Catchment Science and Management

A Guidance Hand Book

Volumes 4 & 5

Vol. 4: Measured Indicator Parameters – Catchment Walks

Vol. 5: Urban Local Catchment Assessments

April 2022

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Department of Housing, Local Government and Heritage

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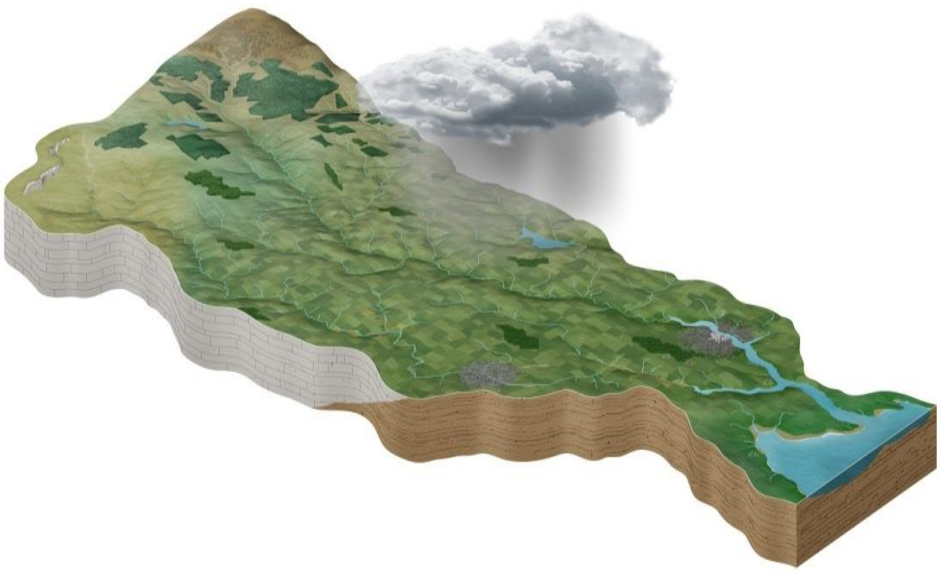
Catchment Science and Management

A Guidance Handbook

Volume 4:
Measured Indicator Parameters – Catchment Walks



October 2021

Version no. 2

Preface

This Volume was written originally in 2018 as **Guidance on Further Characterisation for Local Catchment Assessments Volume 4 (Version 1).** It was initiated by the Catchment Science and Management Unit of the Environmental Protection Agency (EPA). It was primarily intended for use by the LAWPRO catchment scientists and staff in Local Authorities, tasked with undertaking Local Catchment Assessments (originally called Investigative Assessment).

The content in the 2018 Guidance reflected a collaborative effort between invited specialists from several stakeholders with responsibility and vested interests in environmental research and management in Ireland. Contributions were made by members of an Investigative Assessment Development Group, led by the EPA and comprising representatives from public and WFD stakeholder organisations including: Department of Housing, Planning and Local Government; Department of Agriculture, Food and the Marine (Forest Service); Teagasc; Geological Survey Ireland; Irish Water; Inland Fisheries Ireland; Local Authority Waters and Communities Office (LAWCO); Limerick City and County Council; Meath County Council; Dublin City Council; Offaly County Council; Dun Laoghaire-Rathdown County Council; Wexford County Council; Tipperary County Council; as well as CDM Smith consultants. The membership of the Group is listed in Table 1.

Table 1: Membership of Investigative Assessment Development Group

Organisation	Representative
EPA	Marie Archbold Donal Daly Jenny Deakin Bryan Kennedy Anthony Mannix Conor Quinlan Emma Quinlan
Local Authorities	Paul Buggy, Dun Laoghaire-Rathdown County Council Emmet Conboy, Meath County Council Ruth Hennessy, Tipperary County Council Andrew Holmes, Limerick County Council Joan Martin, Offaly County Council Gerry O’Connell, Dublin City Council Mairéad Shore, Wexford County Council
LAWCO	Fran Igoe
Forest Service	Ken Bucke
Inland Fisheries Ireland	Michael Fitzsimons
Teagasc	Edward Burgess Sara Vero
Department of Housing, Community & Local Government	Donal Grant
Geological Survey of Ireland	Taly Hunter Williams
Irish Water	Kate Harrington
Rivercrossing	Brendan Ward
CDM Smith	Pat Barrett Henning Moe

In 2021, a review and updating of the Guidance Volumes were undertaken by LAWPRO and the EPA Catchments Unit.

Contents

1 Introduction

This **Volume 4** provides an overview of field methods for the measurement of streamflow and water quality parameters that are indicative of specific environmental pressures. It outlines the equipment that can be used during catchment walks, and how measurements and monitoring is carried out. It also outlines biological indicators which can be used during the Local Catchment Assessment (LCA). Biological indicators such as macroinvertebrates, macroalgae and macrophytes illustrate the response of the river or its biological communities to stressors affecting the system. This is turn can assist in focusing in on impacted stretches and using a weight of evidence approach to refine where actions will need to be taken to reduce or eliminate a pressure.

This volume provides practical hints and recommendations on methods that can be used during LCA to gather your scientific evidence of impacts. It informs on best practice. It cannot be prescriptive for all situations and problems that might be investigated, and, depending on the nature of the LCA that is to be carried out and the experience of the Assessors, the advice given in this **Volume 4** may be adapted to suit. The experience of LAWPRO has been included in this Version 2 of this volume, but it is expected that as the experience of other users, such as the Local Authorities, is gained doing LCAs, this Version 2 volume will be amended and improved.

The sections and main authors are listed below.

Section	Indicators	2018 Main Contributor(s)	2021 Contributors
2	Measurement of streamflow and spring discharges	Conor Quinlan	Eoin McAleer
3	Water temperature & thermal imaging	Joan Martin, Taly Hunter Williams, Anthony Mannix & Conor Quinlan	Michael Nugent
4	Dissolved oxygen	Michael Fitzsimons & Anthony Mannix	Cormac McConigley
5	pH	Joan Martin & Taly Hunter Williams	Vicky Veerkamp
6	Specific electrical conductivity	Donal Daly & Anthony Mannix	Vicky Veerkamp
7	Sediments	Anna Rymszewicz, Kate Harrington, Robbie Meehan & Emma Quinlan	Anna Rymszewicz
8	Nutrients	Emmett Conboy, Anthony Mannix, Joan Martin & Donal Daly	Mairead Shore, Eoin McAleer
9	Biological indicators	Bryan Kennedy & Martin McGarrigle	Bernie White, Paul O’Callaghan, Stephen Davis, Cormac McConigley, Patsy Ryan

1.1 Staying focussed on the goals

A significant public sector resource is being allocated to the Local Catchment Assessment process. It is vital that this resource is effective in enabling successful water resources protection and management, and achievement of WFD objectives. Two points to keep in mind are given in the Boxes below.

Box 1 – Local Catchment Assessments

What a Local Catchment Assessment isn't: **the collection of more data alone.**

What a Local Catchment Assessment is: **a critical means of enabling either protection or improvement, as relevant, of our water resources.**

This aim is achieved by:

- Undertaking a desk study as the starting point.
- Undertaking catchment walks, if needed.
- Collection, assessment and recording of relevant information and data collected during the catchment walk.
- Concluding, in so far as is practicable, on the significant pressure and its location.
- Evaluating and proposing possible mitigation actions.
- Undertaking (in certain circumstances) the mitigation actions.

Remember: we need to stay focussed on the goals.

Box 2 – The Desk Based Assessment

The desk study is the key to ensuring that the Local Catchment Assessment process is focussed, efficient and effective.

The Role of the Desk Study

- To check the **WFD App** for details on: i) the significant pressure (e.g. domestic wastewater treatment systems); ii) the significant issue (e.g. phosphate); the location of the significant pressure (the specific location for large point sources and the general location for diffuse and small point sources).
- To search for and assess **new information** that may be available.
- If feasible, provide the conclusion on the **required mitigation actions**.
- Where a field-based assessment is needed to: i) **clarify** the objectives; ii) **compile** the information and maps that will assist the fieldwork; and iii) **plan** an appropriate fieldwork/catchment walk programme.

Further details on the Desk-based Assessment are available in Section 10 **Volume 1**. LAWPRO desk studies for Priority Areas for Action can be viewed on the EDEN Portal under WFD POMs, Area for Action, Step 1 Desk Study.

2 Measurement of Streamflow and Spring Discharges

2.1 Introduction

Streamflow is the volume of water passing a specific point over a given time. This is usually measured in litres per second (l/s). Streamflow is usually reported in l/s for small streams and in cubic meters per second (m^3/s) for large streams (rivers).

1000 litres = 1 m^3.
Thus, 1 l/s = 0.001 m^3/s.

Streamflow is a fundamentally important parameter in catchment characterisation and monitoring. Streamflow supports aquatic life and provides for dilution of pollutants that enter the aquatic environment. The higher the streamflow relative to a pollutant input (chemical load), the lower the resulting concentration, and vice versa. Streamflow is, for example, an important input in assimilative capacity calculations of discharges to surface water.

Streamflow is typically described in terms of percentiles: for instance, the median annual flow is a Q50 flow whereas the mean flow is usually approximately the Q30 flow. An important streamflow metric is the Q95 flow, which is the flow in a stream that is exceeded 95% of the time. Certain aquatic ecosystems depend on certain flow conditions, and the Q95 flow is sometimes used as a "simplified" threshold value below which survival of aquatic species may be in jeopardy. In more detailed catchments studies, environmental flows may be defined which are more tailored to specific ecological needs in terms of flow conditions.

The EPA and OPW (and some other public bodies) operate automatic streamflow measurement stations at fixed locations throughout the country – these are referred to as "gauging stations". Often, spot measurements are needed at other locations in ungauged catchments. Specific purposes for spot flow measurements are described below. The methods and techniques that are used are also presented below. These are equally valid for estimation of flow in ditches and drains.

2.2 Purpose

Spot stream flow measurements provide an estimate of stream or river flow at a point in time and location, and can be used for the following purposes:

1. **To provide contextualisation of the hydraulic conditions during which a survey was completed or a sample taken.** Spot flow measurements provide information about the flow in a channel at a given time. Flow is a primary parameter that should always be estimated when completing work in a stream channel, and consistent recording of flow estimation is vital. When investigating groundwater interaction with rivers, changes in river flow following rainfall commonly result in a stream changing temporarily from a gaining to a losing stream in many locations.
2. **To identify significant inflows from point discharges.** This can be assessed by taking streamflow measurements upstream and downstream of discharges.
3. **To calculate loadings of contaminants in streams.** Spot flow measurements when combined with corresponding hydrochemistry data can be used to quantify loadings of contaminants in streams. When this process is repeated throughout a catchment, it provides a picture what proportion of contaminants are coming from various source areas and provides the basis for mass balance calculations.
4. **To measure flow in ditches and drains.**

5. **To calculate increases in stream flow along the length of a river (flow accretion).** Most rivers in Ireland gain water as they more downstream. Spot flow measurements taken at various points along a river (on the same day) can provide an estimate of the rate and locations of such inflows. This provides important information about where groundwater discharges to the surface drainage network, particularly the spatial pattern of groundwater discharge. This characteristic can become extremely important, and easier to quantify during drought conditions as there may be some reaches of streams that dry up completely, while others may be receiving sufficiently buffered groundwater discharge to maintain flow until a drought ends.
6. **To identify locations where streams lose water to groundwater.** In some locations, predominantly on karst aquifers, streams lose flow to groundwater via loosing reaches or swallow holes. This situation can also arise where stream cross gravel deposits. Spot flow measurements taken along rivers (on the same day) can provide evidence of such groundwater recharge and suggest stream reaches that could be examined in further detail. Again, how such rivers behave under drought conditions is important to establish.
7. **To identify streams that are receiving groundwater inflow from outside the topographic catchment of the stream.** In some locations, again predominantly on karst aquifers, water moves via the bedrock aquifer between surface catchments. In such cases the volume of water flowing in a stream can be much higher that could possibly have been generated by rain falling within that catchment. It is important to identify such locations so that the source of such transferred water can be identified.

While spot flow measurements can be used for all five purposes listed above, one of **the main functions of taking spot flow measurements and assessing relative flows and gaining/losing reaches during catchment walks will be to identify the location of groundwater contribution to rivers and to provide sufficient information for loadings of contaminants to be estimated.**

2.3 Significance

Accurate measurement of streamflow provides a record of hydraulic conditions under which a survey was undertaken. Many rivers can change from gaining to loosing streams between high and low flow conditions – or vice versa. Often groundwater seepages and springs will only be visible under a small proportion of flow rates, and it is important to have a record of what conditions a river walk was or was not carried out under so the presence of such groundwater-surface water interactions are not erroneously ruled out. In flashy catchments, where flow rates change quickly and dramatically following rainfall, accurate post-survey estimation of stream slow is likely to be impossible. It is therefore vital that such information is recorded on site during the survey.

By quantifying the load and therefore proportion of pollutants in each reach of a river in a catchment, it may be possible to identify the source areas from which such pollutants originated and the proportional contribution of each area of the catchment.

