during construction • Designation of specific HGC routes • Provision of alternative access routes • Clear use of signage

3.3 Phase 3. Environmental Monitoring During the Legacy Phase

Once the managed realignment project has been completed there will be a requirement to monitor environmental change caused by the delivery of the scheme to ascertain whether the desired outcomes are being achieved and to ensure that any identified potential risks do not become issues. Monitoring may also be required to ensure that any planning conditions are met that extend into the project's legacy phase. This may include, for example, the monitoring of the establishment of any new landscape plantings specified as a planning condition and the development of new inter-tidal habitats.

Many environmental benefits are associated with managed realignment schemes that create saltmarsh and mudflat. These include the sequestration of carbon and the creation of high-quality nursery grounds for fish species. Environmental monitoring and evaluation into the legacy phase ensures it is known whether or not these benefits result as envisaged. Along with socio-economic monitoring it can help support the development of other schemes by helping to demonstrate 'proof of case' of the scheme's value to society.

Two key conditions related to environmental monitoring and evaluation during the legacy phase of LORP were associated with the planning consent granted. These were the submission of a *Landscape and Ecological Management Plan* (LEMP) and the submission of a *Habitat Monitoring Plan*. The key monitoring elements of these are shown in Table 2.3a.

Table 3.3 Environmental Monitoring and evaluation during the legacy phase of LORP

Monitoring theme	Priority	Why?	How?
1. Geomorphological change within the existing lower estuary	High	Outlined as desirable by the project's Environment Statement which recommended that the existing Otter Estuary SSSI, beach and the shingle barrier should be subject to monitoring before and after the implementation of the Scheme due to the likelihood of changes in water movement to impact on these. The are some implications of morphological changes on the safety of access of the public. The collection of data will also help inform future project design/assessment	There is synergy with the existing *Coastal Monitoring Programme* run by the Plymouth Coastal Observatory (PCO) which carries out costal monitoring around the English coastline. • Drone every month for first year and then every six months for five years thereafter • Lidar at least once every 5 years through the existing PCO programme (which dictates three flights over a six- year period). Negotiation with PCO required as some additional area capture required. • Aerial photos for habitat mapping from PCO through their Integrated Habitat System – at least once every 5 years. • Subtidal bathymetry • Topographic profiles of spit and lower estuary (from PCO) • Reporting: more intensive over first 6 months to capture large initial changes, annual thereafter.
2. Habitat change within the existing lower estuary SSSI	High	Outlined as desirable by the project's Environment Statement to monitor 1) impacts of habitat loss (including habitat for breeding and overwintering birds) within the existing Otter Estuary SSSI as a result of erosion, and 2) changes to the Marine Coastal Zone as a result of natural erosion processes in the existing estuary and mouth.	• Aerial photographic mapping undertaken through PCO • National Vegetation Classification (NVC) survey every five years to compare with baseline collected during development phase • Structured walkover transects and fixed-point photography

Monitoring theme	Priority	Why?	How?
3. Geomorphological change within the project site (agricultural land) to become tidal	High	Required by the Environment Statement to help understand habitat development (pasture to inter-tidal habitat) to ensure that the project has achieved its objectives.	• Drone every month for first year and then every six months for five years thereafter • Lidar at least once every 5 years through the existing PCO programme (which dictates three flights over a six-year period). Negotiation with PCO required as some additional area capture required. • Aerial photos for habitat mapping from PCO through their Integrated Habitat System – at least once every 5 years.
4. Habitat development within the project site	High	Required by the Environment Statement to monitor new inter-tidal areas for establishment of saltmarsh and mudflat habitat. The delivery of 55 hectares of mudflat and saltmarsh is a statutory requirement specific to LORP related to the 2017 Habitat Regulations and the delivery of compensatory habitat on the Exe Estuary Special Protection Area.	• Drone every month for first year and then every six months for five years thereafter • Aerial photos for habitat mapping from PCO through their Integrated Habitat System – at least once every 5 years. • National Vegetation Classification (NVC) survey every five years to compare with baseline collected during development phase • Structured walkover transects and fixed-point photography
5. Mitigation planting for habitats lost due to project delivery	High	Required by the Environment Statement and a statutory obligation under the scheme's planning condition related to the Landscape and Ecological Management Plan (LEMP) to ensure successful establishment of all new hedgerow and woodland plantings and to identify situations where remedial actions may be required.	• Annual monitoring of new hedgerow and woodland plantings for 5-year period.
6. Translocation of nationally scarce species	High	Required by the Environment Statement to safeguard the rarest (nationally scarce) plant species within the project area including galingale (Cyperus longus) and divided sedge (Carex divisa).	• Annual monitoring of all translocated plant species confirming presence/absence, with relative abundance estimated using the DAFOR scale • Fixed point photography

Monitoring theme	Priority	Why?	How?
7. Surcharge settlement + ground water	High	Required by the Environment Statement to monitor groundwater for indicators of contamination related to the installation of the highway embankment on top of the landfill which will surcharge the soft compressible landfill material during construction.	• Settlement of landfill surcharge • Ground water (level & quality) during and following construction/ embankment surcharge • Surface water (watching brief/visual observation/ quality sampling) adjacent surcharge areas and upstream/ downstream during channel excavation and bridge construction over trunk main • Watching brief to be undertaken by an Ecological Clerk of Works
8. Water levels and quality of ground water + estuary salinity	High	Required by the Environment Statement to monitor possible changes in groundwater salinity around the area of Little Marsh arising from the scheme that might impact the SWW abstraction boreholes at Otterton. Residual uncertainties are attached to groundwater modelling assessments. To include some monitoring of salinity within the main channel of the Otter.	• Existing and new data from existing boreholes • New data from new boreholes in vicinity of Little Marsh •
9. Water quality of surface water (site and estuary)	High	Required by the Environment Statement to monitor surface water quality (salinity) in the River Otter to support groundwater monitoring strategy (see above). There is the potential for the scheme to reduce the negative contribution to poor water quality from livestock /fertilizers etc. due to the conversion of agricultural land to inter-tidal habitat.	• Monitoring of salinity within main channel of River Otter • Visual observation
10. Bird use	High	Required by the Environment Statement to monitor the success of the provision of functional habitat for Special Protection Area (SPA) qualifying bird species such as brent geese and black-tailed godwit.	• Annual analysis of existing WEBS data recording for SPA qualifying bird species • Supplementary data collected annually through citizen science volunteers
11. Invertebrate sampling of site	Low	Although not required by the Environment Statement there is value in understanding invertebrate abundance and diversity as this is a key component of inter-tidal habitat diversity and indicator of estuarine health. In addition, invertebrates are a key	• Only to be undertaken if there are low bird counts to help understand reason.

Monitoring theme	Priority	Why?	How?
		food source for key target wading species. Baseline data is available for the estuary.	
12. Fish monitoring - use of the site by juvenile species #1	Low	Although not required by the Environment Statement there is a benefit in understanding the use of the new estuary area by marine fish species as inter-tidal habitats are known to be important nursery grounds. This data to provide further supporting evidence.	• Seine and fyke netting
13. Fish monitoring – change in fish passage outside site #2	Low	Although not required by the Environment Statement there is a potential impact of LORP in misdirecting/trapping migrating fish due to the introduction of new freshwater lures although this is not thought to be significant. The scheme also potentially offers benefits in fish movements (trout) into Budleigh Brook which will be removed from the aqueduct and placed in the floodplain.	• Fish surveys on the Budleigh brook, including through the use of electrofishing
14. (Mainly) Mitigation work monitoring. Rare and protected species (e.g. Dormice)	high	Required by the Environment Statement to ascertain the degree of how effective mitigation related to protected species has been (e.g. reptile refugia/dormouse boxes).	• Reptile monitoring 1, 3, 5 yrs • Dormice nest box checks each spring for 5 years with monthly monitoring between April and October in years 1, 3 and 5. This in accordance with the European Protected Species derogation licence conditions • Bat box check annually for 5 years Owl box check annually for 5 years
15. Carbon sequestration	High	Although not required by the Environment Statement it is desirable to monitor the degree to which the new inter-tidal habitats will be storing carbon. Carbon sequestration within saltmarsh and mudflat is known to be significant and can assist with responding to the climate emergency. Understanding carbon storage when compared to baseline levels and the carbon footprint of the project provides valuable learning on carbon storage value.	• Sediment samples and analysis • Accretion monitoring from Lidar + ground truthing • Sedimentation pins • Baseline survey required
16. Visitor use and management	High	Required by the Environment Statement to understand the impact of visitors on wading bird populations.	• Car park counters and people counters on path • Core Counts, involving continued observation over a fixed time period (1 hour

Monitoring theme	Priority	Why?	How?
			and 45 minutes), recording the birds present, human activity, and any interactions between people and birds. • Vantage Point Counts, involving quick, ‘snapshot’, counts recording the number of birds present and the distribution of human activity.