By identifying parts of a stream that are gaining water from or contributing (losing) water to groundwater, it may be possible to identify groundwater-surface water pathways and thus sources of contaminants in catchments. Similarly, if the flow in a stream is measured and found to be higher than could have been generated from rain falling within the topographic catchment of the river, this indicates that there is groundwater flow entering the stream from outside the catchment. In such case, if groundwater is a relevant pathway, Assessors should look outside the catchment boundaries to identify potential groundwater source areas from which such contamination could have originated.

2.4 Methods of Measurement

Accurate stream spot flow measurement utilises impeller current meters and Acoustic Doppler Current Profilers (ADCPs) and is a relatively specialised task. Even under laboratory conditions an error estimate of +/-9% is generally accepted as standard. For the purposes of data collection during catchment walks, simpler methods can be employed. The first method described can be quite accurate, while the second method is less so. They are suitable for IA purposes and it is important to note that consistency of application is important to facilitate meaningful comparison of flow estimates between different sites. Measurements should also be taken on the same day within a catchment so that the flows measured reflect similar hydraulic conditions. It is also important that significant abstractions and discharges within a catchment are identified at the desk-study stage and taken account of during a catchment walk.

The methods described below can be used in isolation or can be applied across a catchment and combined with time-series data from permanent hydrometric stations where such exist. Where these methods are applied throughout a catchment, 'bridge-hopping' is a widely practiced technique where measurements will be taken near bridges where the channel can be accessed easily and safely.

2.4.1 Bucket method

This method is useful for measuring the flow in small, relatively steep-sloping stream with flows of up to 10 litres /second (l/s). The basic principle is to derive the flow rate from the time taken to capture a known volume of water in a bucket (Figure 2-1).

Equipment: strong plastic graduated measuring bucket (15-20 litre capacity) and a stopwatch.

Procedure:

1. Identify a suitable step or small cascade in the channel under which the bucket can be safely placed to capture all the flow in the channel. Alternatively, a plastic pipe or v-notch plate can be temporarily placed into the channel to funnel the flow and sealed with sods or clay.
2. Place the bucket into the stream flow and immediately start the stopwatch. When the bucket is about to reach capacity simultaneously remove the bucket and stop the timer.
3. Divide the volume of water collected by the number of seconds taken to collect it, e.g. 5 litres in 10 seconds = 5/10 = 0.5 l/s.
4. Repeat this process 3 times and take the average result as the final flow measurement.

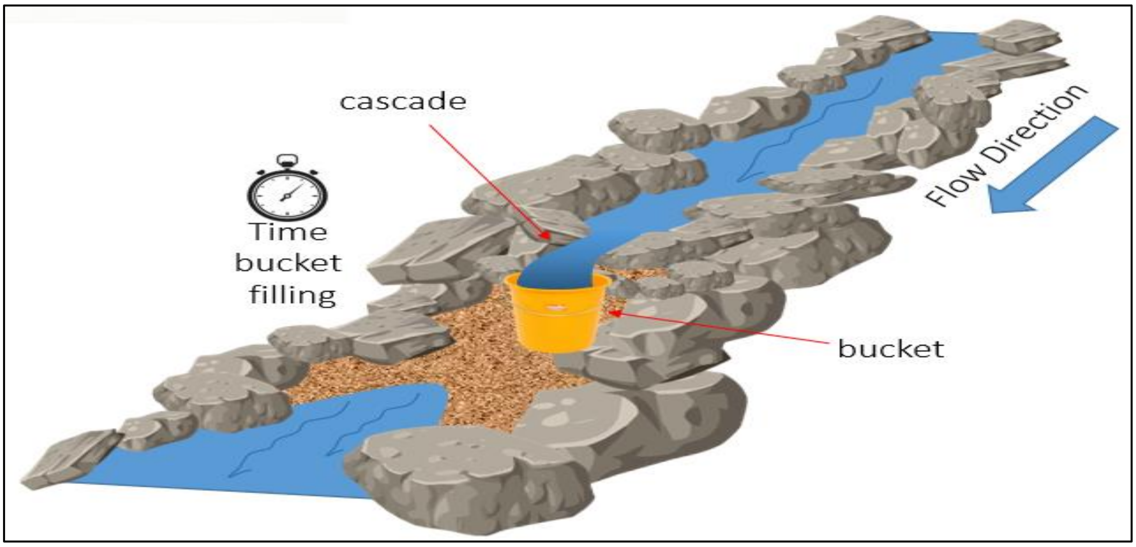


Figure 2-1: Typical setup for bucket method

2.4.2 Float method

This method is useful for measuring the flow in small to medium streams and rivers that can be safely accessed on foot. The basic principle is to derive the flow rate by multiplying the cross-sectional area of the stream or river by the measured velocity in the channel.

Equipment: measuring tape, a float (typically a 0.5 plastic bottle 2/3 filled with water), a stopwatch and possibly a net to retrieve the float (depending on the size of the channel). This technique requires a minimum of two people to complete.

Procedure:

1. Identify a straight reach of channel 20-50m in length that has a roughly uniform cross section along its length, with a relatively smooth bank and bed that has as little turbulence as possible and that can be safely accessed on foot.
2. Measure the cross-sectional area of the wetted channel (Figure 2-2). This should be done by measuring the width of the wetted channel and then measuring the depth at equal distances from the bank (see diagram below). Calculate the average depth measurement, including the channel edge depth measurements, and divide by the total number of depth measurements to provide the average channel depth. Multiply this by the channel width to calculate the cross-sectional area of the stream in meters. Repeat this measurement at the other end of the reach to be measured. Calculate the average of both cross sections. Also measure the length of the reach from the start to finish point.
3. One member of the team stands at the upstream starting point of the reach and the other at the downstream finishing end (Figure 2-3).
4. The person upstream launches the float into the centre of the channel just upstream of the starting point and starts the timer when the float passes the starting point. The person downstream signals when the float passes the finishing point and the timer is stopped. The float is then retrieved.
5. Divide the total reach length (in meters) by the number of seconds taken for the float to travel the length of the reach to calculate the stream velocity in meters/second.
6. Multiply the average cross-sectional area of the stream by the velocity to calculate the flow in meters^3/second. For reference, remember that 1m^3 = 1,000 litres and 1 litre = 0.001 m^3.
7. Repeat this process 3 times and take the average result as the final flow measurement.

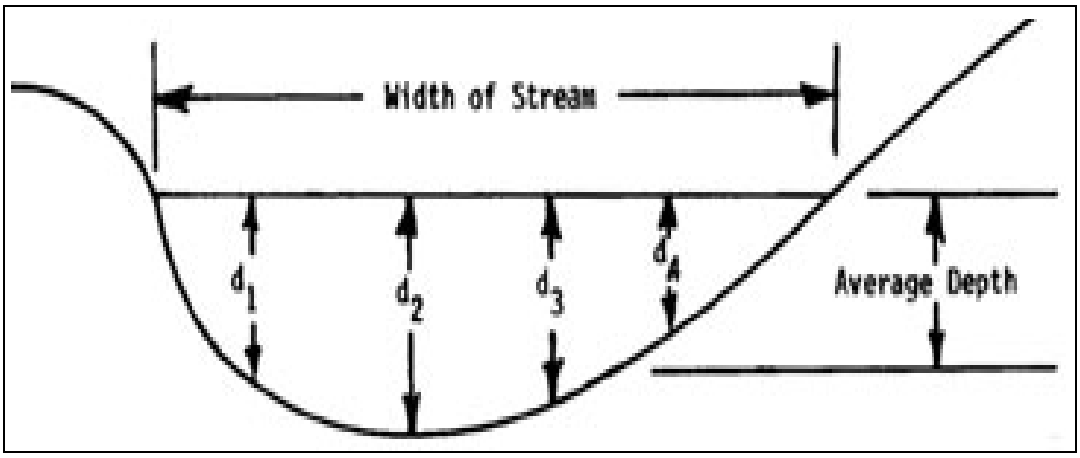


Figure 2-2: Stream cross-section measurement.

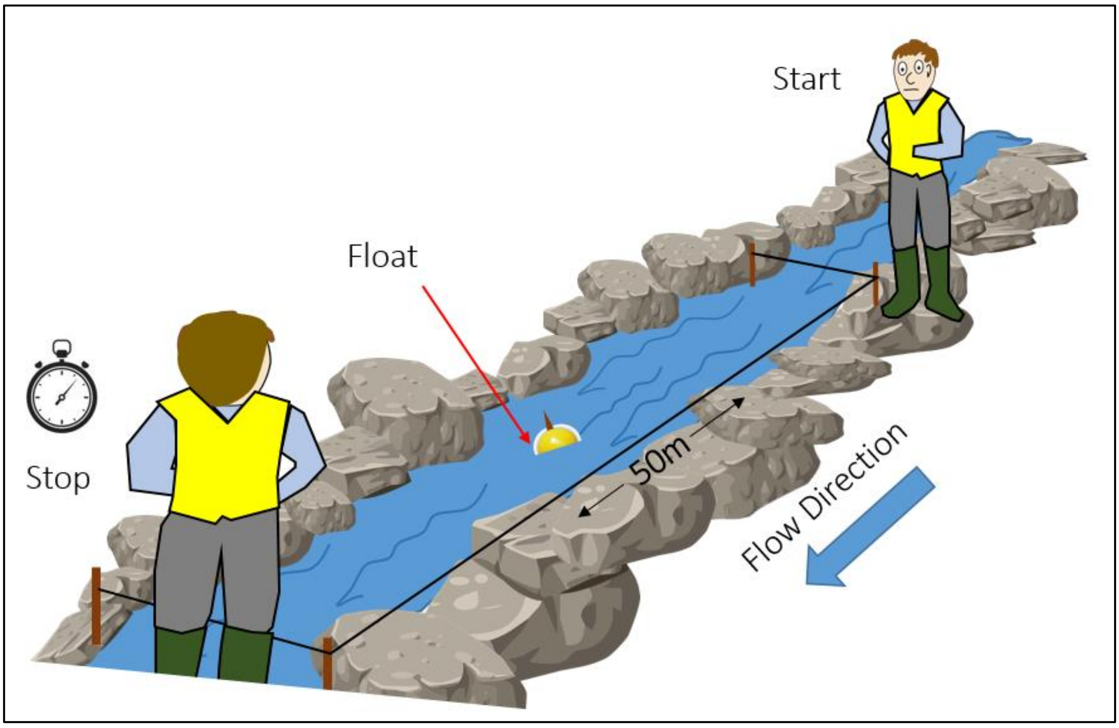


Figure 2-3: Typical site setup for float method.

2.5 Approaches to Consider

Broadly speaking, two approaches to stream flow measurement should be considered. Firstly, when carrying out a catchment-wide investigation, it may be advantageous to undertake a set of stream flow measurements on the same day at points throughout the catchment. Ideally the measurement points would coincide with water quality measurement locations. The resulting flow data set can be used to calculate proportional loadings across the catchment and to gain a foundational understanding of the relative flows and water contributions in each channel across the catchment.

Secondly, when carrying out a stream walk, it is advisable to measure or estimate the stream flow at both the upstream and downstream ends of the survey. In karst areas or where significant tributaries enter the channel, additional flow measurements may be advised. Capturing flow information in this way provides important information regarding the hydrological conditions under which the survey was undertaken and a basic measurement of the hydraulic behaviour of the stream reach in question.

Additional information and resources to estimate streamflow in catchments is provided in **Appendix A**. These include:

- Comments on the accuracy versus practicality of methods.
- A detailed description of the velocity-area method (using a current meter) including site selection, theory, setup and a worked example.
- A description of how to access and quality check existing hydrometric information.
- Example of how to utilise hydrometric information in interpreting water quality.
- Up-scaling and down-scaling flows based upon catchment area (worked example).
- Modelled flows: Hydro-tools and the rainfall-area method (worked example).

Hyperlinks are also provided within the Appendix; these include links to:

- Available hydrometric data.
- Available meteorological data.
- Hydro-tools model.
- OPW subcatchment generation tool (FSU portal).

2.6 Useful References

Herschy, R. W., 1995. *Streamflow Measurement*. Chapter 6. CRC Press.

Harrelson, C.C., Rawlins, C.L. and Potyondy, J.P., 1994, *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*, USDA Forest Service. Available at: https://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf.

3 Water Quality Indicator – Water Temperature and Thermal Imaging

3.1 Purpose

Water temperature is a physical property which expresses how hot or cold water is. Water temperature is the dynamic response to climate and hydrological patterns in a catchment. Temperature is helpful in identifying changes in the environmental conditions along streams, and identifying anthropogenic influences from point sources of pollution (e.g., wastewater discharges). Temperature is also important because it is sometimes used to adjust or correct measurements of other water quality parameters or processes (e.g. estimating ammonia toxicity).

This section describes the role of temperature and gives information on the collection and interpretation of temperature measurements. It also describes a novel approach – thermal imaging – to collecting and using temperature.