4. Elements of monitoring and evaluation in the Saâne Valley

Monitoring undertaken outside of the project framework

Although providing ecological baseline data and contributing knowledge of value to the scheme related to ongoing ecological status, significant monitoring that was undertaken was not considered to be part of the more tightly defined Saâne territorial project. Monitoring of river water and bathing water quality began before the territorial project was conceived and will continue after the project is completed. Monitoring activities have contributed to the "knowledge" aspect of the lower Saâne valley, the understanding of its initial ecological condition and the causes of environmental degradation. They have also made it possible to target operations that will be most impactful in improving the ecological condition of the valley.

Monitoring includes: the quality of the river's water, organised as part of the monitoring imposed by the European Water Framework Directive; regulatory assessments of the quality of bathing water for the health authorisations of the beaches of Quiberville and Sainte-Marguerite.

See Accompanying Document No. 4 of the SDAGE Seine Basin and Normandy Coastal Rivers on the water status monitoring programme (https://www.eau-seine-normandie.fr/sites/public_file/inline-files/4_Resume_prg_de_surveillance_de_l_etat_des_eaux_et_etat_actu_cle7f5588.pdf), and the annual reports of the Regional Health Agency on bathing areas (https://www.normandie.ars.sante.fr/qualite-des-eaux-de-baignade-en-normandie-94-des-sites-de-baignades-sont-de-bonne-ou-dexcellente)

This monitoring is ongoing and independent of the territorial (PACCo) project.

Monitoring carried out within the framework of the Saâne territorial project

Various studies have contributed to building the database on the initial ecological status of the lower Saâne valley. They are the result of regulatory obligations or additional studies carried out to respond to specific problems (e.g. the beach vulnerability profile in 2015) or to provide input for discussions on the territory's future approach in adapting to climate change.

This includes in particular the studies carried out as part of the Interreg project "Littoraux et Changements Côtiers" in 2011-2014 (https://licco.eu/what-is-licco/), the monitoring of water quality upstream and downstream of the wastewater treatment plant carried out by the Terroir de Caux Community of Municipalities, the fauna-flora-habitat inventories in 2021-2022, which will be used in particular for the environmental assessment of the territorial

project, and the hydrological and piezometric monitoring carried out since mid-2022 under the supervision of the Syndicat Mixte des Bassins Versants Saâne Vienne Scie.

Specific monitoring prior to the works was also carried out in 2021-2022 on the site of the new tourist facility, and in the lower valley on the rights of way affected by the reconnection of the Saâne to the sea. This included: soil quality and geotechnics, assessment of the pyrotechnic (unexploded ordnance) risk given the site's past during the Second World War, archaeology.

European Water Framework Directive (WFD)

The European Water Framework Directive (WFD) requires that good ecological status of rivers be achieved by 2021 with this assessed on the basis of the abundance and diversity of biological populations (particularly fish), and physical-chemical parameters (e.g. presence of nitrates, phosphorus, organic matter, etc.).

As part of the project management for the restructuring and extension of the wastewater systems in the lower Saâne valley sector, the objective was to define an initial state of the bacterial load of the receiving environment in the area of future discharge and then to implement monitoring of the future quality of the discharges with one objective being to create a warning system in the event of a waste water system failure.

Environmental Assessment

Environmental assessment is a process aimed at integrating environmental considerations and processes into the development of a project or a planning document, right from the project’s early stages. It serves to inform both the project lead organisation and the administration of follow-up work for the project with regard to environmental issues and those relating to human health in the area concerned, as well as to inform and secure public participation. It needs to give an account of the potential or proven effects of the project or programme on the environment and enable the choices made to be analysed and justified with regard to the issues identified in the area concerned. The environmental assessment must be carried out as early as possible and cover the entire project and its impacts. The order of 3 August 2016 in France (reforming the procedures intended to ensure public information and participation in the preparation of certain decisions likely to have an impact on the environment) has shaped this approach; in particular, to transpose the European directive of 16 April 2014 on the assessment of the effects of certain public and private projects on the environment.

The environmental assessment is a process consisting of:

- The preparation of an environmental impact assessment report (impact study for projects, environmental impact report for plans and programmes) by the project owner or the public person responsible for the plan or programme. The report includes in particular: a description of the initial state of the environment, its prospects for development without implementation of the plan or programme, the main environmental issues, the environmental characteristics of the area; a description and

assessment of the significant effects of the plan or document on the environment and human health; the measures planned to reduce and, as far as possible, compensate for the significant negative effects of the plan or programme on the environment (ERC sequence: Avoid, Reduce, Compensate); the criteria, indicators and procedures adopted to monitor the effects of the document on the environment.

- The implementation of the planned consultations, in particular the consultation of the environmental authority, which provides a formal opinion on the project, plan or programme and on the environmental impact assessment report, and the consultation of the public.
- Examination by the authority authorising the project or approving the plan or programme of the information contained in the assessment report and received during the consultations.

The environment must be considered in its entirety with focus including: population and human health, biodiversity, land, soil, water, air and climate, material assets, cultural heritage and landscape, as well as the interactions between these elements.

The list of categories of plans and programmes subject to a case-by-case examination or systematic environmental assessment is given in Article R.122-17 of the Environmental Code.

An environmental assessment is therefore underway for the entire Basse Saâne 2050 territorial project for the following actions: new wastewater treatment plant in Longueil; relocation of the campsite; reconnection of the river and the lower valley to the Channel. It is supported by the Syndicat Mixte des Bassins Versants Saâne Vienne Scie.

For the Saâne territorial project, this environmental assessment incorporates the results of case-by-case studies carried out for the operations of the wastewater treatment plant, the sewerage networks (zoning) and the Quiberville tourist facility. It complements these review procedures by providing an overview of the project and its environmental impacts, rather than assessing each of the project operations independently of the common objectives. It also includes assessments specific to the operation of reconnecting the river to the sea.

Designing and carrying out projects resulting in the least environmental impact implies respecting the '**avoid**, **reduce** and **compensate**' sequence and the related regulations. This sequence is the common basis for environmental procedures for many project appraisals (e.g. impact studies ; land clearing ; water law ; Natura 2000 ; protected species, etc.).

All of these environmental procedures require:

- Carrying out an initial environmental assessment of a site that is the subject of installation works or activity (IOTA) focusing on fauna/flora/habitats/wetlands/surface water quality aspects etc.
- Assessment of the direct and indirect impacts of the project on the environment
- The search for avoidance, reduction and compensation measures
- Article L. 122-1 III of the Environmental Code specifies that environmental evaluation is a process consisting of:

- Carrying out an environmental impact study to enable the developer to prepare for a project while at the same time assessing its effects on the environment in order to either avoid negative impacts, reduce those that could not be sufficiently avoided and, if possible, compensate for the significant effects that could not be avoided or sufficiently reduced. To this end, the environmental assessment must be carried out at the project design stage and is an instrument for improving the quality of the project and its integration into the environment;
- Consultations with the environmental authority, local authorities and their groupings, and the public should inform the project owner, the public and the authority competent on decision making;
- The mechanism for identifying the avoidance, reduction and compensation measures proposed by the project is the impact study. The impact study approach has been strengthened in France (Article R. 122-5 of the Environmental Code). This is the responsibility of the project owner, with the impact study undertaken by competent experts (VII of Article R. 122-5);
- A decision to authorise the project is undertaken in accordance with the conditions defined in Article L.122-1-1 of the Environmental Code. The authority competent to issue this decision prescribes, on the basis of the project owner's proposals and the opinions received, "the avoidance, reduction and/or compensation measures that the project owner must respect". It also specifies the procedures for monitoring the project's impact on the environment and human health. An allied article regulates the case of projects that are not subject to an authorisation that meets these conditions.

During decision making related to environmental impacts the project must be considered "as a whole, including in the event of fragmentation in time and space and in the event of multiple project owners, so that its impact on the environment is assessed as a whole". Furthermore, the impacts are assessed when the first authorisation is issued.

The impact study must therefore: consider the environment in its entirety; be proportionate to the environmental issues of the project and the area; justify the project, its choices and its location with regard to environmental criteria; give an account of the foreseeable effects of the project, including during the construction phase; propose measures to avoid, reduce or compensate for potential impacts; indicate how these measures and their effects will be monitored after the project is completed.

The continuous, progressive and iterative environmental assessment process is carried out under the responsibility of the project developer. It requires exchanges between the project designers and the consultancy(ies) responsible for the impact study from the outset of the project. The iterative approach makes it possible to study different development options and compare their effects on the environment in order to define a project with the least environmental impact. This approach must not be reduced to the production of a study that justifies, after the fact, choices already made without having really contributed to the development of the project.