3.2 Significance

Water temperature influences other parameters indirectly and can alter the physical and chemical properties of water. In this regard, water temperature should be accounted for when measuring and/or determining:

- **Dissolved oxygen (DO)**. The solubility of oxygen decreases as water temperature increases.
- **Chemical processes.** Temperature affects the solubility and reaction rates of chemicals. In general, the rate of chemical reactions increases with increasing water temperature.
- **Biological processes.** Temperature affects metabolism, growth, and reproduction. Plants and animals are affected by water temperature. Importantly algal photosynthesis will increase with increasing water temperatures.
- **Species composition of the aquatic ecosystem**. Many aquatic species can survive only within a limited temperature range. The optimal health of aquatic organisms from microbes to fish depends on temperature. Salmonids and sensitive taxa such *Plecoptera and Ephemeroptera* require high level of dissolved oxygen and thus will only thrive in colder waters that hold more dissolved oxygen. If temperatures are outside the optimal range for a prolonged period, organisms are stressed and can die. For fish, the reproductive stage (including spawning and embryo development) is the most temperature-sensitive period. Macroinvertebrates (for example, insects, crayfish, worms, clams, and snails) will move about in the stream bed to find their optimal temperature.
- **Water density and stratification**. Stratification is a seasonal phenomenon in deeper more stagnant water bodies such as lakes where the heat in summer substantially raises the temperature of the upper water layer. As water temperatures increase, the density decreases. Thus, sun-warmed water will remain at the surface, while the denser, cooler water settles at the bottom. Differences in water temperature and density between layers of water in deep water bodies leads to stratification and seasonal turnover.
- **Environmental cues for life-history stages**. Changes in water temperature may act as a signal for aquatic insects to emerge or for fish to spawn.

3.3 Equipment/Instruments

Temperature of water is measured with simple hand-held instruments which range from the simple and cheap to the more complex and costly. Examples are provided below. Temperature can also be measured with a simple alcohol-filled thermometer. Temperature can be measured alone or with a wide range of “multi-parameter” water quality measurement devices.

Expression of Results: Temperature readings should be recorded to one decimal place in degrees Celsius.

All thermometers must be checked against an externally calibrated working thermometer before being put into use, and then annually thereafter. Thermometers that do not meet the documented QC/QA criteria (e.g. ± 0.2°C of the true temperature) must be replaced. Examples are shown in Figure 3-1 and Figure 3-2.

Figure 3-1: Example of a hand-held probe for spot measurements (OxyGuard Handy Polaris, which measures temperature and dissolved oxygen).

a b

Figure 3-2: Example of more advanced probes for continuous measurements: a) Hanna (combined temperature and pH); b) YSi (pH, temperature, oxygen redox potential, dissolved oxygen, electrical conductivity, with case and cable for downloads, etc).

3.3.1 Specifications:

Standard probes should be suitable for the thermal regimes of Ireland, mostly within the range 0-30°C.

3.3.2 Calibration:

The equipment should be calibrated according to the manufacturer's instructions.

3.4 Method of Measurement

Water temperature is measured in-situ, quickly (usually over a few seconds), either directly from the water body or from a sample taken, allowing the thermometer to come to equilibrium before recording the value.

3.4.1 How to take measurement

Simply place the probe into the body of water, taking appropriate H&S precaution to prevent slip and trip falls. Hold the probe a few centimetres below the water surface, for a period of approximately 15-30 seconds. Read the temperature from the display and record on field sheet.

In streams or drainage channels, avoid pools or sections of stagnant water, as measurements at such locations will not provide representative results.

At springs, take the measurements as close to the spring discharge point as possible, taking appropriate H&S precautions to prevent slip and trip falls.

For pipe discharges, take the measurement in the resulting stream from the pipe, alternatively, take the measurement in a bucket which is used to capture the discharge. Try to take the measurements in a non-turbulent flow of water.

As part of a catchment walk, temperature would be measured:

- Upstream and downstream of stream confluences;
- Upstream and downstream of drain or pipe discharges;
- Regularly at, for instance, 50 m intervals along the walk.

3.5 Interpretation

3.5.1 Variations in temperature

Water temperature fluctuates between day and night (diurnal temperature changes) and over time periods (e.g., episodically or seasonally). There are no definitive standards or ranges that apply. However, as a guide, values for surface water in Ireland generally range between 0°C and 25°C seasonally, depending on variables such as climate, rainfall, water depth, shading, and baseflow.

Groundwater is slightly different. Groundwater that discharges at springs in non-karst environments shows less fluctuation seasonally, and as a rule of thumb, non-karstic groundwater has a temperature that is close to the average annual ambient temperature. Across Ireland, the temperature of groundwater measured under the national EPA groundwater quality monitoring programme in recent years have ranged between 9°C and 13°C in more than 80% of measurements (Table 3-1). Temperatures above 11°C may be influenced by geothermal heat sources. Groundwater temperatures in karst terrains show more variability, as groundwater flow in open conduits and cave systems is influenced by surface conditions.

Table 3-1: Summary of temperature data in the EPA groundwater monitoring database

	n	5th Percentile	10th Percentile	Median	90th Percentile	95th Percentile
Temperature (°C)	10654	8.9	9.6	11.0	12.7	13.6

*These data are from a combination of abstraction boreholes, non-pumped boreholes and springs. Varied sampling methods across the sites could impact the temperature, however, all data have been used to give a context. The data for all sites are available from EPA Hydrometric and Groundwater Section for more detailed assessment.

In streams and lakes, cooler water is generally considered "healthier" than warmer water. Diurnal variations in temperature can be caused by the photosynthesis and respiration cycles of algae in eutrophic waters, and this should be taken into account during catchment walks.

Temperature differences in surface waters can arise from:

- **Direct rainwater input and overland flow:** rainfall events, depending on their nature, can have different temperatures. This variation will be expressed in the surface water temperature.
- **Diurnal temperature variations:** the temperature of the stream will be affected by daytime and night-time air temperatures. Water temperatures will also be influenced by the amount of direct sun on the water.
- **Groundwater inflows:** groundwater flowing in bedrock or sand and gravel aquifers tend to have a very stable temperature that varies only slightly during the year. Average groundwater temperatures are similar to average annual air temperatures for the region, and vary from around 9-10°C in the north of the country to 11-12°C in the south of the country. Groundwater temperatures above 13°C would be considered to have a geothermal component or be polluted by heat from human activities.
- **Groundwater can flow into surface water bodies diffusely or at discrete points.** Temperature contrasts at point inflow locations may be picked up using appropriate measuring devices.
- **Piped shallow 'groundwater'/interflow (may not have sufficient temperature contrast):** water that flows underground in the soils and subsoils, but that has not reached the main body of groundwater in the aquifer, is known as 'interflow'. It can seep into streams and rivers or may be piped from land drains before entering the surface water body. The temperature may be very close to the surface water, or slightly different depending on how long the water has been underground and how much heat it has absorbed from or lost to the ground.
- **Piped inflows of drainage or effluent:** authorised or unauthorised discharge of effluent from trade, septic systems, land or road drainage may have a temperature different to the surface water body. Piped discharges may cause temperature changes at a point along the river or stream.

3.5.2 Approaches and Influencing Factors

Because temperature is an easy parameter to measure, it should be recorded every time a different water quality parameter is measured. Guidance is provided below on different scenarios which commonly arise during catchment walks.

To identify thermal pollution: To get a measure of thermal pollution you must find two places along the river at an appropriate distance apart that have the same conditions, then two people measure the temperature at approximately the same time. If the difference is greater than 2 degrees Celsius, then there is thermal pollution to the water body. Sources can include discharges and runoff associated with urbanisation, and discharges from industries especially with cooling processes. Human activities affecting water temperature can include the discharge of cooling water or heated industrial effluents, agriculture and forest harvesting (due to effects on shading), urban development that alters the characteristics and path of stormwater runoff, and climate change.

Temperature Profiling: Collecting temperature measurements at regular intervals (e.g. 50 m) along a river stretch can aid in identifying the location and source of pollution, as follows:

- A gradual increase may indicate a land use change / geology change diffuse contribution (e.g. surface drainage)
- A sharp and sustained increase indicates a localised contribution (e.g. surface drainage, piped input)
- A sharp but temporary increase may indicate a smaller localised discharge (e.g. piped input).

Upstream and Downstream: Collecting temperature readings upstream and downstream of a known (or suspected) point source will aid in assessing the impact on the receiving water body.

Temporal temperature variability. Temporal variability can be a good measure of rapid runoff and accompanying pollutants to streams. Sustained elevated values at a location may indicate the presence of piped input. Urbanisation can alter the temperature of receiving waters.

Geological/hydrogeological setting. Temperature values will depend on the groundwater influx.

3.5.3 Role of Urbanisation

Studies have shown that rates of warming are most rapid in urban areas. Urbanisation is associated with increased river temperature compared with rural environments due diffuse and point sources associated with urban wastewater e.g. storm water runoff of water across warmed paved surfaces and from combined sewer overflows. The increasing use of Sustainable Urban Drainage Systems (SUDS), may minimise the impact of surface water runoff from urban developments.

3.5.4 Other sources and activities that can influence temperature

- Removal of upland vegetation
- Heated effluent from power plants and other industries that require cooling may have a profound warming impact
- Direct flow augmentation and abstraction change river thermal capacity
- Climate change will have direct and indirect impacts on water temperatures
- Stream order and baseflow contribution
- Land-use change from riparian forest to grassland for agriculture may elevate water temperatures in summer.

3.6 Thermal Imaging

Thermal imaging or thermography is a suite of methods that use the heat energy emitted by objects to produce images of the objects. Environmental thermal imaging can be carried out using satellite, aerial (conventional aircraft or drone) or hand-held, ground based cameras. Hand-held thermal imaging cameras provide a cost-effective, fast and safe means of remotely and visually identifying discharges into surface waters. This guidance is concerned with relevant techniques using hand-held, mobile phone-mounted thermal imaging cameras.

3.6.1 Purpose/Objective

Thermal images provide a visual evidence record of groundwater, wastewater or other discharge into a stream, river or lake that are a different temperature to the receiving water and can be used for the following purposes:

1. **To identify locations where groundwater discharges to a stream, river or lake at discrete points (springs).** Under conditions where groundwater and surface waters are different temperatures, thermal imagery can be used to identify spring discharges to surface waters. Spring discharges that enter streams, rivers and lakes below the water surface can also be identified through thermal imagery, where there is no visible evidence of discharge on the water's surface.
2. **To identify locations where groundwater discharges to a stream river or lake in a diffuse zone**. Provided the groundwater and surface water are different temperatures, diffuse seepage zones (i.e. reaches along rivers or lake shores where groundwater seeps out along a wide front) to surface water can be identified, especially during summer, when groundwater is usually colder than surface water.

3. **To identify locations where wastewater or industrial discharges enter the streams, rivers or lakes.** Provided there is a temperature difference between such discharges and the receiving water, such discharges can be identified, even through dense vegetation, and in cases where the discharge is released below the surface of the receiving water (i.e. if there is no visual indication of influent water).
4. **To identify water movement through wetlands.** In cases where groundwater or surface water is seeping or slowly flowing through wetlands, such movement is often visually imperceptible. Thermal imagery can be used, provided there is a temperature variation between the moving and stagnant water, to identify zones or channels where such seepage or flow is occurring.
5. **To identify and characterise mixing zones**. Thermal imagery can provide a quick and simple method of visually mapping the thermal mixing zone for a discharge into a surface channel or lake, or at a stream confluence where there is a difference in temperature between water in the merging channels.

The main benefits of thermal imaging are that it can be used to identify discharges into surface water; a) remotely, without the need to access the channel, b) where there is no visual evidence of a discharge on the water surface, c) where discharges may be obscured by vegetation and d) by providing a permanent, time-stamped and georeferenced image record that can be assessed by future investigators. However, seasonal thermal variations must be accounted for.

3.6.2 Significance

By identifying parts of a stream that are gaining water from groundwater, either point or diffuse, it may be possible to identify groundwater-surface water interaction pathways and thus sources of groundwater-borne contaminants in catchments. The same holds true for wastewater discharges to surface waters. Such wastewater discharges are usually point discharges, but may be relatively small, and therefore difficult to locate by visual means alone. The accurate identification of such small but potentially polluting discharges is an important element in the successful completion of Local Catchment Assessments.

If water samples are to be taken in wetlands or at discharge mixing zones, it is important to ensure that water is being sampled from the correct location. It is common in wetlands and in mixing zones for significant differences in water chemistry to occur over small horizontal distances (<0.5m) due to areas of stagnant (dead) water, or due to fast moving currents in receiving waters that push influent water towards the banks of a channel. Thermal imagery provides a simple and rapid means of identifying the areas where such samples should be taken, and thus helps remove one source of ambiguity related to such sampling.

3.6.3 Methods and Approaches to Consider

This guidance has been based on methods tested using a hand-held mobile phone-based thermal imaging device (a Flir One, android thermal imaging unit). The unit in question takes simultaneous thermal and normal visual spectrum images through two separate cameras mounted in the unit. These images can be overlain and examined together using various transparency settings, or side by side. The specifications of individual devices will vary, but there are some general points that apply regardless of the thermal imaging unit being used.