In accordance with Article R.122-5 of the Environmental Code, the study must include the following items:

1. The **non-technical summary**, which may be the subject of a separate document
2. **Description of the project**: location; physical characteristics; main characteristics of the operational phase (including demolition works if applicable); estimated types and quantities of waste and emissions
3. A description of the **relevant aspects of the current state,** the so-called '*baseline scenario'*, and their evolution in the event of project implementation, as well as an overview of the likely evolution of the environment in the absence of project implementation
4. Description of **factors likely to be significantly affected** by the project: population; human health; biodiversity; land; soil; water; air; climate; physical assets; cultural heritage and landscape.
5. A description of the **significant environmental impacts** that the project is likely to have as a result of: the construction, existence and demolition of the project; the use of natural resources; the emission of pollutants, noise, vibration, light emissions, heat, radiation, creation of nuisances, waste disposal and recovery; risks to human health, cultural heritage or the environment; the cumulative impact with other existing or approved projects; the project's impact on the climate and the project's vulnerability to climate change; the technologies and substances used.
6. Description of the **significant negative impacts** of the project.
7. A description of the **alternatives** and an indication of the main reasons for the choice made.
8. Measures to **avoid, reduce or compensate for** the effects, together with the corresponding cost estimates.
9. **Modalities for monitoring** measures and their effects.
10. A description of the **predictive methods** or evidence used to identify and assess the significant environmental effects.

(the above text is an excerpt from the specifications for the recruitment of the consultancy firm in charge of preparing the environmental assessment file)

4.1 Phase 1. Project preparation and development

Water quality of the river

A water quality measurement station has been installed in Longueil since 2010 as part of the European Water Framework Directive monitoring network, under the supervision of the Seine Normandy Water Agency (see https://seine-normandie.eaufrance.fr/eaux-de-surface/contenu-et-programme-de-surveillance/). Measurements are taken monthly and concern the physicochemical and hydrobiological quality of the river (IBD Diatom Biological Index, IBGN Standardised Global Biological Index, IBMR Macrophytic Biological Index in Rivers, IPR Fish Index).

The sampling and analysis protocols are AFNOR standardised with data made available to the public in Naïades (http://www.naiades.eaufrance.fr/). Each station has its own SANDRE code which allows all available results to be made available on a site-specific basis. At Longueil, the SANDRE code of the station is 03216000.

Station 03216000 LA SAÂNE A LONGUEIL 1 was created in March 2010. This is the representative station for the water body FRHR168 La Saâne from its source to the mouth. It is positioned on the RCS (Réseau de contrôle de surveillance) monitoring network. The RCS must enable the general state of the water to be assessed, as well as its long-term evolution.

The parameters monitored on the water can be divided into three components:

- physico-chemical: Basic parameters, major ions and PSEE (specific pollutants of ecological status) monitored annually with a monthly frequency.

- biology: (Macroinvertebrates, Diatoms, macrophytes and fish).

- Chemistry: monitoring of priority substances including pesticides, relevant and toxic substances every other year, with a frequency of six per year.

Bathing water

This monitoring is undertaken by the ARS Normandie (Regional Health Agency). It enables the quality of bathing water to be checked, particularly for *E. coli* contamination. The results have highlighted the shortcomings of the existing sewage systems in the valley. For example, in 2016, the bathing water was assessed as "non-compliant" with "poor" water quality, resulting in days of closure of the bathing area. Since 2018, each annual report includes a "chronic vulnerability". In 2015, the Vulnerability Profile established that this chronic vulnerability was due to the failure of wastewater systems in the valley.

LiCCo - Littoraux et Changements Côtiers

During the LiCCo (Littoraux et Changements Côtiers) project, a large amount of monitoring was carried out and served as a basis for the development of the Saâne territorial project. This provided a complementary source to the monitoring carried out in recent years: developments have already been noted between the LiCCo project (2011-2014) and the PACCo project (2020-2023).

The monitoring that was undertaken between 2011 and 2014 is as follows:

- Ecological functions for birdlife,
- Functional approach to fish and carcinofauna species assemblages,
- Composition of fish populations,
- Sources of disturbance to fish populations,
- Fish data,
- Flora (and plant communities) of the lower Saâne valley. Prospective reflections and monitoring proposal,

- Topography of the Saâne

Water quality monitoring upstream and downstream of the wastewater treatment plant discharge

This study, commissioned in 2021 by the Communauté de communes Terroir de Caux, aimed to carry out an initial assessment of the bacteriological quality of the water of the Saâne.

This study is complementary to the one carried out in 2020 on the physico-chemical and hydrobiological quality of the Ouville-la-Rivière and Longueil sectors.

In order to define this initial state, four specific campaigns was carried out:

- 1 campaign during high water in dry weather;
- 1 campaign during high water in wet weather;
- 1 campaign during low water in dry weather;
- 1 campaign during low water in rainy weather.

Extract from Study of the initial state of the bacteriological quality of the Saâne as part of the project management for the restructuring and extension of the wastewater systems in the Lower Saâne Valley sector, (EEC/CCTC, January 2021)

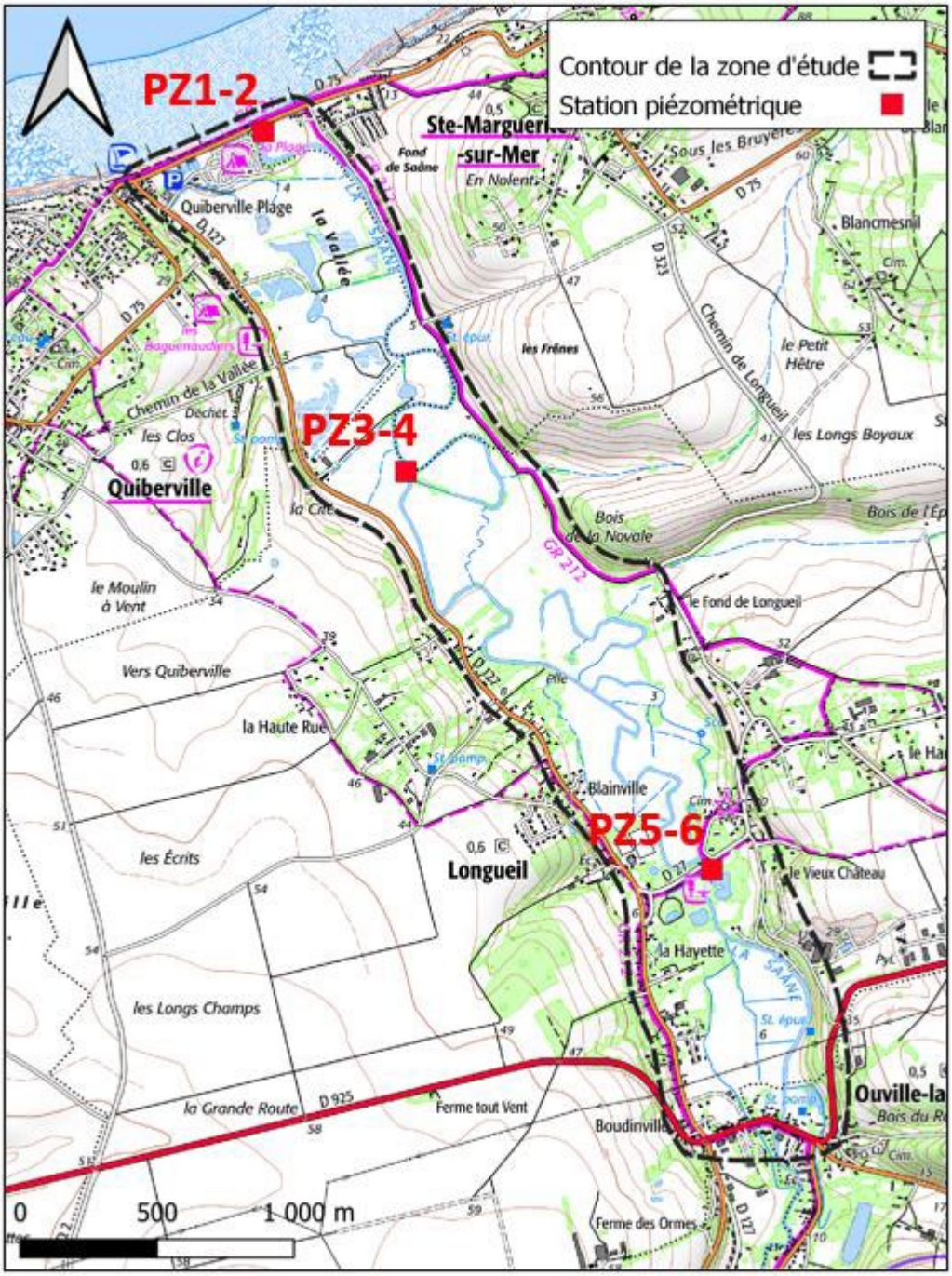
Hydrological and piezometric monitoring

In order to carry out monitoring of the future reconnection of the lower valley to the sea, a study was initiated starting in 2021 using qualitative and quantitative indicators.

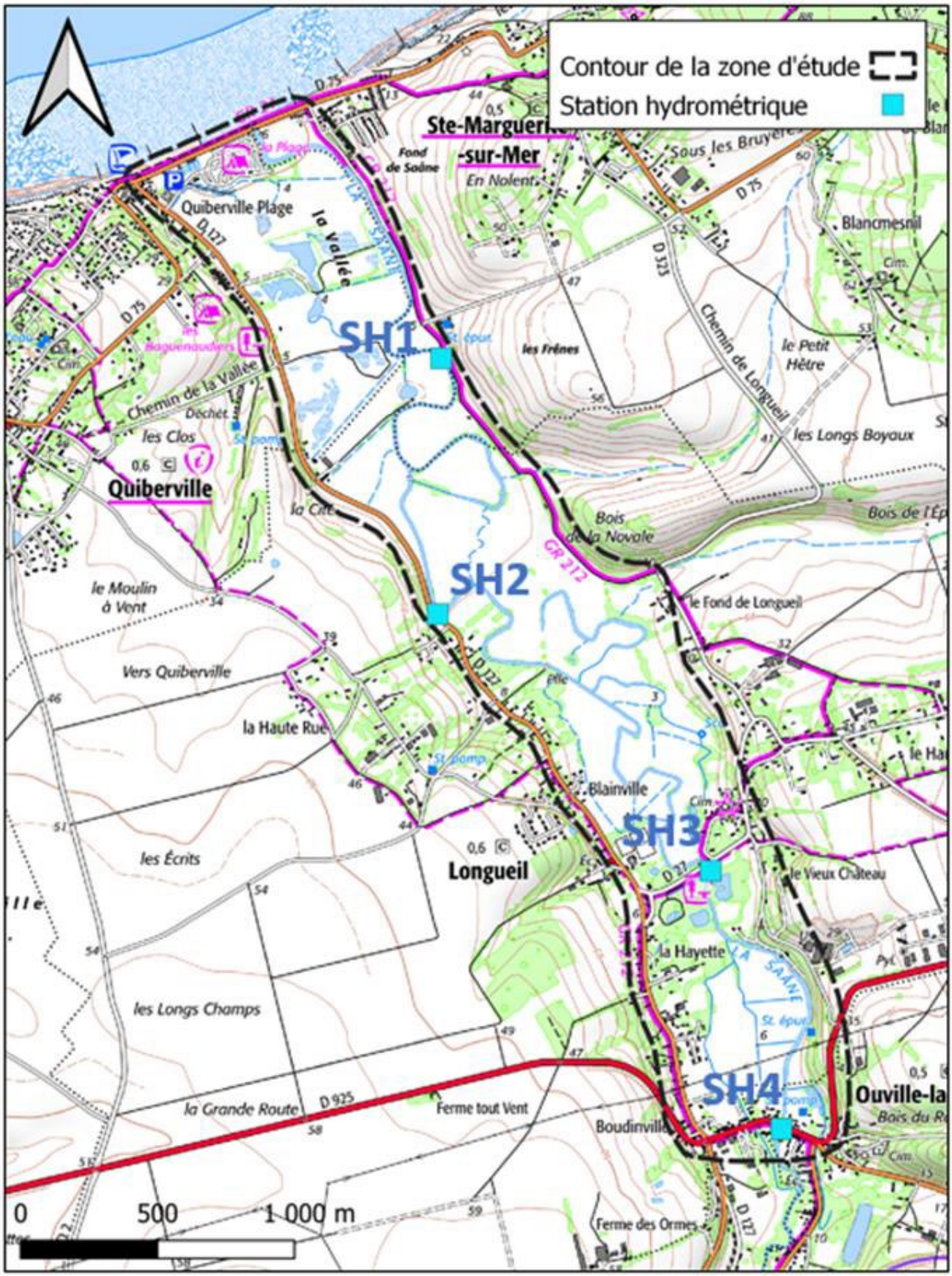
In the framework of the Reconnection Project, the validation of the environmental benefits of the project feedback requires qualitative and quantitative monitoring and the use and tracking of indicators. To this end, long-term monitoring of surface water and groundwater has been undertaken.

In 2021, a monitoring network was defined in partnership with the Seine-Normandy Water Agency and the local stakeholders involved in the project. As a result, a network of instruments for monitoring water levels and salinity in surface and groundwater was established across the lower valley. Implementation took place during 2022, with all installations completed September 2022 and subsequently commissioned.

Over a depth of four kilometres, three piezometric stations (deep chalk water table and water table accompanying the watercourse) and four hydrometric stations were installed



In addition to variations in the water table, the water quality criteria monitored at the piezometric stations are electrical conductivity (salinity), temperature and dissolved oxygen.



The most upstream hydrometric station (SH4) is located outside the zone of influence of the Saâne spur gate; it constitutes a control station. All the other stations are located in this zone of influence.

The monitoring programme concerns the following parameters: pressure, temperature, electrical conductivity (salinity), dissolved oxygen and turbidity. Water level gauges will be installed at each station to allow a visual reading of the water level.

Initial state

One of the most important studies included in the environmental assessment consisted of inventories of natural environments undertaken on an annual cycle. These were carried out in 2021-2022 under the supervision of the Syndicat Mixte des Bassins Versants Saâne Vienne Scie with funding from the Seine-Normandie Water Agency, and were completed in June 2022. The aim of this assessment was to establish the most exhaustive inventory possible of the project area, which covers 260 hectares.

Various aspects were investigated: wetlands; fauna; flora and habitats; water quality (physico-chemistry and hydrobiology). This work was undertaken in order to establish an assessment of the general ecological sensitivity of the site, to evaluate the expected ecological gain following the development work and to propose action guidelines to optimise this gain.

The greatest proportion of inventories was carried out in the downstream part of the study area and in the valley bottom; no inventories were carried out in the built-up sectors or in the overgrazed eutrophic grasslands; a brief inventory was carried out on the foreshore where the river outflow meets the sea, in particular on the algae whose populations are likely to evolve during the reconnection process; the connectivity between the other non-surveyed habitats of the extended study area was also studied. This perimeter is consistent with the one surveyed in 2012-2013 by the Conservatoire botanique national de Bailleul (CBNBl), which allowed a comparison of the two inventories and an initial image of the evolutionary trajectory of the lower valley.

Wetland

The objective was to delimit, characterise and map the wetlands likely to be impacted by the component projects using floristic and pedological criteria. This analysis was carried out on the sectors of the study perimeter likely to be impacted by the works.

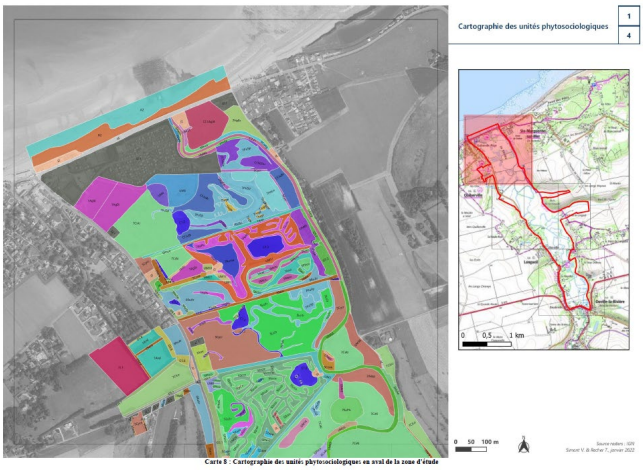
Several complementary methods were used to delimit and characterise the wetlands of the lower Saâne valley in the study area. First of all, an initial delimitation was undertaken using a drone survey carried out on 24/04/2021. Subsequently there was a site walkover to compile a floristic list of wetland species in order to calculate their coverage. Soil surveys and pH measurements were also undertaken in areas where there was little vegetation due to overgrazing in order to complete the inventory. Finally, Ellenberg indices were used to characterise the wetlands inventoried.

Fauna and Flora

The implementation of a flora-fauna habitat section made it possible to draw up an inventory of the terrestrial and semi-aquatic flora and fauna of the lower Saâne valley, as well as to identify the habitats that are already indicative of marine influence and that are likely to

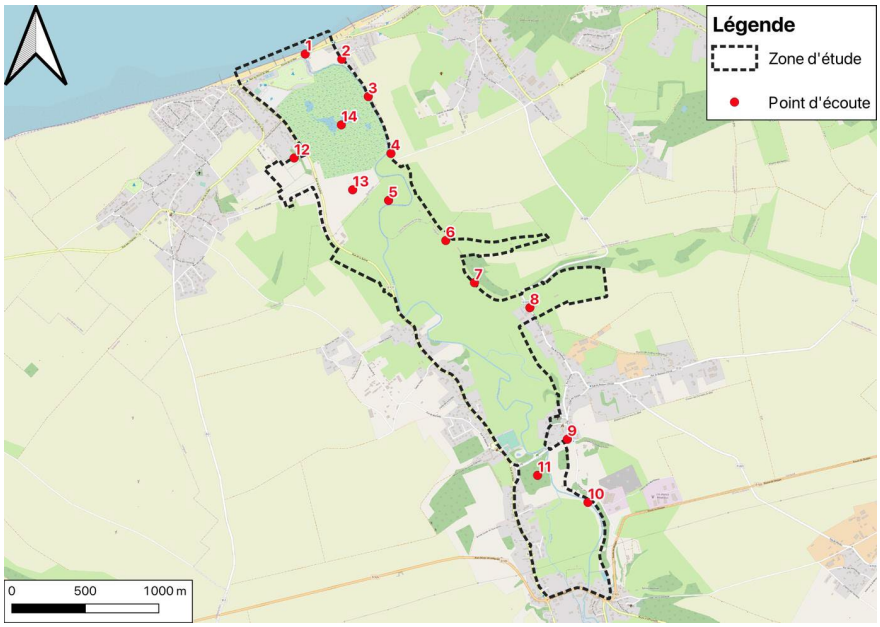
develop after the reconnection of the valley to the sea. Inventories were made of flora, amphibians, reptiles, invertebrates (orthopterans, lepidopterans, odonates), avifauna and mammals (chiropterans, semi-aquatic mammals (in particular the amphibian vole and the aquatic crossover) and protected terrestrial mammals.