Thermal imaging devices can be used to identify discharges to surface water provided there is a thermal difference between the discharging and receiving waters. Current hand-held units claim to have a thermal resolution of 0.1 Degrees Celsius. However, various factors may impact the ability of the device to function to this standard including; the ambient air temperature, the angle that the image is taken at, solar radiation and shadow effects, the distance from the target object and thermal stratification of target waters. The overall impact of these factors in terms of identifying discharges to streams, rivers or lakes tends to be that they may lead to false negatives rather than false positives, in that these factors will mask discharges under certain conditions. Therefore, care should be taken in interpreting the results; for instance, use more than one line of evidence.

When using a phone-mounted device, the device's georeferencing capability should always be turned on so that all images captured are stored with the location coordinates embedded in the images. Various thermal image colour ramps can be selected in the viewer screen. The operator should choose a colour ramp that enables them to easily identify thermal variations on the day based on the weather, location characteristics, stream temperature etc. encountered.

The unit camera will auto calibrate, similarly to how a digital camera autofocuses. The operator should allow the camera to auto calibrate and then cross-check the image temperature estimate in the stream or lake with a hand-held thermometer. Experience has shown that there is typically <0.5°C difference between the thermal image and thermometer estimates. Numerous thermal images of each object of interest should be taken at various distances and angles. The clearest results will usually be obtained by taking images as close to the object of interest as possible and at a perpendicular angle to the object or water surface if possible.

In some cases, more than one site visit may be required under different weather conditions such as summer and winter, to assess discharges effectively using thermal imagery. Published literature and field testing in an Irish context has shown that there are significant seasonal differences in how discharges are characterised by thermal imagery under different weather conditions at different times of the year.

In summer, typical surface water temperatures may often be >11°C, while in winter they are often <10°C. Groundwater in Ireland remains at a more-or-less constant temperature year-round of ~10.5°C. Therefore, discharging groundwater usually appears colder that the receiving surface water on thermal images taken in summer months, while groundwater discharges appears warmer than surface water during winter months. The temperature of wastewater is dependent on several factors, but it is commonly warmer than surface water year-round, typically as a result of microbial activity. An important point to note is that in summer groundwater usually appears colder than surface waters on thermal imagers while wastewater appears warmer than surface waters. Conversely, in winter, both groundwater and wastewater usually appear warmer than surface waters and cannot therefore be differentiated from each other in thermal images taken during cold times of the year.

The most effective time to use thermal imagery appears to be during the coldest part of winter when the temperature difference between surface water and groundwater/wastewater is greatest. It should also be remembered that if no thermal variation is observed in a channel, this does not mean that there is no groundwater of wastewater discharge into the channel. It could simply mean that there is no temperature difference between the influent water and the receiving water. Therefore, thermal imaging is unlikely to lead to false positive identification of discharges, but it could lead to false negative assessments.

The following images illustrate groundwater and wastewater discharge identification under Irish conditions. The thermal images on the left and visible spectrum images on the right were taken simultaneously using the Flir One thermal imaging unit.

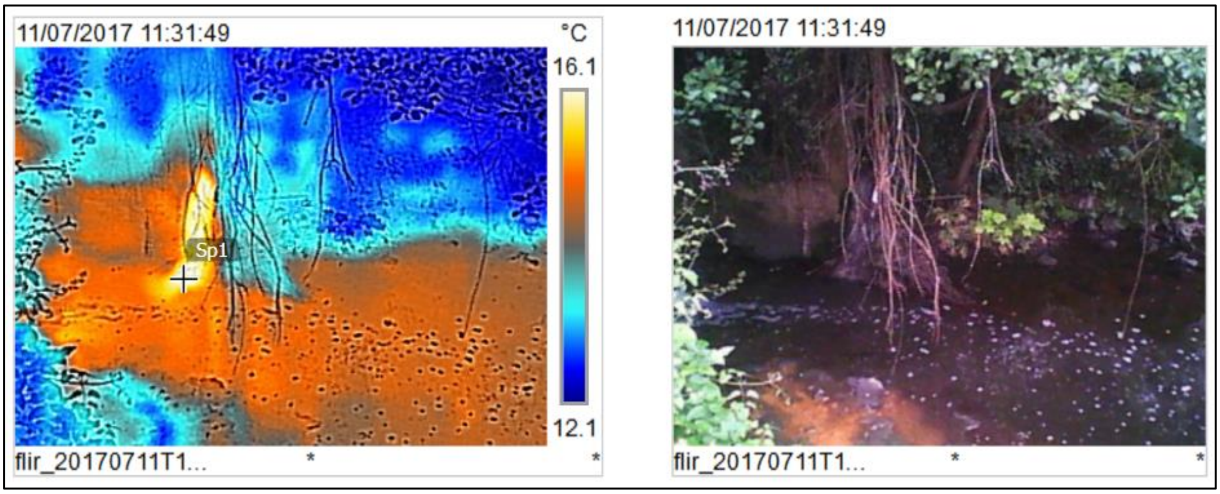


Figure 3-3: Thermal and visible spectrum images showing a wastewater discharge (yellow) entering a river channel during <u>summer</u>. (Note the discharge is warmer than the river water.)

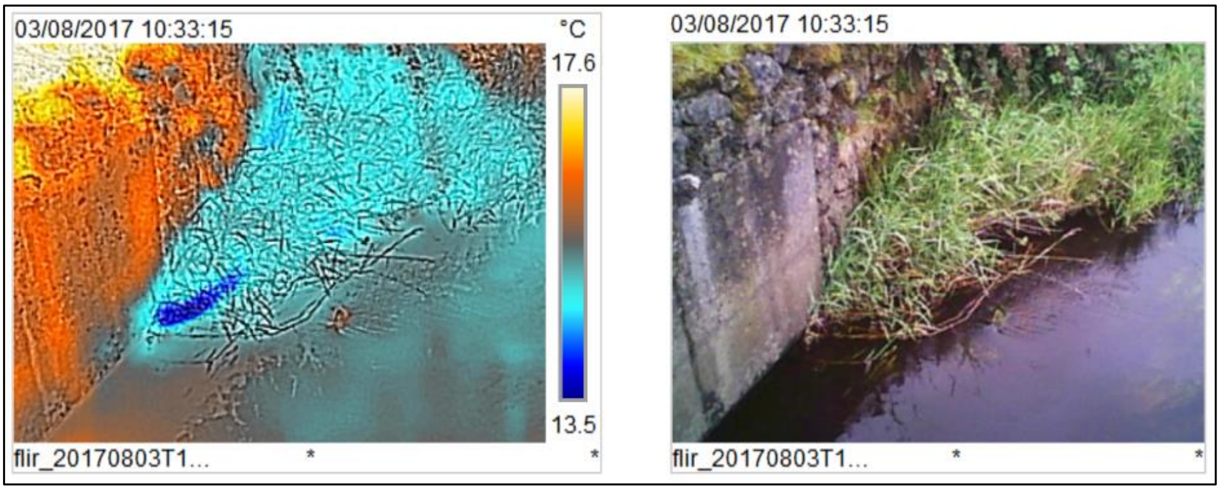


Figure 3-4: Thermal and visible spectrum images showing a groundwater discharge (blue) entering a river channel during <u>summer</u>. (Note the discharge is colder than the river water.)

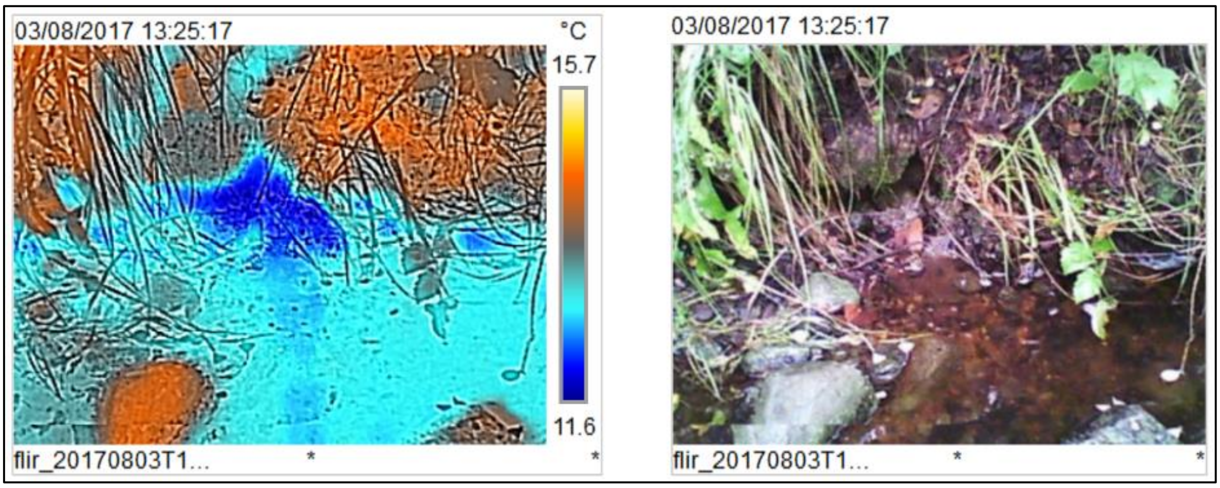


Figure 3-5: Thermal and visible spectrum images showing a groundwater discharge (blue) seeping into a stream channel and providing baseflow to the stream during <u>summer</u>. (Note the seepage is colder than the river water and surrounding soil and stones.)

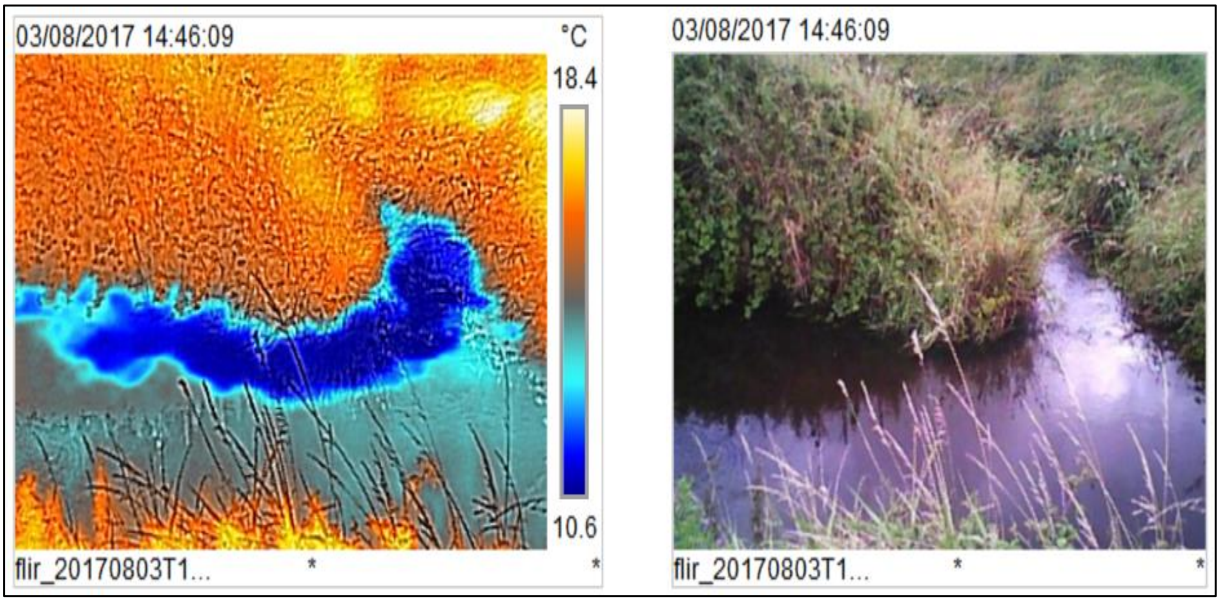


Figure 3-6: Thermal and visible spectrum images showing a groundwater discharge (blue) from a large spring entering a river channel during summer. (Note the discharge is colder than the river water and clearly defined within the main river channel. Also note how the spring discharge is pushed into the bank of the main channel by the current in the receiving waterway.)

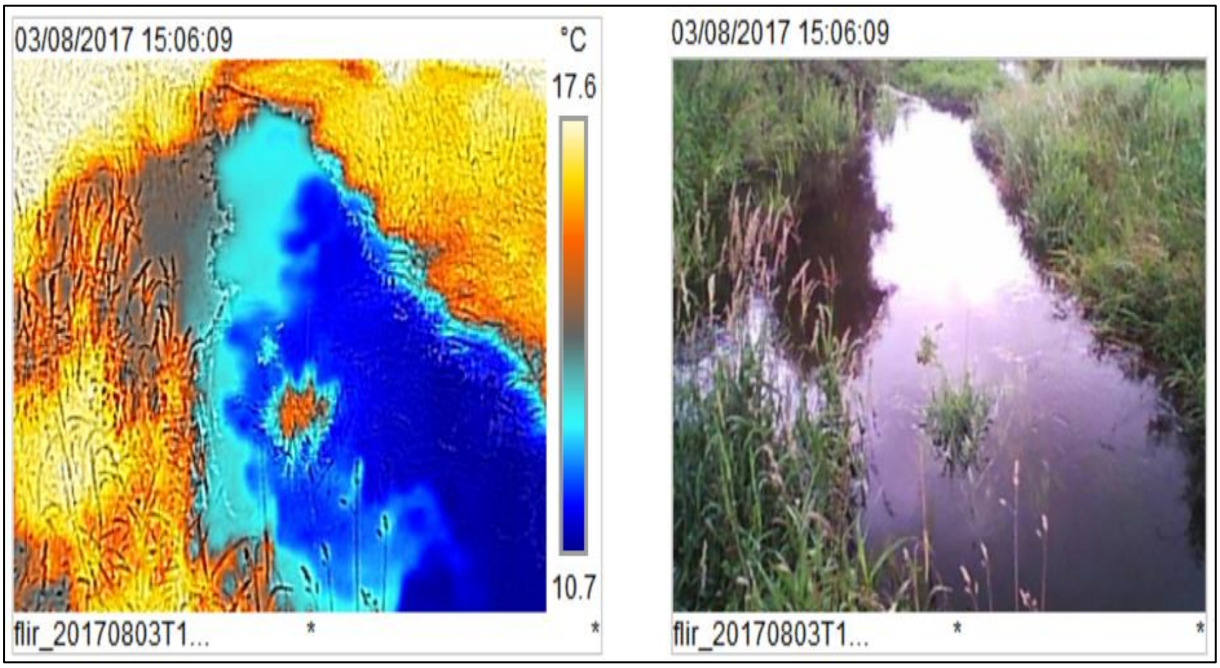


Figure 3-7: Thermal and visible spectrum images showing a groundwater discharge (blue) entering a river channel during summer. (Note the discharge is colder than the river water. Of particular interest in this and the previous image is the mixing zone. Water samples taken 0.2-0.3m apart could have entirely different sources.)

These locations will be visited during the winter and the field tests will be repeated, and the results will be included in a future version of this Guidance.

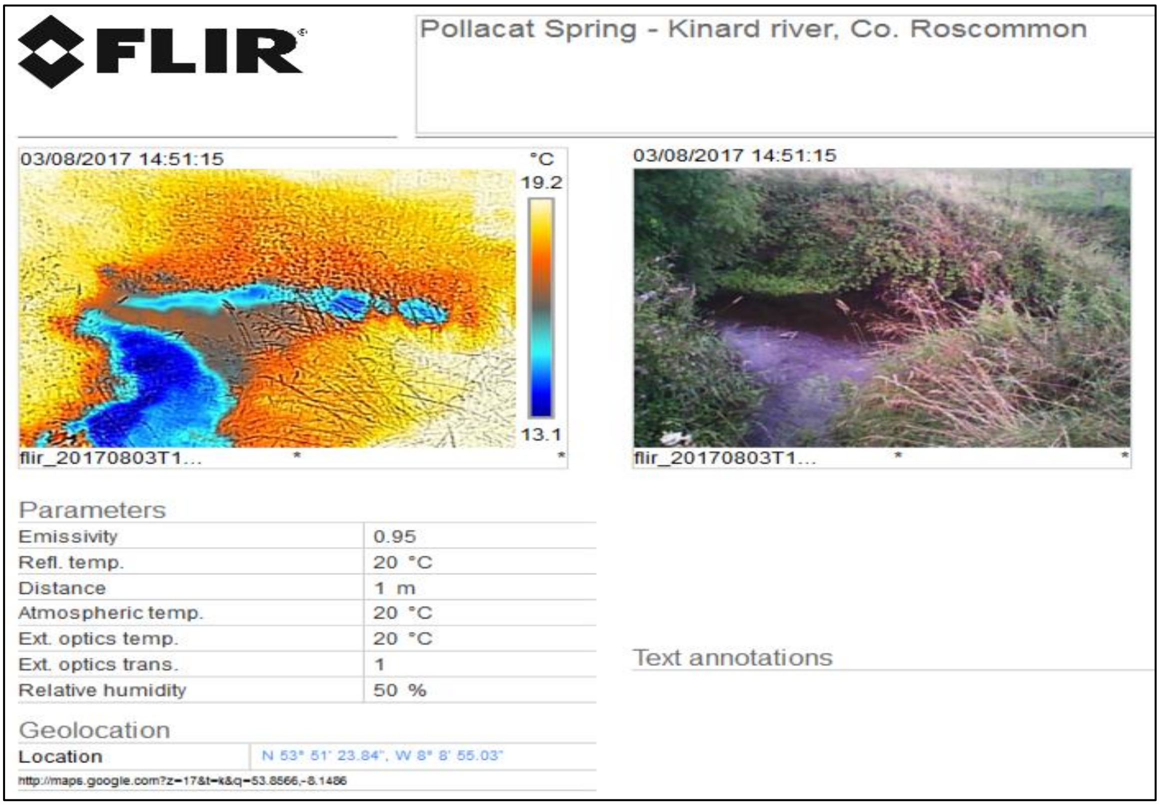


Figure 3-8: Thermal imagery report generated by the device's proprietary software. (Note the metadata table which provides a permanent record of survey conditions. The temperature recorded in every pixel of the thermal image is stored and can be queried at a future date.)

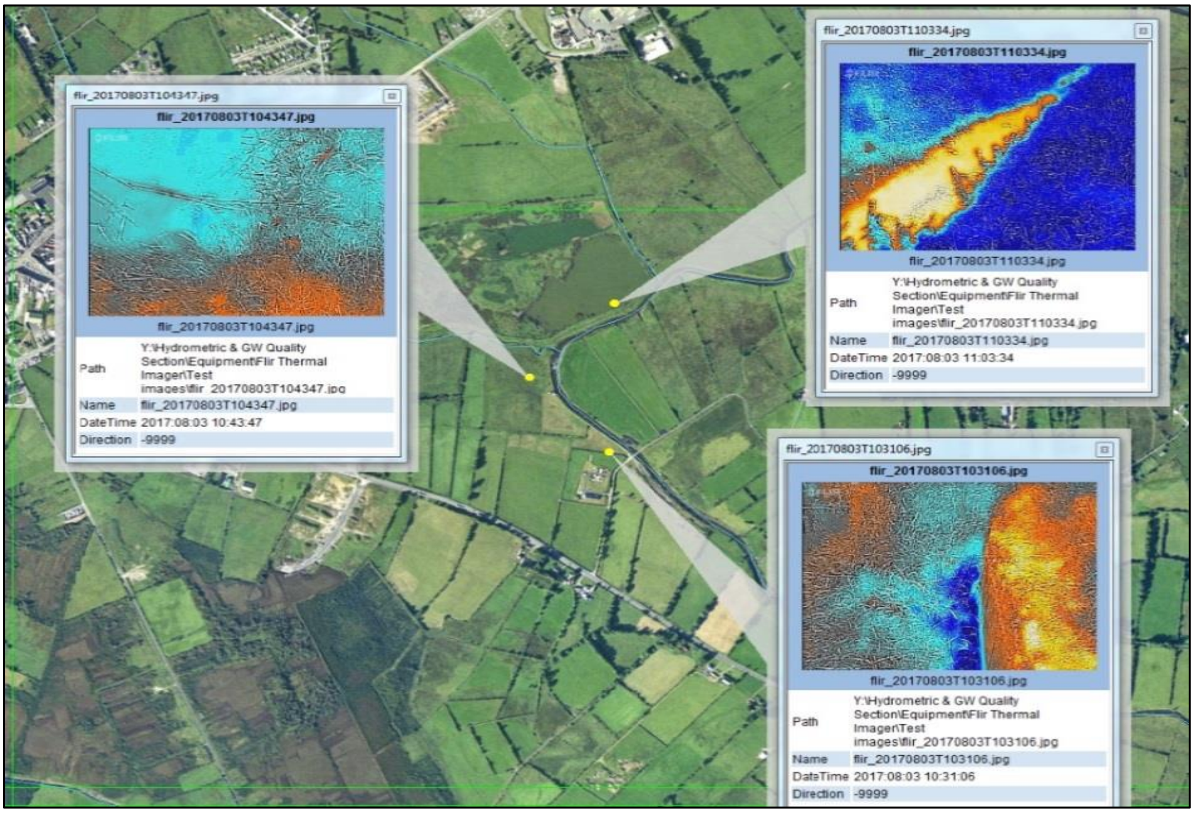


Figure 3-9: Display of georeferenced thermal images in ArcGIS

3.6.4 Approaches to Consider

Hand-held thermal imagery provides a fast means of scanning river channel or lakeshores for temperature variations. Taking thermal images from bridges or high river banks where possible is a good approach that minimises issues associated with the angle of the camera to the water surface. Also, scanning the channel from side to side while walking upstream has proven to be an effective means of identifying discharges, in particular small seepages of groundwater that provide baseflow to surface channels.

3.6.5 Thermal Imaging Cameras

Thermal imaging cameras are particularly useful for identifying and mapping groundwater discharges along streams and effluent discharges. Useful details are given at the links below.

General: https://water.usgs.gov/ogw/bgas/thermal-cam/

The following link is to a video showing groundwater and surface water imaging using a thermal camera. From 2 minutes in: https://water.usgs.gov/ogw/bgas/thermal-cam/ozarks.html

Table 3-1: Imaging Camera Types and Costs:

Make/model	Type	Cost	Spec	Link
FLIR One	Add on to smartphones and tablets	€251	Range -20° to 120°C Detect temperature differences as small as 0.18° F (0.1° C).	http://www.flir.eu/flirone/ios-android/
FLIR C3	Pocket sized thermal camera	€623	Range -20° to 300°C Thermal sensitivity <0.1° C. Can show some of visible light context. Records videos.	https://www.flir.eu/products/c3-x/

3.7 Useful References

Deitchman, R.S. and Loheide, S.P., 2009. *Ground-based thermal imaging of groundwater flow processes at the seepage face.* Geophysical Research Letters 36 (14).

Mundy, E., Gleeson, T., Roberts, M., Baraer, M. and McKenzie, J. M., 2017. *Thermal Imagery of Groundwater Seeps: Possibilities and Limitations*. Groundwater 55 (2).

Pfister, L., McDonnell, J. J., Hissler, C., and Hoffmann, L., 2010. *Ground-based thermal imagery as a simple, practical tool for mapping saturated area connectivity and dynamics*. Hydrological Processes 24 (21).

Hannah, D.M. and Garner, G., 2015. *River water temperature in the United Kingdom: Changes over the 20th century and possible changes over the 21st century*. Progress in Physical Geogrpahy: Earth and Environment 39(1). Available at: https://us.sagepub.com/en-us/nam/home.

O'Grady, M.F., 1993. *Initial observations on the effects of various levels of deciduous bankside vegetation on salmonid stocks in Irish waters*. Aquaculture and Fisheries Management 24 (4): 563–573.

Bjorn, T.C. and Reiser, D.W., 1991. *Habitat requirements of salmonids in streams. In: Meehan, WR (ed). Influences of forest management on salmonid fishes & their habitats.* American Fisheries Society, Bethesda.

4 Water Quality Indicator – Dissolved Oxygen

4.1 Purpose

DO measurements are taken to record the concentrations of dissolved oxygen in water. Availability of oxygen is important for the survival of aquatic species.

4.2 Significance

Oxygen is "sparingly soluble" into water. Oxygen can get into water by slowly diffusing across the water surface, aided by wind agitation and turbulent flow. It can also be mixed into the water by photosynthesis from aquatic vegetation (macrophytes and algae). The solubility of oxygen into water is affected by hydrostatic pressure, temperature and air pressure.

The European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. 272 of 2009) provide lower and upper limits of dissolved oxygen – 80-120% saturation. Furthermore, Toner and O'Sullivan (2009) stated that for clean water at 15^0C, the oxygen saturation concentration is 10.2 mg/l (~100% saturation) (Toner and O'Sullivan, 1977). Under normal unpolluted conditions, DO levels in the range of 8–10 mg/l can be expected in Irish streams. Lower values are indicative of organic pollution and possibly eutrophication. In well oxygenated waters, DO levels can rise to between 10 mg/l and 14 mg/l, which is considered "supersaturated".

Changes in DO content in freshwater is primarily due to the discharge of organic effluents, but can also result naturally from the decomposition of organic matter. The release of nutrients may subsequently give rise to eutrophication which supports excessive development of algae. Significant changes in DO can be caused by:

- Organic discharges (wastewater treatment plants, agricultural manure/slurry or silage effluent).
- Thermal discharges.
- Algal blooms, particularly in eutrophic lakes.

Eutrophication in rivers and lakes can cause significant diurnal variation in DO content. Diurnal variations of DO can give rise to night-time low DO levels, below the threshold at which fish will survive. For salmonids, which are the most DO-sensitive species, the threshold is about 3 mg/L. Excess nutrients promote the growth of significant algae blooms. In the upper surface layer during daylight hours, photosynthesis produces supersaturated levels of oxygen. At night, algal respiration could drop this level significantly. Furthermore, the dense algal growth can interrupt light penetration to stands of Chara, for example, on a lake bed. The dense stands of Chara can die back, significantly reducing dissolved oxygen concentrations in the body of the lake. In addition, the Chara also supports huge populations of invertebrates which are grazed on by trout and therefore, this resource for fish can be reduced.