Protected species have been identified, and key floristic species precisely located.



Example of phytosociological habitat mapping

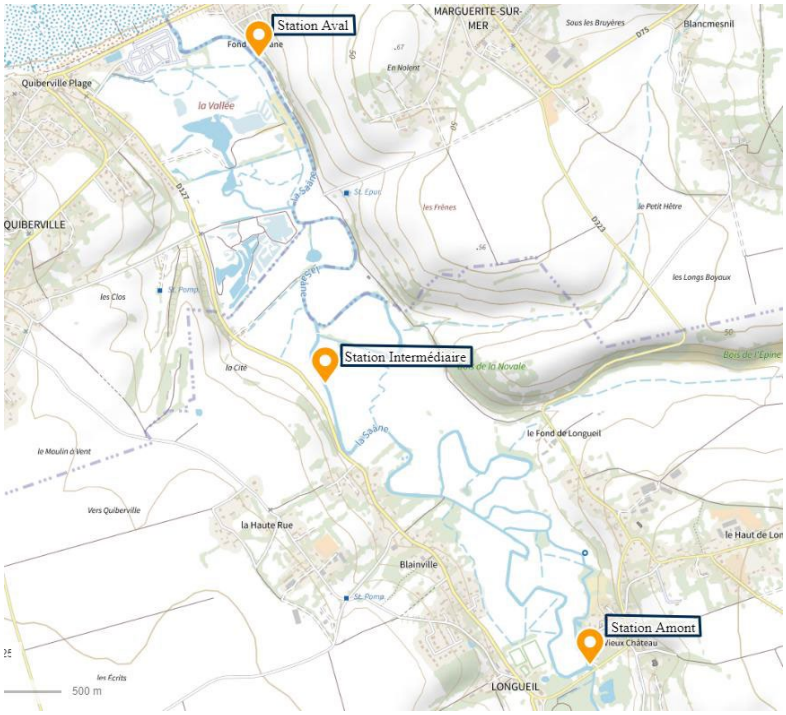
In order to determine with sufficient precision the bird species frequenting the different parts of the study area and their respective numbers at different times of the year, a monthly census was carried out over a period of one year, starting in February 2021, with 14 observation (listening) points (and 12 transects) in order to cover the surface area and the habitats present.



An inventory of amphibians was carried out by listening to the sound emissions of anurans, fishing with dip nets (including the detection of larval forms), nocturnal surveys with lamps, and the installation of creels. About forty ponds and hydraulic annexes were surveyed, by day and night.

Water Quality

In order to characterise the initial state of surface water quality, physico-chemical analyses, flow measurements and biological indices were carried out at three stations upstream and downstream of the Saâne in the study area. Four physical chemistry and flow measurement campaigns were carried out on 23 June, 5 July, 16 September and 23 September to cover dry and wet weather situations.



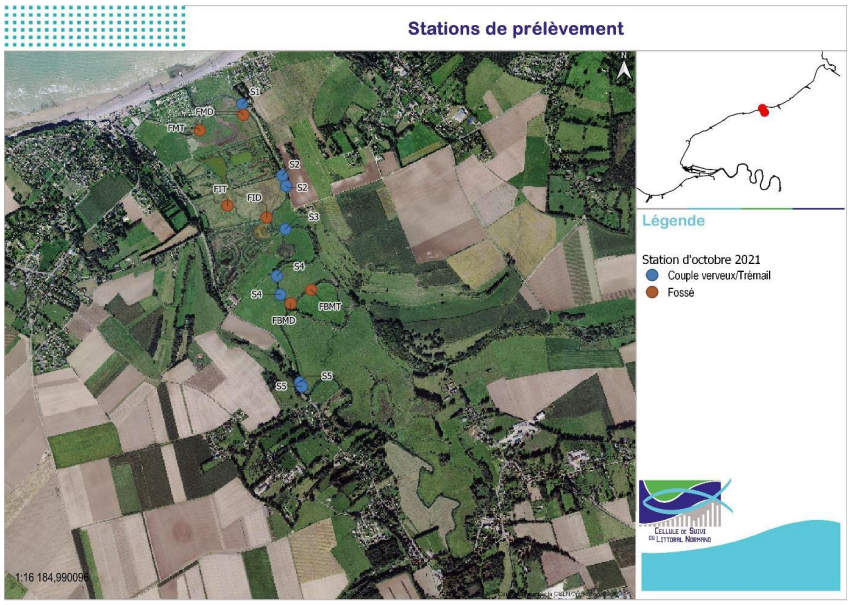
Location of the physico-chemical and hydrobiological monitoring stations on the Saâne

The sampling techniques for physico-chemical analyses are in accordance with ISO 5667-1; 5667-2; 5667-3 and 5667-6 for water. For the flows, the measurements will be carried out using a current meter in accordance with standard NF EN ISO 748 (X10 301). The physico-chemical parameters analysed in situ are Conductivity, pH (min, max), dissolved oxygen, oxygen saturation rate and water temperature. The table overleaf belowsummarises the laboratory analyses (methods and quantification thresholds):

Paramètres	Méthodes	Seuils de quantification
Demande Biologique en Oxygène : DBO5	NF EN 1899-2	0.5 mg/L O2
Demande Chimique en Oxygène : DCO	ISO 15705	10 mg/L O2
Matière En Suspension : MES	NF EN 872	0.5 mg/L
Turbidité	VF EN ISO 7027	0.1 NFU
Ammonium : NH4	Flux séquentiel	0.01 mg/L NH4
Azote de Kjeldahl : NTK	NF EN 25663	0.2 mg/L
Nitrites : NO2	Flux séquentiel	0.01 mg/L NO2
Nitrates : NO3	Flux séquentiel	0.5 mg/L NO3
Orthophosphates : PO4	Flux séquentiel	0.015 mg/L PO4
Phosphore total : Pt	NF EN ISO 15681-2	0.05 mg/L Pt
Chlorures : Cl	Flux séquentiel	1 mg/l
Sulfates : SO4	Flux séquentiel	0.5 mg/l
Carbone organique dissous : COD	NF EN 1484	0.2 mg/ C
Carbonne Organique Total : COT	NF EN 1484	0.2 mg/L C
Escherichia coli	NF EN ISO 9308-3	38/100 ml
Entérocoques	NF EN ISO 78799-1	38/100 ml

With regard to hydrobiology, samples and analyses concerned the following indices in application of the protocols established for the European Water Framework Directive: Diatom Biological Index (DBI); Macrophytic Biological Index in Rivers (MBI); River Fish Index (RFI).

Finally, inventories of fish in the various water systems (ditches, backwaters) and freshwater molluscs completed the biological system.



Map of the actual position of the fishing stations in the minor bed, ditches and a dead end of the Saâne during the October 2021 campaign

Finally, on an experimental basis, eDNA inventories completed the knowledge of the initial state of the study area for three target groups: fish, molluscs and amphibians. This inventory complements the classic inventories that can be difficult to carry out in a brackish environment. The monitoring in the watercourse was completed by an inventory of algae, molluscs and crustaceans on the foreshore.

Photographic monitoring

In order to better illustrate the evolution of the lower valley, a photographic monitoring system was established. It comprised two systems:

- Fixed point photography (cameras fixed on supports) at regular intervals, allowing the creation of a film of the evolution of the construction sites (timelapse);
- Regular aerial views (from drones) to capture the evolution of the construction sites but also of the lower valley as a whole. Viewpoints were defined to try to capture the evolution of the lower valley as well as possible.

WQI-L: ecological quality indicator for the coastline

The WQI-L (IQE-L) is the result of a partnership between the Museum National d'Histoire Naturelle (MNHN) and the Conservatoire du littoral, in the framework of the adapto project (https://www.lifeadapto.eu/home.html).