Bacteria use the carbon and nutrients contained in organic waste as a food source. Their metabolism requires oxygen and this is obtained directly from the water itself. With high organic content the bacterial population can double every half hour and quickly give rise to anaerobic conditions. The consequences of this on aquatic species such as invertebrates and particularly fish are devastating. A "fish-kill" is mostly associated with high-strength effluents polluting waterways. Temperature is also an important factor, with higher temperatures reducing the solubility of oxygen in water, which increases the stress on aquatic species (particularly fish).

The Freshwater Fish Directive gives limits for dissolved oxygen within salmonid waters: see http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:264:0020:0031:EN:PDF. In addition, Table 4-1 is extracted from a report by the European Inland Fisheries Advisory Commission (EIFAC, 1973) which indicates the minimum DO levels that are likely to be required for certain attributes.

Table 4-1: Tentative minimum sustained DO for maintaining the normal attributes of the life cycle of fish under otherwise favourable conditions (from EIFAC, 1973)

Attribute	DO mg/l
Survival of juveniles and adults for one day or longer	3.0
Fecundity, hatch of eggs, larval survival	5.0
10% reduction in hatched larval weight	7.0
Larval growth	5.0
Juvenile growth (could be reduced to 20%)	4.0
Growth of juvenile Carp (Cyprinus carpio)	3.0
Cruising/ swimming speed	5.0
Upstream migration of Pacific and Atlantic salmon	5.0
Upstream migration of American shad	2.0
Schooling behaviour of American shad	5.0
Sheltering behaviour of walleye salmon	6.0

Sensitivity to low DO differs between species and also the stages of growth. Table 4-2 gives an indication of oxygen requirements for fish.

Table 4-2: Dissolved oxygen requirements

Species	50%ile value (mg/L)	5%ile value (mg/L)
Roach (coarse fish)	>5	2
Salmonids (adult)	9	5
Fish survivability	5	
Rate of growth (salmonid)	At 3, slight reduction	
Migrating salmon (estuary)	5	2

Source: EIFAC

The European Inland Fisheries Advisory Commission (EIFAC) field observations have indicated that *"a minimum constant value of 5 mg/l would be satisfactory for most stages and activities in the life-cycle in that some processes, such as juvenile growth, fecundity, hatch of eggs, larvae morphology and survival, upstream movement of migrating salmon and schooling behaviours of some species including shad are not particularly susceptible to levels of DDO above 5 mg/l"*

If DO values are greater ≥ 3 mg/L, acute lethal effects on fish may be avoided but even at this level while fish survive their ability to feed can be reduced.

DO concentration is a primary determinant of habitat suitability for sensitive classes of invertebrates and fish. The DO within "interstitial habitat" will also be influenced by the sediment regime, particularly in lower gradient reaches. A proliferation of opportunistic algae can increase sedimentation, or limit mixing between surface water and the hyporheic zone. Significant DO sags follow increased biological activity in waters with a high "biochemical oxygen demand" (BOD) and in extreme cases the river bed will appear blackened or "anoxic" when near zero or anaerobic conditions are prevalent.

4.2.1 DO in Groundwater

Groundwater discharging to surface water can affect the DO levels in receiving waters. Some studies have concluded that although groundwater discharging to streams may have relatively low DO concentrations, this may be balanced out by the cooling of streams by groundwater inflows, especially during summer months, increasing the capacity of surface water to dissolve oxygen. However, this needs to be assessed based on the specifics of a given catchment.

The dissolved oxygen data from EPA groundwater monitoring have been analysed and are described in Table 4-3 below. The median measured value is noticeably lower for poorly productive bedrock than other aquifer types. In the more productive bedrock aquifers the higher values may relate to relatively high velocities (especially in karst) with less contact time for chemical reaction or for natural degassing. There may also be greater recharge of oxygen rich waters along the flow path in the productive aquifers.

Table 4.3: Summary description of dissolved oxygen in EPA groundwater monitoring data*

		Dissolved Oxygen (mg/l)		
Aquifer Type	**n**	**5th Percentile**	**Median**	**95th Percentile**
Gravel	702	2.6	6.7	10.7
Karstic	3196	1.0	5.2	10.0
Productive Fissured Bedrock	1129	0.6	5.8	9.9
Poorly Productive Bedrock	2804	0.2	3.8	10.2

*These data are from a combination of abstraction boreholes, non-pumped boreholes and springs. Varied sampling methods across the sites could impact the DO concentrations, however, all data have been used to give a context. The data for all sites are available from EPA Hydrometric and Groundwater Section for more detailed assessment.

In areas with karst bedrock the relatively high dissolved oxygen concentration in groundwater can be related to the high degree of groundwater-surface water interaction in karst scenarios. Groundwater flow can be relatively turbulent as it quickly flows through conduits contributing to relatively high dissolved oxygen concentrations.

The greater the proportion of surface water flow that is made up with groundwater, the greater impact it could have. This can be considered in relation to the groundwater contribution to surface water flow on average, based on different aquifer types (Table 4-4). It should be considered that at low river flows in dry weather conditions the proportion of groundwater making up the river flow increases. At low flows the dissolved oxygen in discharging groundwater may also be lower than at other times relating to a greater average amount of time spent in the aquifer.

Table 4-4: Estimated groundwater contributions to surface water for different aquifer types (EPA, 2010).

Aquifer Type	**% of annual average surface water flow from groundwater**
Gravel	90
Karstic	74
Productive fissured bedrock	65
Poorly productive bedrock	21 to 27

Where there are naturally occurring minerals such as pyrite (FeS_2), there can be reduction processes at work which deplete the DO levels in groundwater. The GSI have produced a map indicating where this may occur. In areas where aquifers are confined, the depletion of DO can also occur, influencing chemical processes in groundwater such as denitrification.

Groundwater temperature should also be considered. When the temperature of surface waters is higher than the temperature of groundwater during the summer, the cooling of the stream by groundwater inflow increases the capacity of the surface water to dissolve oxygen. The temperature of groundwater measured as part of the EPA groundwater quality monitoring programme were presented in Table 3-1.

4.3 Equipment/Instruments

DO is measured using a hand-held instrument, like those described in Section 3. Temperature readings must be taken along with any measurement of DO.

Expression of Results: DO is measured and recorded in mg/l or % saturation.

A good quality DO meter is essential. Practically speaking, a multi-probe meter is used which offers DO, pH, temperature and electrical conductivity. Most probes are fitted with short cable lengths of 2–3 m. However, lengths of 10 m (or more) can be procured, which can be beneficial for taking measurements from bridges and in lake situations.

4.3.1 Specifications

Standard probes should be able to measure concentrations between 0-15 mg/L.

4.3.2 Calibration

The equipment should be calibrated according to the manufacturer's instructions. Regular calibration, even in the field, is essential. It is suggested, depending on the equipment used, that calibration should take place a minimum of 3 to 4 times in the course of a day. However, some instruments may require more frequent calibration depending on the time span between use. Absence of calibration can be indicated by erratic, unstable readings.

Most DO metres are calibrated using the "water saturated air method." It is important to ensure that the sponges in the metres are maintained in a very damp condition to ensure that air in the calibration container will be maintained at a "water saturated state".

4.4 Methods of Measurement

DO in surface water and springs is measured in-situ and directly from the water body, allowing the DO reading to stabilize before recording the value.

4.4.1 How to take measurements

The probe is lowered in water and left submerged until readings stabilize, usually within seconds. It is important that the probe remains submerged during measurement. In streams and spring discharges, there should be a constant flow of water over the probe. Gentle movement of the probe may be necessary to ensure that this happens to obtain consistent and valid readings.

4.5 Approaches and Influencing Factors

Because of the importance of DO to aquatic species, Assessors should take DO measurements at regular intervals during catchment walks, along with temperature. DO would especially be measured:

- Upstream and downstream of stream confluences;
- Upstream and downstream of drain or pipe discharges or other effluent discharges such as from farmyards.

Measurement from bridges is useful when covering large distances, however, it must be remembered that if a polluting event is taking place, the oxygen "sag" may not be detected if measurement distances are too large.

Instability in readings can be caused by lack of maintenance of the electrodes covered by the semipermeable membrane. This may require a professional service to remove deposits from the electrodes.

A very low DO reading can indicate the location of the "oxygen sag", however, the actual cause may be some distance upstream. The photographs below indicate areas where low DO levels might be expected.

4.6 Useful References

EPA, 2010. *Methodology for establishing groundwater threshold values and the assessment of chemical and quantitative status of groundwater, including an assessment of pollution trends and trend reversal*. Environmental Protection Agency. Available at: http://www.epa.ie/pubs/reports/water/ground/groundwaterthresholdvaluesandassessmentofchemicalandquantitativestatus.html.

Toner, P.F and O'Sullivan, A.J., 1977. *Water Pollution in Ireland – a review of the existing situation, current investigations and future research needs*. Published by National Science Council, Dublin Stationery Office: pp4.

EIFAC, 1973. *Report on dissolved oxygen and inland fisheries*. EIFAC technical paper number 19. European Inland Fisheries Advisory Commission. FAO, 21pp. Available at: http://www.fao.org/docrep/017/d8126e/d8126e.pdf.

Alabaster, J.S. and Lloyd, R., 1982. *Water Quality Criteria for Freshwater Fish 2nd Edition.* Published by Food and Agricultural Organisation of the United Nations and Butterworths press: 127 – 142.

British Columbia, 2018. *British Columbia approved Water Quality Guidelines: Aquatic Life Wildlife and Agriculture*. Summary Report. Water Protection & Sustainability Branch, Ministry of Environment & Climate Change Strategy. Available at: http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidlines/approved-water-quality-guidlines.

5 Water Quality Indicator – pH

5.1 Purpose

pH is a measure of whether a liquid is acid or basic. pH is ranked on a scale of 0 (very acidic) to 14 (very basic), with pH 7 being neutral. pH is the negative logarithm of the hydrogen ion concentration of a solution. When the concentration of H^+ ions in solution increases, acidity increases and pH gets lower, and vice versa. pH is a logarithmic function - one unit change in pH (e.g. from 7 to 6) indicates a ten-fold change in hydrogen ion concentration in that solution.

The pH of water is an important variable in water quality assessment as it influences many biological and chemical processes within a waterbody, and governs the behaviour of other parameters of water quality (e.g. ammonium toxicity). In unpolluted waters, pH is principally controlled by the balance between carbon dioxide, carbonate and bicarbonate ions as well as natural compounds such as humic and fulvic acids.

5.2 Significance

If low pH values are exhibited in the field and the catchment is on siliceous (non-carbonate) geology, the alkalinity of the water should be assessed. Low pH (<5.5) and low alkalinity (<10 mg/l CaCO3) are clearly indicative of low buffering capacity. As a result, the catchment may be designated as "acid sensitive". This means that it is sensitive to pH or salinity changes. Acid sensitive catchments are characterised by slow-weathering geologies such as granites, schist and quartzite, and are often overlain by blanket peat and/or peaty podzols. Extensive acid-sensitive areas occur in the upland areas west of Ireland, Wicklow and in parts of Galway and Donegal. The available literature indicates that little impact has been found in areas draining geologies with high buffering capacity (carbonates, specifically limestones) as they and their soils contain calcium ions which neutralise the acid ions.

Forestry is one of the main pressures known to increase the acidification of waters, principally due to the ability of forest canopies to capture more acid sulphur and nitrogen pollutants from the atmosphere. Many waterbodies rise in, or receive drainage from upland forested areas and indeed a significant portion of the High Status Objective sites (Q4-5, Q5) are located in these catchments. It is important to manage catchments appropriately to ensure acidification is not exacerbated as these waterbodies are also an important nursery area for salmonids. It is critical that measures are taken to avoid increased rates of acidification, particularly those relating to anthropogenic changes in land use as studies have shown that acidified waters reduce the diversity of ecology including macroinvertebrates and fish and increases the bioavailability of toxic metals such as aluminium into the environment.

Naturally acidic streams often have high levels of dissolved humic substances, which may ameliorate the toxicity of metals, primarily inorganic aluminium, which has documented toxic effects on biota in acidified freshwaters. The biggest impacts can be seen where the pH is lowered through anthropogenic sources and these pressures should be minimised where possible:

- Atmospheric deposition of acidifying pollutants, such as sulphate and nitrate, in these waters results in a reduction in surface water pH values (acid rain has pH values less that <5.6).
- Plantation forests and their management can influence pH in water quality in a number of ways and at different stages of the forest cycle – see Section 7 in **Volume 2** for further information.
- Industrial discharges (see Section 11 in **Volume 2** for further information).
- Acid mine drainage water (see Section 10 in **Volume 2** for further information).

Studies have shown that in anthropogenically-acidified streams there is a distinct change in the benthic invertebrate faunal community composition. Some taxa disappear or become scarce, particularly mayflies, some caddisflies, crustaceans such as Gammarus species and molluscs. As a result, species diversity is reduced. The surviving communities are typically dominated by nemourid stonefly species (and include Leuctra, Protonemura and Nemoura). These taxa are considered more acid tolerant and may benefit from the absence of specialist feeders by opportunistic feeding behaviour. In contrast, studies of naturally acidic streams suggest that they support a diverse and functional macroinvertebrate community.

5.3 Equipment/Instruments

pH is measured using a hand-held instrument, along with the multi-meters introduced in Sections 3 and 4. pH can also be read using test strips which are colour coded, and the pH value is read off a corresponding colour chart.

Expression of Results: pH values are unitless. pH values that are read from metering equipment should be recorded to two decimal places. Test strips usually allow for pH measurements to a single decimal.

5.3.1 Specifications

Standard probes should be able to take readings between pH 2 and 12.

5.3.2 Calibration

Hand-held pH meters should be calibrated according to the manufacturer's instructions. Test strips do not require calibration.

A calibrated pH meter is necessary for precise and continuous measuring. pH electrodes must be calibrated from time to time (usually weekly at a minimum) to maintain measurement accuracy. Performance of pH sensors degrade over time. The time period and related loss of sensor performance varies considerably with equipment types, applications and unique conditions.

Instability in readings can be caused by lack of maintenance of the equipment. This may require a professional service to remove potential clogging or deposits on internal electrodes.

5.4 Methods of Measurement

pH is measured in-situ and directly from the water body, allowing the pH reading to stabilize before recording the value.

5.4.1 How to take measurements

The probe, if used, is lowered in water and left submerged until readings stabilize, usually within seconds. It is important that the probe remains submerged during measurement. In streams and spring discharges, there should be a constant flow of water over the probe. Gentle movement of the probe may be necessary to ensure that this happens to obtain consistent and valid readings.

Test strips are dipped into water for a few seconds. When removed, the test strip will change colour after a further few seconds. The test strip colour is then held up to compare against a colour chart which is provided with the test strip equipment. The colour-coded value that corresponds to the colour observed on the test strip is then recorded.

5.5 Data Quality and Interpretation

Sources of data error are:

- Temperature can affect the pH measurement. As water temperature changes, the pH value also changes. Samples should be read at the same temperature i.e. in the field to eliminate this potential error source.

- Air bubbles, dirt strong acids & grease can cause slow stabilization or error in measurement and instruments should be cleaned periodically and pH sensors are stored in 3.5 M KCl solution to prevent dehydration.

The reliable interpretation of pH data must consider catchment-specific factors that could influence the readings during a catchment walk, including land use and geology. Thus, the prior desk-study work should identify what the underlying factors in a given catchment are.

Table 5-1 lists typical pH ranges for various waterbodies and common pollutants. Water with a pH of less than 4.8 or greater than 9.2 can be harmful to aquatic life. Most freshwater fish prefer water with a pH range between 6.5 and 8.4.

Table 5.1: Typical ranges of pH values and common pollutants

Water type/scenario	pH units
Rainwater	5-9
Acid Rain	4.9
Freshwater lakes	4.2 to 8.48
Peaty Catchments	4.5
Eutrophic waters	Up to 10
Soiled water from farms	6-7.4
Silage effluent	3.0-6.0
Landfill leachate	4.5-9.0
Acid mine drainage water	2.6-3.0

5.6 Approaches and Influencing Factors

As part of a catchment walk, pH should be recorded with temperature and DO readings. pH would especially be measured:

- Upstream and downstream of stream confluences;
- Upstream and downstream of drain or pipe discharges or other effluent discharges such as from farmyards, quarries and mines.
- Upstream and downstream of forested areas.

Measurement from bridges is useful when covering large distances, however, it must be remembered that if pollutant load is taking place, the precise location of pH changes may not be discerned if measurement distances are too large.

Practical reasons and tips for taking pH readings are listed below.

Identify and map variability of pH spatially and temporally. Water samples should be collected from streams or rivers at ‘high flow’, when conditions tend to be most acidic so that worst case scenarios are assessed. ‘High flow’ should generally be taken to mean a ‘spate’ following heavy rainfall but not a real ‘flood’; flows need to be at least above average. Such flows can occur at any time of the year but are most common during winter and spring periods. They will usually only last for a matter of hours to, at most, one or two days following significant rain event.

pH is a basic indicator parameter and it is important to determine if you are in a potentially acid sensitive catchment area by assessing the pH, alkalinity and geology of the catchment.

pH measurements are also helpful in identifying changed conditions along a stream for example an environmental change has occurred whose natural or anthropogenic cause can be identified or further tracked. This can be done by measuring upstream and downstream of confluences and of potential acidifying sources.

Diurnal variations in pH can be caused by the photosynthesis and respiration cycles of algae in eutrophic waters.

Temporal pH variability. Temporal variability can be a good measure of rapid runoff and accompanying pollutants to streams. Sustained elevated values at a location may indicate the presence of piped input.

Geological/hydrogeological setting. pH values will depend on the geology (calcareous/siliceous bedrock).

pH Profiling: Collecting pH measurements at regular intervals (e.g. 50 m) along a river stretch can aid in identifying the location and source of pollution, as follows:

- A gradual increase indicates a land use change / geology change diffuse contribution (e.g., surface drainage).
- A sharp and sustained increase indicates a localised contribution (e.g., surface drainage, piped input).
- A sharp but temporary increase may indicate a smaller localised discharge (e.g., piped input).

Upstream and Downstream: Collecting pH readings upstream and downstream of a known (or suspected) point source will aid in assessing the impact on the receiving water body

5.7 Useful References

Johnson, J., Farrell, E., Baars, J., Cruikshanks, R., Matson, R. and Kelly-Quinn, M., 2008. *Literature Review: Forests and Surface Water Acidification.* Water Framework Directive Western River Basin. District. Environmental Protection Agency, Ireland.

Cruikshanks, R., Lauridsen, R., Harrison, A., Hartl, M., Kelly-Quinn, M., Giller, P.S. and O'Halloran, J., 2006. *Evaluation of the use of the Sodium Dominance Index as a potential measure of acid sensitivity*. Technical report. Available at:
http://www.epa.ie/pubs/reports/research/water/sodiumdominanceindex-acidsensitivityertdireport50.html.

6 Water Quality Indicator – Specific Electrical Conductivity

Specific Electrical Conductivity (SEC), also commonly referred to as Electrical Conductivity (EC), or conductivity in short, is a measurement of the ability of water to conduct an electric current. The greater the content of dissolved ionic salts in the water, the greater the SEC. Measurements in water are quick and easy to take (matter of seconds), using a simple hand-held instrument. Because measurements are affected by temperature (the warmer the water, the higher the SEC), measurements are typically reported at 25^{o}C (a default setting of most instruments), in units of micro-Siemens per centimetre (µS/cm).

SEC can be an indicator of pollution, but it can also be an indicator of the natural type and origin of water. This is described further below. An additional technical note on electrical conductivity can be found in **Appendix B**.

6.1 Purpose

Measurements of SEC in water can be used for the following purposes:

1. **As a general measure of total dissolved solids (TDS).** SEC indirectly measures the presence of dissolved inorganic components such as chloride (a good indicator of pollutant input in both rural and urban areas), bicarbonate, sulphate, nitrate, calcium, magnesium, sodium, potassium and iron – the higher the SEC, the higher the TDS. Both diffuse and point sources of pollution are generally characterised by the presence nutrients and chloride, which increase the SEC in streams.
2. **To show variability of TDS temporally and spatially**. SEC measurements are especially helpful in identifying changed conditions along a stream. For example, where sudden changes in SEC values are noted, an environmental change has occurred whose natural or anthropogenic cause can be identified or further tracked. The change could be due to a pollution source, mixing of waters, or represent a change in hydrogeology whereby the geochemical signature of groundwater discharges (contributing water to a stream) affects TDS/SEC. The degree of change of TDS in a stream depends on the level of dilution in the stream. Therefore, SEC is a more effective indicator of changes in smaller streams. It is less effective in large streams or stream with naturally high TDS/SEC (e.g. limestone areas, see below). SEC is lowered after dilution by rainfall. It is therefore generally lower in winter and higher during low-flow conditions. Groundwater nearly always has higher SEC values than rainwater. SEC therefore increases when groundwater is the main contributor to flow in streams. Temporal variability can be a good measure of the susceptibility to rapid runoff with accompanying pollutants to streams. Also, SEC in groundwater and surface water is generally slightly higher close to the coast due to the presence of NaCl in rainwater.
3. **To reflect the geological/hydrogeological setting**. In general terms in Ireland, the highest SEC values (>600 µS/cm) are found in limestone bedrock and limestone-dominated subsoil (glacial till, sand/gravel) areas, due to the presence mainly of calcium bicarbonate ($CaHCO_3$) arising from solution of the limestones, with the lowest (<200 µS/cm)) in granite bedrock areas.
4. **To indicate input of pollutants.** Both diffuse and point sources of pollution are generally characterised by the presence nutrients and chloride, which will then increase the conductivity in streams. As mentioned above, SEC is a more effective indicator in smaller streams. The key is to look for and note spatial changes during a catchment walk.
5. **To indicate input of groundwater to a stream**. Soil, subsoil and bedrock release solids into the waters that flow through them. Therefore, in areas where groundwater is discharging to streams, particularly where this is focussed in certain stream stretches, an increase in SEC will indicate this.

6. **To detect presence of saline waters**. SEC may be useful to determine the importance of saline intrusion and its potential to influence the biological communities expected near tidal areas.

Installation of automated SEC and temperature data loggers for short periods in streams can be useful to enable temporal variations in water quality to be assessed. There are circumstances where this approach would be beneficial in tracking intermittent inputs of pollutants.

While SEC can be used for all five purposes listed above, **the main function of taking SEC readings and noting changes during catchment walks will be to locate the presence of inputting pollutants**.

6.2 Significance

Typical ranges of SEC values in surface water and groundwater in Ireland are summarised in Table 6-1. There are overlapping ranges, implying that similar values can occur in different settings and situations. There is, therefore, the need for prior awareness of the features and factors that influence SEC, and an appreciation of the general environmental setting of an investigation area, in order to interpret results correctly. Further information on ranges in groundwater in different aquifer types are documented in Table 6-2 based on Tedd et al. 2017[1].

In general terms in Ireland, the highest SEC values (>600 µS/cm) in groundwater are found in limestone bedrock and limestone-dominated subsoil (glacial till, sand/gravel) areas, due to the presence mainly of calcium bicarbonate ($CaHCO_3$) arising from solution of the limestones, with the lowest (<200 µS/cm) in granite bedrock areas. Also, SEC in groundwater and surface water is generally slightly higher close to the coast due to the presence of NaCl in rainwater.

6.3 Equipment/Instruments

SEC is measured using a hand-held instrument, like the multi-meters shown in Sections 3.

Expression of Results: SEC values are measured and recorded in micro-Siemens per centimetre (µS/cm) or Siemens per centimetre (S/cm). SEC values are rarely recorded in decimals.

6.3.1 Specifications

Standard probes for freshwater environments should be able to make accurate readings between 10 and 5,000 µS/cm (fresh to upper end of brackish waters). Higher values indicate saline environments (e.g. estuarine, tidal marine).

6.3.2 Calibration

Hand-held SEC meters should be calibrated according to the manufacturer's instructions. A calibrated SEC meter is necessary for precise and continuous measurement. SEC electrodes must be calibrated from time to time (usually weekly at a minimum) to maintain measurement accuracy.

6.4 Methods of Measurement

SEC is measured in-situ and directly from the water body, allowing the SEC reading to stabilize before recording the value.

6.4.1 How to take measurements

The probe, if used, is lowered in water and left submerged until readings stabilize, usually within seconds. It is important that the probe remains submerged during measurement. In streams and spring discharges, there should be a constant flow of water over the probe. Gentle movement of the probe may be necessary to ensure that this happens to obtain consistent and valid readings.

[1] www.epa.ie/pubs/reports/research/water/EPA%20RR%20183%20Essentra_web.pdf

Table 6.1: Typical ranges of SEC values[2]

Water type/scenario	SEC (µS/cm)
Rainwater	2-100
Freshwater lakes	2-100
Streams dominated by surface runoff	2-200
Groundwater	<100 - >1,000 (lowest values reflect karst systems; highest values reflect confined and/or brackish groundwater). Natural SEC values above 1,000 µS/cm are rare in Irish freshwaters[3] (Flynn and Deakin, 2016)
Groundwater in sand and gravel aquifers	400-600 (modified range based on Tedd et al., 2017)
Groundwater in calcareous fractured bedrock aquifers	300-700 (modified range based on Tedd et al., 2017)
Groundwater in karstified limestone aquifers	<100-700 (lower values reflect rapid throughflow of rainwater or surface water in open conduits; higher values (400-700) reflect slower moving groundwater in fissures and fractures – longer groundwater residence time
Groundwater in non-calcareous fractured bedrock aquifers of sedimentary origin (e.g. sandstone)	100-400 (modified range based on Tedd et al., 2017)
Groundwater in fractured bedrock aquifers of igneous (volcanic) origin	Generally <200 (due to low degree of rock-water interaction and localised flow cells, i.e. short groundwater residence times)
Brines	>50,000-500,000
Ocean water	~ 50,000
Landfill leachate	10,000
Acid mine drainage	up to 500,000

Table 6.2: Values of SEC recorded in EPA's groundwater monitoring network

SEC (µS/cm)	n	5th Percentile	10th Percentile	Median	90th Percentile	95th Percentile
Sand and Gravel Aquifers	962	289	519	672	780	809
Karstified Limestone Aquifers	4595	354	450	657	781	815
Poorly Productive Bedrock Aquifers	3925	152	233	510	755	799
Productive Fissured Bedrock Aquifer	1720	180	204	532	830	940

[2] Sanders, L.L. (1998) *A Manual of Field Hydrogeology*: Prentice-Hall, NJ, 381p.; and Tedd et al. (2017).