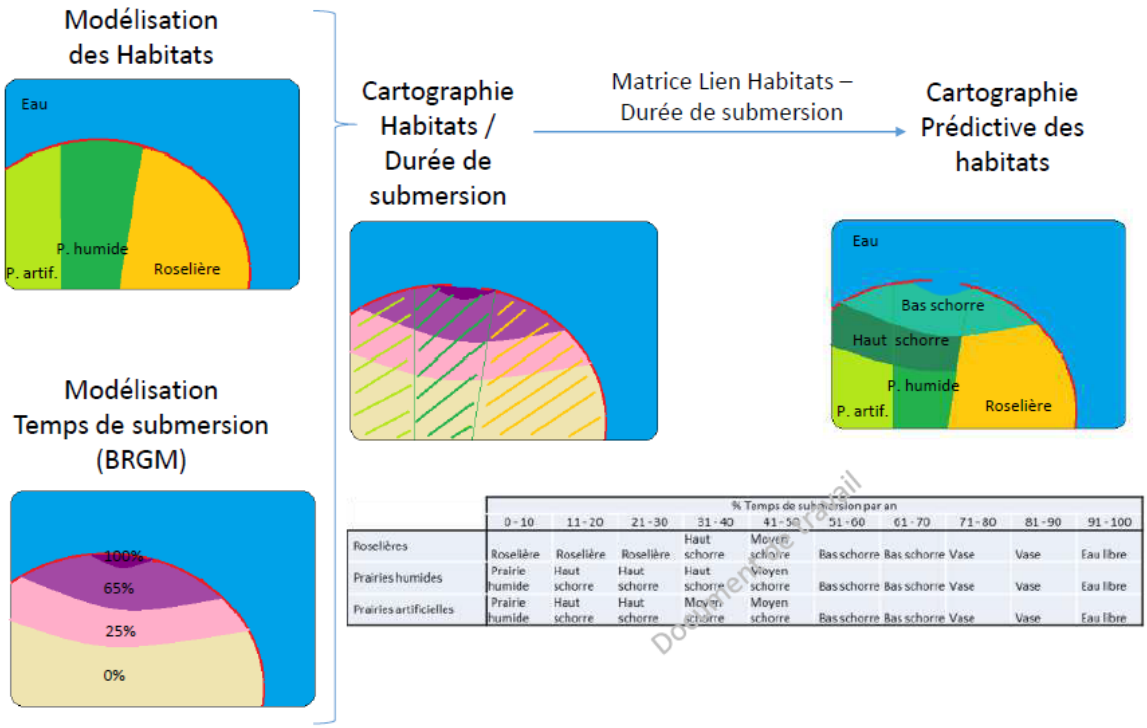
The indicator makes it possible to study the ecological quality of depoldered sites (where dike protection is moved inland) at a given time. It can take into account future developments and changes in sea level.

To assess ecological quality, a simplified habitat map is used, coupled with a biological capacity matrix. A radar diagram is then obtained which allows the evaluation of different characteristics of the site (defined with the Conservatoire du littoral): functionality; structure; diversity; heritage.

In the absence of habitat mapping, it is possible to carry out a model based on the interpretation of aerial views (orthophotos and topography from the National Geographic Institute) and completed by a field visit.

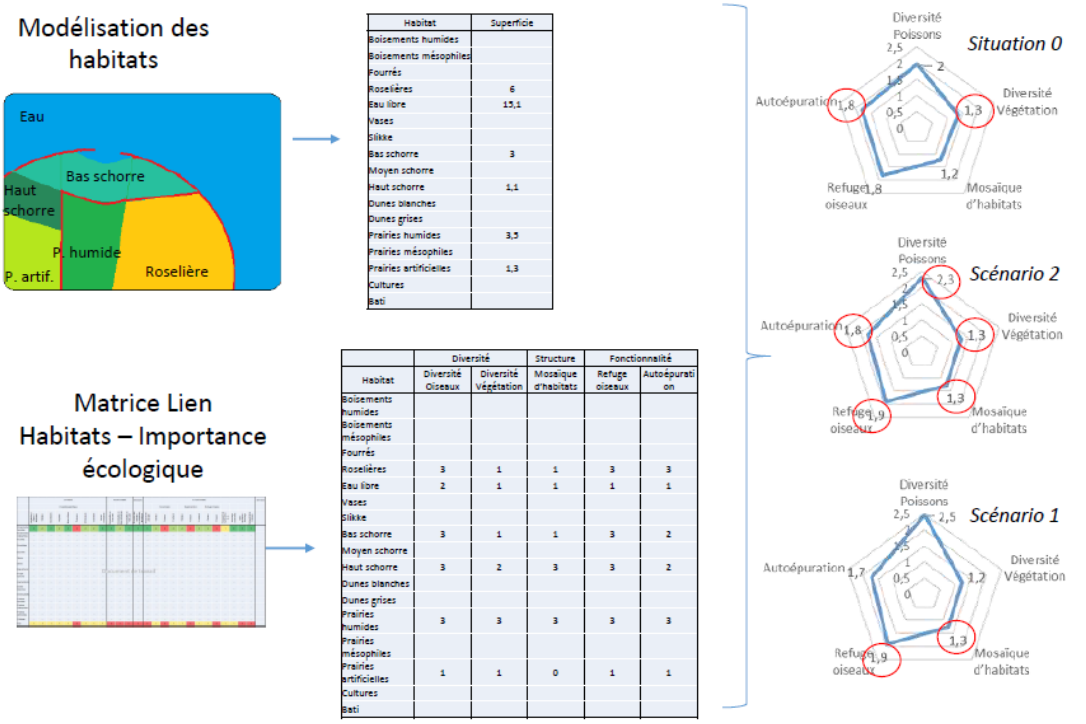
The biological capacity matrix allows the ecological importance of each habitat to be assessed in relation to a given criterion. It associates a score per criterion for each habitat. These scores are defined on the basis of expert opinion and bibliographical research. It is currently being written and should be finalised summer 2023.

To assess the site following development and the evolution of the sea level, a submersion map is being used, produced by the Bureau de Recherches Géologiques et Minières (BRGM). This gives submersion times for a given site (based on the synthesis of tidal coefficients over the last few years). This submergence mapping, associated with a submergence matrix, makes it possible to obtain a predictive mapping of habitats. Indeed, depending on the time of submersion and the type of habitat present, the submersion matrix indicates the probable evolution of the habitat.



Translation of above terms from diagram (left to right:
Habitat modelling
Modelling of submergence time (BRGM)
Habitat / duration of submergence mapping
Habitat link matrix – duration of submergence
Predictive habitat mapping

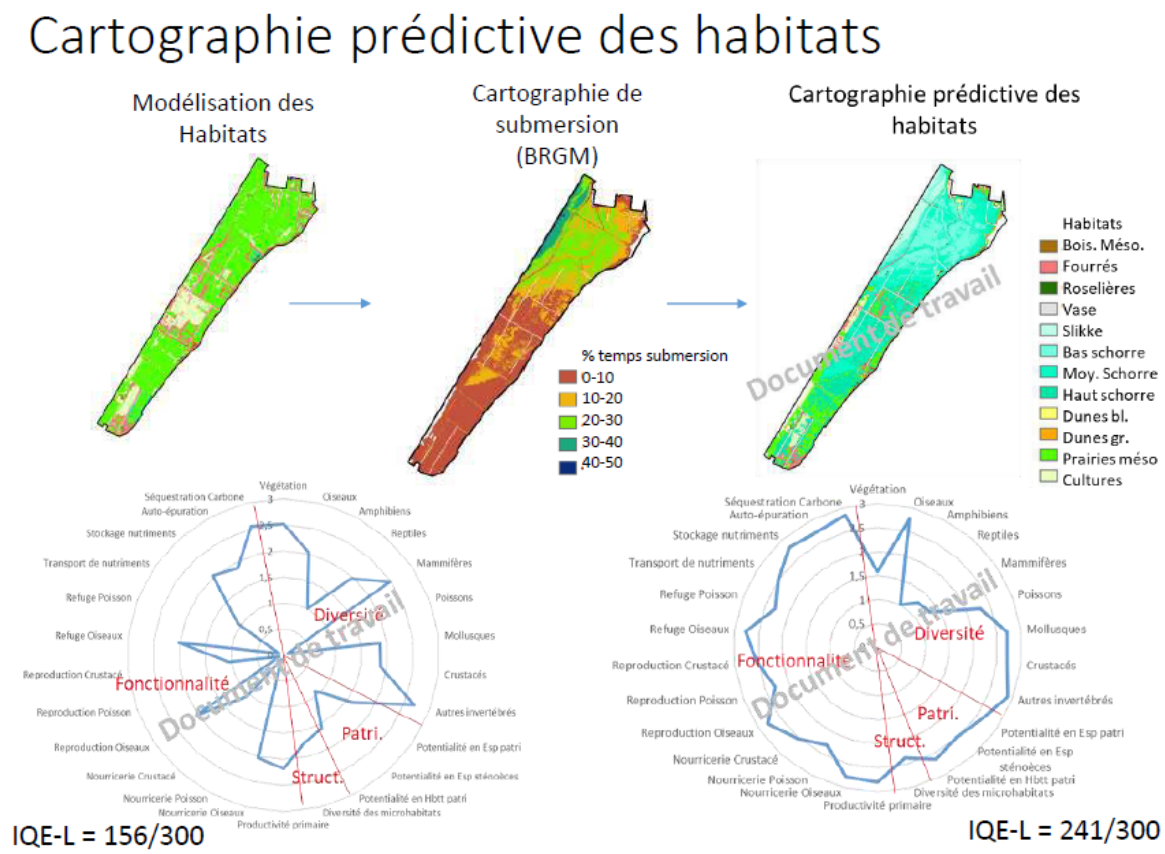
Then, with this predictive habitat mapping, the biological capacity matrix can be used again to obtain a new radar diagram indicating the potential ecological quality of the site. Comparisons can then be made between a current situation (situation 0) and various scenarios.



This tool could be used as a dialogue tool for communication, as a decision-making tool for the emergence of other projects and also for site management.

The example below shows the impact of intertidal habitat restoration on the functionality, heritage, diversity and structure of a site (test carried out by MNHN during the construction of the WQI-L, to introduce the tool).

Diagram showing predictive mapping of habitats:



The fauna-flora habitat inventories carried out in the lower Saâne valley will make it possible to test this indicator and to monitor, after the works, whether or not the trajectory actually observed is in line with the WQI-L forecasts.

4.2 Phase 2. Construction and delivery

Monitoring of the quality of the river and bathing water, as well as water upstream and downstream of the discharge point of the treatment plant and hydrological and piezometric monitoring continue throughout this project phase. In addition, attention is paid to any pyrotechnic (ordnance) or archaeological finds uncovered during the works.

Photographic monitoring

The photographic monitoring is continued, with changes in its frequency: in order to better perceive and follow the rapid evolution of the construction sites and the environment, the shots are taken more frequently.

These photos also help to show the implications of carrying out work in wetlands. The timelapses can effectively highlight the impact of the machinery used on the environment and underline, for example, the need to think about a traffic plan to minimise impacting on fragile environments.

Pyrotechnic (unexploded ordnance) diagnostics

These diagnoses are only carried out in sensitive areas, where it is still possible to discover dangerous munitions. Many munitions from the Second World War are still potentially present on the Normandy coast. This mission therefore aims to protect the people who will subsequently carry out the archaeological diagnostics and the reconnection work to the sea.

Archaeological diagnostics

These diagnoses are defined according to the maps of identifying areas of archaeological interest as highlighted by the Direction Régionale des Affaires Culturelles (DRAC). They are drawn up on the basis of old maps and additional historical evidence available to the DRAC for locating archaeological remains. These maps are approximate. During development projects, they are used by the services of the Institut national de recherches archéologiques préventives (INRAP), which is responsible for diagnostics. The analysis of the results of these diagnoses can lead to a second stage of research: archaeological excavations.

The purpose of these investigations and excavations is to preserve important archaeological remains (and the knowledge they provide), which could be buried in plots where development projects are planned.

In the context of the Saâne project, a DRAC map suggested that remains could be found, either on the site of the new tourist facility at Quiberville or in the lower valley, on the site of the reconnection works to the sea.

A first phase of diagnostics was carried out in 2021, on the site of the new tourist facility in Quiberville. The findings of the INRAP services were not sufficiently conclusive to lead to excavations.

A second phase of diagnostics (2022-2023) targets the lower valley, where work will be carried out to reconnect the river to the sea and restore inter-tidal habitat. Exchanges between the Conservatoire du littoral, the Syndicat Mixte des Bassins Versants Saâne Vienne Scie (SMBVSVS) and the services of the DRAC and INRAP have made it possible to target the areas where work will be undertaken. Indeed, fauna and flora studies of wetland habitat, carried out by the SMBVSVS in 2021, showed that these areas were already home to interesting habitats and heritage species. Given that the reconnection work does not cover the entire downstream zone of the lower valley, it seemed appropriate that the

archaeological surveys should cover the same area. As part of the work at the mouth of the river on the beach (in the public maritime domain), the Department of Underwater Archaeological Research (DRASSM) was asked to lead the archaeological investigations on the upper beach, also carried out by INRAP.

Archaeological diagnostic report on the site of the new tourist facility in Quiberville: https://drive.google.com/drive/folders/1jV3ACKxEGPaOkC5_vL9q48oXA88a2GiQ?usp=share_link

4.3 Phase 3. Post-work monitoring phase

During this phase, as in previous ones, the quality of the river and bathing water, the quality of the water upstream and downstream of the wastewater treatment plant discharge point and hydrological and piezometric monitoring are maintained.

Photographic monitoring

Photographic monitoring aims to highlight the evolution of the environment. Drone monitoring seems to be the most appropriate for longer-term monitoring at a reasonable cost.

Fauna-flora-habitat study

Concerning biodiversity (fauna, flora) and habitats, inventories similar to those of the 2021-2022 initial state will be repeated after the reconnection. Particular attention will be paid to protected species and estuarine features.

LIDAR hydrosedimentary monitoring with photoinfrared

LIDAR monitoring is carried out over the entire Normandy and Hauts de France coastline by the Réseau d'Observation du Littoral (ROL) every three years. The use of these data will allow the topographic evolution of the lower valley to be observed.

A scientific partnership is being formalised with the University of Rouen M2C (Laboratoire Morphodynamique Continentale et Côtière) for the organisation of monitoring on two themes:

1. Collection/validation of piezometry, hydrometry and salinisation data for surface and groundwater: the initial state began in the summer of 2022, the post-breach evolution is envisaged for a period of at least 5 to 10 years. The use of artificial intelligence will allow the construction of models and simulations of hydrological variability.

2. The construction of a programme to evaluate the hydrosedimentary trajectory in the reconnected lower valley: the initial state is envisaged for the 2nd half of 2023 with post-construction monitoring making it possible to follow the mobility of the sediments and landings on a regular basis (infra-annual frequency to be defined) and after

particularly intense events (floods, storms). The techniques used will include topographic monitoring and thermal imaging by drone.

The objective is to map the evolution of the zones under the influence of salt water intrusion (exploitation of monitoring data, measurement of the electrical conductivity of the subsoil from the surface and of intertidal habitats). Attention could also be paid to water exchanges between the river, the aquifers and the unsaturated zone.

Monitoring of the Soléa wastewater treatment plant

Permanent diagnosis

The decree of 30 July 2020, amending the decree of 21 July 2015, requires existing wastewater systems intended to collect and treat a gross organic pollution load of less than 600 kg/d of BOD5 and greater than or equal to 120 kg/d of BOD5, to establish a permanent diagnosis by 31 December 2024 at the latest.

In anticipation, a permanent diagnosis will be implemented in order to ensure the proper management of the sanitation system by considering the following impacts:

- *Environmental* due to waterproofing or structural failure that can lead to leakage and seepage.
    - Reinforced monitoring every five years will be implemented at the level of the double-skinned passages in the borehole protection perimeter
- *Operational* due to complete or partial blockage of the collector or due to an electrical failure at the discharge stations that may lead to additional operating costs
    - All stations will be remotely controlled with fault alarms.
- *Structural* due to collapse or weakening of the collector structure

The points will be specified as the network project progresses. They will be strategically located to monitor the watertightness and performance of the networks in the various municipalities independently. Piezos will be installed on structures likely to be subject to rising water tables, mainly at the level of the pumping stations; information on water tables will be transmitted via remote monitoring.

Discharge control

Structures will be developed to allow withdrawals from:

- The effluent at the inlet to the treatment plant,
- The clarified effluent before discharge to the natural environment.

Two types of analyses will be carried out on the effluent of the treatment plant:

- Self-monitoring analyses carried out by the operator of the treatment plant site,
- Analyses carried out by a control body approved by the Seine-Normandy Water Agency.

The results will be sent to the department responsible for the Water Police and to the Water Agency.

Self-monitoring

The self-monitoring undertaken will comply with the obligations of the Order of 21 July 2015. It imposes a minimum frequency of measurement for several parameters allowing, in particular, the evaluation of the polluting loads discharged.

The regulation imposes the following minimum treatment performances for the parameters BOD5, COD and SS:

Paramètres	Concentration maximale à respecter Moyenne journalière	Rendement minimum à atteindre Moyenne journalière	Concentration rédhibitoire Moyenne journalière
DBO5	25 mg (O2)/l	80%	50 mg (O2)/l
DCO	125 mg (O2)/l	75%	250 mg (O2)/l
MES	35 mg/l	90%	85 mg/l

The equipment for self-monitoring of the plant is as follows:

- Upstream self-monitoring

Within the framework of self-monitoring, a measurement system using an electromagnetic flow meter with a sampling point pre-equipped to receive a refrigerated mobile sampler controlled by the flow rate is planned in order to count all the effluents sent to the treatment facilities.

- Downstream self-monitoring

Within the framework of self-monitoring, it is planned to measure flows associated with an ultrasound probe.

The outlet metering channel will be equipped with a pre-equipped sampling point to receive a refrigerated mobile sampler controlled by the flow rate, in order to count all the treated water discharged into the natural environment.

- Sludge

A flowmeter will be used to count the sludge generated at the plant as well as outside sludge. A sampling system will be possible to qualify the sludge before treatment.

5. Monitoring Case Studies (LORP)

Case Study 1. Fish

Estuaries are extremely productive environments, playing a crucial part in the life cycle of many fish species. They act as key marine fish nursery grounds, as well as vital corridors

for migratory species. Under PACCo there was a desire to conduct a fish survey programme in the Lower Otter estuary and associated salt marshes in advance of the scheme being implemented to provide a baseline from which to measure improvements to this ecological functionality.

Effective methods to capture fish in the intertidal margins of estuaries and saltmarsh require a clear understanding of how the tide moves across the site. Through the training of citizen scientists, seine netting techniques were applied to the Otter Estuary over a period of two years focusing on high water slack and low water slack to minimise flow with fixed fyke nets set after low water and then removed during the ebb before fish became stranded.

The fish community in the Lower Otter estuary and associated saltmarshes has similar characteristics to that observed in the adjacent Exe estuary, dominated by common goby, bass and grey mullet species. These species have all been regularly reported from estuaries, saltmarshes and managed realignments in England, showing a high degree of penetration and utilisation. It is very likely that these species will utilise the new habitats now under construction in the Lower Otter estuary in a similar manner. With reconnection to the natural floodplain, these may well be joined by both freshwater species such as dace and possibly migratory species such as eel and sea trout. Fish surveys led by citizen scientists will continue into the legacy phase of the project focusing on the restored inter-tidal habitat.



Case study 2. Carbon

The Lower Otter Restoration Project will create ca. 55 hectares of mudflat and saltmarsh by restoring tidal inundation to the Lower Otter Valley. In addition to increasing climate resilience by providing improved protection from sea-level rise and storm surge, the project is anticipated to help climate mitigation through carbon sequestration and storage within the restored saltmarsh and mudflats. To understand its current and potential carbon

storage value a carbon storage monitoring strategy was devised with a baseline carbon assessment for the Lower Otter site undertaken.

The carbon storage and sequestration of the existing vegetation was estimated by assessing areal coverage using a point-based mapping approach and combining these areas with literature values of carbon. Sampling of soils was stratified based on National Vegetation Classification (NVC) maps with ten sampling locations selected for sampling across the site. The sampling locations were determined based on the primary vegetation strata in combination with management regime (i.e. grazing intensity) and soil conditions (e.g. moistness). A core for soil carbon analysis and a surface soil sample for determination of dry bulk density were collected at each sampling location. Soil cores were collected to a depth of ~60-70 cm or until strong resistance was encountered with cores sub-sampled into ~10 cm lengths in the field. Using Lidar images the potential for sedimentation was evaluated from the difference in elevation between the lidar image (current pre-restoration elevations) and the level of Highest Astronomic Tide giving the maximum potential depth of sediment that could accumulate at each location

It was estimated that the current tree/hedgerow/shrub cover stores ca. 1,200 tonnes of carbon (ca. 4400 t CO2e) and sequestering a further 20 t carbon annually (74 t CO2e). Above-ground grass/herbaceous vegetation was estimated to store ca. 80 t C, and sequester ca. 23 t annually. It was estimated that the soils contained ca. 8 to 17 kg carbon per square metre (to 50 cm depth), with a site wide estimate of ca. 8,500 tonnes carbon. It was also estimated that a total of c. 8,000 – 20,000 tonnes of organic carbon (29,000-74,000 tonnes of CO2e) could be accumulated (over a period of c. 44-72 years) on the Lower Otter managed realignment site in the sediment that accretes after the restoration.

The volume of sediment deposition, in addition to the density of carbon in that sediment, is a key determinant in the carbon accumulation on the managed realignment. Future monitoring will use sediment pins at multiple locations (the expected low sedimentation rates mean that this method should be successful) corresponding to sediment sampling.

Case Study 3. Bird disturbance monitoring

Significant changes to the lower Otter estuary are imminent due to the implementation of the restoration scheme with 55 hectares of mudflat, transitional marsh and saltmarsh to be created. An important measure of success will be its future support of populations of wading, migratory and over-wintering birds. Recreational activity has the potential to impact adversely on achieving this key objective. The location of the estuary next to the popular Budleigh beach and main car park makes it easily accessible to the public with a number of footpaths running through and adjacent to the estuary. The main recreational issues that might cause disturbance to birds are water sports (including kayaking, paddle boarding, kite surfing and swimming) and trespass on foot - particularly by dogs from the embankment path.

Supported by PACCo a disturbance monitoring programme has been established with this comprising of two different fieldwork elements: (1) *core counts*, involving continued observation over a fixed time period (1 hour and 45 minutes), recording the birds present, human activity, and any interactions between people and birds; and (2) *vantage point counts*, involving quick, 'snapshot', counts recording the number of birds present and the distribution of human activity. Core counts will provide detailed data relating to the responses of birds and prolonged observation across a fixed recording area. Vantage point counts are much quicker and easier to carry out, cover a much wider area, and are undertaken much more frequently than the core counts. The vantage point counts therefore provide the best indication of how frequently there is disturbance.

A disturbance events is categorised as a 'potential disturbance event' if it coincides with birds being present within the count area and occurred within 200m of birds within the recording area, or there was a behavioural response recorded for birds within the recording area (i.e. seen to become alert, change position, or were flushed). For each potential disturbance event, the response of the birds is recorded, even if no behavioural response was logged – i.e. if the birds were not visibly disturbed.

6. References & Further Reading

Modular river surveys (Modular River Survey online assessment method and tools*)

Monitoring and evaluating your project (RRC 2017)

Practical River Restoration Appraisal Guidance for Monitoring Options (RRC 2014)

REFORM river restoration wiki (REstoring rivers FOR effective catchment Management website*)

River Restoration Centre Monitoring Planner (free RRC online tool*)

scenic photos posts. http://cairngorms.co.uk/photo-posts/ [Accessed 03/05/18]

Conveyance Estimation System – Roughness advisor. This provides unit roughness values. http://www.river-conveyance.net/ [Accessed 20/02/18]

Environment Agency guidance on measurements of flow and level (Chapter 6). https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/654431/Working_with_natural_processes_evidence_directory.pdf [Access 16/02/18]

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EU Restore. Guidance and tools for hydromorphological assessment and physical restoration of rivers and streams in Europe. http://wiki.reformrivers.eu/index.php/Main_Page [Accessed 20/02/2018]

Forestry Commission Scotland Guidance on fixed point photography. http://scotland.forestry.gov.uk/woodland-grazing-toolbox/monitoring/fixed-point-photography [Access 20/02/18]

JNCC Common Standards Monitoring Guidance. http://jncc.defra.gov.uk/page-2272

JNCC National Vegetation Classification http://jncc.defra.gov.uk/page-4259 [Accessed 20/02/2018]

Modular river surveys (Modular River Survey online assessment method and tools*)

Monitoring and evaluating your project (RRC 2017)

Practical River Restoration Appraisal Guidance for Monitoring Options (RRC 2014)

REFORM river restoration wiki (REstoring rivers FOR effective catchment Management website*)

River Habitat Survey Guidance Manual in Britain and Ireland. https://www.gov.uk/government/publications/river-habitat-survey-guidance-manual [Accessed 01/05/2018]/

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Starkey, E. and Parkin, G. (2015). Community Involvement in UK Catchment Management. http://www.fwr.org/Catchment/frr0021.pdf

Starkey, E., Parkin, G., Birkinshaw, S., Large, A., Quinn, P., Gibson, C. (2017) 'Demonstrating the value of community-based (‘citizen science’) observations for catchment modelling and characterisation'. Journal of Hydrology: http://doi.org/10.1016/j.jhydrol.2017.03.019

The modular river survey. https://modularriversurvey.org/ [Accessed 20/02/2018]

List of abbreviations

DAFOR scale – Dominant, Abundant, Frequent, Occasional, Rare.

ECoW - Environmental Clerk of Works.

EDPHCT – East Devon Pebblebed Heaths Conservation Trust.

EIA – Environmental Impact Assessment.

FCE – France Channel England.

LEMP - Landscape and Ecological Management Plan.

LORP – Lower Otter Restoration Project.

NVC – National Vegetation Classification.

PACCo - Promoting Adaptation to Changing Coasts.

PCO – Plymouth Coastal Observatory.

SSSI – Site of Special Scientific Interest.

SWW – South West Water.

TCW sites – Transitional Coastal Waters.