[3] Flynn and Deakin (2016). https://www.catchments.ie/download/catchments-newsletter-sharing-science-stories-june-2016/

6.5 Data Quality and Interpretation

The main function of taking SEC readings and recording changes during catchment walks will be to locate the presence of pollutant inputs. Measured SEC values in excess of the expected groundwater ranges in a given catchment imply the presence of pollutant inputs. Thus, ideally, SEC is measured during lower flow conditions, i.e. not at or during peak storm events.

All measurement should be taken with calibrated instruments. The reliable interpretation of SEC data must consider catchment-specific factors that could influence the SEC readings during a catchment walk, including land use and geology/hydrogeology. Thus, the prior desk-study work should identify what the underlying factors in a given catchment are.

- **Flowing vs stagnant waters:** SEC readings should be avoided in standing or disconnected pools of water, as temperature influences SEC, and evaporation can increase the concentrations of dissolved solids. Moreover, stagnant or pooled water would not be representative of an active flow system.
- **Temporal SEC variability.** Temporal variability can be a good measure of rapid runoff and accompanying pollutants to streams. Sustained elevated values at a location may indicate the presence of piped input.
- **Geological/hydrogeological setting.** SEC values elevated above expected background levels may indicate a contaminant input.
- **Groundwater Contribution.** In areas where groundwater is discharging to streams, particularly where this is focussed in certain stream stretches, an increase in SEC will be observed, especially during low-flow conditions and in small streams.
- **Saline waters**. Increases in SEC close to the coast or estuaries may indicate influence of seawater.

6.6 Approaches and Influencing Factors

SEC Profiling: Collecting SEC measurements at regular intervals (e.g. 50 m) along a river stretch can aid in identifying the location and source of pollution, as follows:

- A gradual increase indicates a diffuse high SEC contribution (e.g. surface drainage or groundwater);
- A sharp and sustained increase indicates a localised high SEC contribution (e.g. surface drainage, piped input, or a spring)
- A sharp but temporary increase may indicate a smaller localised high SEC discharge (e.g. field drain or spring)

Upstream and Downstream: Collecting SEC readings upstream and downstream of a known (or suspected) point source will aid in assessing the impact on the receiving water body.
Automatic sampling: Installation of automated SEC and temperature data loggers for short periods in streams can enable temporal variations in water quality to be assessed. This approach can be beneficial in tracking intermittent inputs of pollutants. It can also be beneficial in quantifying the natural range of karst systems, whereby SEC values can vary significantly across rainfall events.

6.7 Useful References

Flynn, R., Buick, K. and Macklin, F. 2016. *Catchments, water quality and community science – a tale from County Antrim*. Catchments Newsletter, Issue 4. Available at: https://www.catchments.ie/catchments-newsletter/.

Flynn, R. and Deakin, J. 2016. *Technical Note: Electrical Conductivity – A useful tool for investigating catchment hydrology*. Catchments Newsletter, Issue 3. Available at: https://www.catchments.ie/catchments-newsletter/.

Tedd, K., Coxon, C., Misstear, B., Daly, D., Craig, M., Mannix, A. and Hunter Williams, T. *Assessing and developing background levels for chemical parameters in Irish Groundwater*. EPA Research Report No. 183. Environmental Protection Agency, 155pp. Available at: http://www.epa.ie/pubs/reports/research/water/EPA%20RR%20183%20Essentra_web.pdf.

7 Water Quality Indicator – Sediments

Sediment, for aquatic monitoring, can be classified as that which has been deposited or that which is suspended. Deposited sediment (both fine and coarse – see Section 7.4.1 for a description of size ranges) is that found on the bed of a river while suspended sediment is that found within the water column, transported by water movement. The deposition of fine sediment (particularly silt and clay) on the surface or within the stream bed is referred to as siltation[4]. Sediment transport and deposition in rivers are natural processes within a river system, but alteration to these processes can often be an indicator of disturbance and damage to riverine habitats, though there may also be a natural element to this as well.

Figure 7-1: Suspended sediment in a small stream (Photo: Kate Harington).

7.1 Purpose

Measurements or observations of the amount of sediment within a river can indicate whether there is a disturbance, damage, or pollution of a watercourse. Human activities affecting sedimentological conditions can include:

- Channelisation (and channel maintenance) or other morphological modifications to the watercourse;
- Land drainage;
- Cultivation of land beside the watercourse (i.e., with limited to no buffer zone);
- Run-off from agricultural areas, particularly tillage, close to the watercourse;

[4] 'Siltation', though having 'silt' inherent in its title, refers to both 'silt' and 'clay' size ranges.

- Cattle poaching, cattle access and accelerated erosion of river-banks;
- Forestry planting and clear-felling;
- Quarrying or other extractive activities close to the watercourse;
- Urbanisation and the construction of single dwellings and farmyards in more rural areas;
- Impoundment or abstraction of river water (i.e., changes to flow).

See **Section 2, Volume 2** for more information on hydromorphological pressures and the implications for sediment conditions.

7.2 Significance

The coarser fraction of sediment (see Section 7.4.1 below) provides habitat, bed stability and refuge to aquatic species but the finer fraction, while important ecologically for some aquatic species (e.g., juvenile lamprey), can have negative ecological consequences. Therefore, the rest of this section will mainly focus on the implications of elevated levels of fine sediment.

While fine sediment is present naturally in rivers, the level of such sediments can become unnaturally high for relatively short time periods because of human activities and intensive land use. The effect of excessive siltation is recognised as a major impact on river water quality and ecological status. High levels of fine deposited sediment can deplete oxygen levels within gravel beds, affect habitats and early life stages of a range of aquatic species. Organic rich suspended sediments can also indirectly reduce DO levels in the water column and, once deposited, sediment-associated organic matter can additionally negatively influence the supply of oxygen in the spawning gravels.

Reduced visibility/transparency in the water column because of high suspended sediments can affect foraging animals and can hinder natural vegetation growth. Direct impacts to fish include, for example, increased stress levels, reduced growth rate and/or clogging of fish gills. Macroinvertebrate communities can be also affected through organisms' burial or drift, resulting in reduced abundance and community richness. The effects on one part of the food chain can have consequences for species at other trophic levels, affecting the diversity and composition of biotic communities.

Nutrients can also be transported from the terrestrial to aquatic environment using fine sediment as a vector, resulting in increased eutrophication. Sediment particles can act as a vector for transport of other pollutants (e.g., heavy metals, PAHs, PCBs). This is caused by a high affinity (and consequently adsorption) of those compounds to fine sediment particles. This can potentially extend the impacts (e.g., eutrophication or accumulation of toxic compounds) to downstream lakes and coastal waters.

7.3 Data Interpretation

7.3.1 Natural sediment regimes

It is important to determine the expected sediment regime in a watercourse during low flow periods before assessing the potential for excessive siltation. This can be done at the desk study stage. If a river is set within a catchment dominated by clay- or silt-dominated subsoil, these sediments will be common within the river channel naturally. Such a situation is common in Ireland (See Study Box 1). Heavy rainfall events may then trigger fine sediment release to waters, and so timing surveys around these events could be informative.

STUDY BOX 1: THE HISTORICAL DEVELOPMENT OF IRISH RIVER SYSTEMS

The past two million years of Earth's history have been characterised by major climatic fluctuations. During glacial periods, glacier ice covered up to about thirty per cent of the Earth surface, including covering Ireland (e.g., Mitchell, 1976). Both glacial and non-glacial (periglacial) cold-climate regions are severely affected by climate warming. Since the end of the Ice Age, previous glacial environments are experiencing a climatic crisis leading to a 'paraglacial' geomorphological readjustment. These environments are termed 'Paraglacial landsystems' (Ballantyne, 2008). Etymologically, the term 'paraglacial' means 'next to the ice', consisting of the Greek prefix 'para', next to, and the Latin 'glacies', ice.

Most Irish river systems can be considered 'paraglacial', in that the form of their channels has been directly conditioned by what developed there during glaciation and, particularly, deglaciation (Figure 1). This means that conventional, purist 'fluvial' concepts, whereby rivers have three stages: straight, incising stretches in their upper reaches; gentle meanders in their middle portions, and, strongly meandering forms before they reach the sea (e.g., Strahler, 1972; Gregory, 1977), do not apply to the Irish rivers. Rivers in Ireland flow and meander as do all fluvial watercourses etching into soft sediment, but the constraining glacial geomorphological element, as well as the glacial sediment provided to the rivers for erosion, transport, and deposition, both dominate the channels' macro-morphology and conditions the form that the rivers within will take.

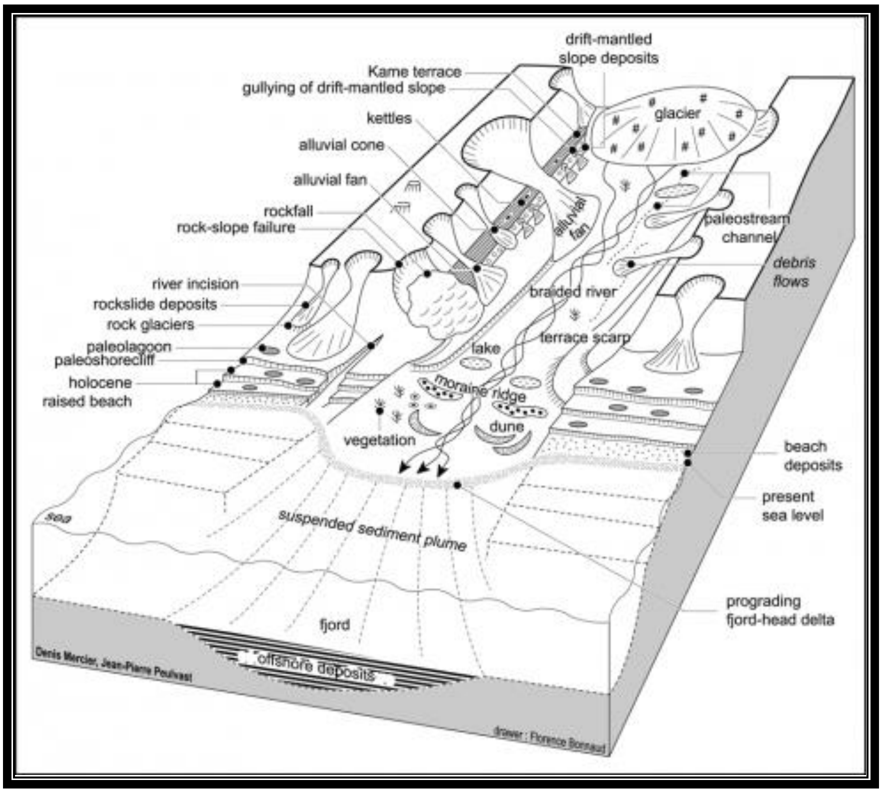


Figure 1: Example schematic of the development of a 'paraglacial' landsystem (after Mercier, 2008).

This means that Irish rivers are, in the majority, constricted within larger meltwater channels formed under and by the melting ice during the last deglaciation (10,000 to 14,000 years ago). The sides of these meltwater channel are either in bedrock or glacial till and the rivers themselves are completely enclosed between the bedrock/till sidewalls. This can often be seen by examining the DEM of channels throughout Ireland, whereby the course of the rivers follows the course of the thalweg (line of lowest elevation) of the meltwater channels.

This also means that, while across the majority of Europe, river floodplains have been acting as river floodplains for millions of years, Irish (and Scottish, Scandinavian, Finnish and some other north European regions) river floodplains have only been acting as river floodplains for approximately 10,000 years.

Figure 2: The wide meltwater channel etched in till that is the upper portion of the Carrigower River, near Donard in County Wicklow.

References

Ballantyne C.K., 2002. *Paraglacial geomorphology*. Quaternary Science Reviews 21, 1935-2017.

Gregory, K.J., 1977. *River Channel Changes*. John Wiley & Sons, London. 448pp.

Mercier, D., 2008. *Paraglacial and paraperiglacial landsystems: concepts, temporal scales and spatial distribution.* Geomorphology, Relief, Processes and Environment, 4, 223-233.

Mitchell, G.F., 1976. *The Irish Landscape*. Collins, Glasgow, 242pp.

Strahler, A.H., 1972. *Planet Earth: Its Physical Systems Through Geological Time.* New York: Harper & Row.

New assessment resources are being developed[5], to assist with the conceptual understanding of sediment regimes within Irish river catchments. These resources will include Natural Sediment Accumulation mapping (showing the propensity for a waterbody to accumulate fine sediment naturally, Figure 7-2), Expected River Substrate Setting mapping (Figure 7-3) and Topographic Settings maps. These maps were developed using GIS layers of soils, subsoils permeability and channel gradient and can be used at the desk study stage as a guide on the expected substrate and natural levels of fine sediments within the catchment.

[5] Resources are being developed by the EPA, Dr. Robbie Meehan, and LAWPRO. These maps will be made available when completed by the EPA.

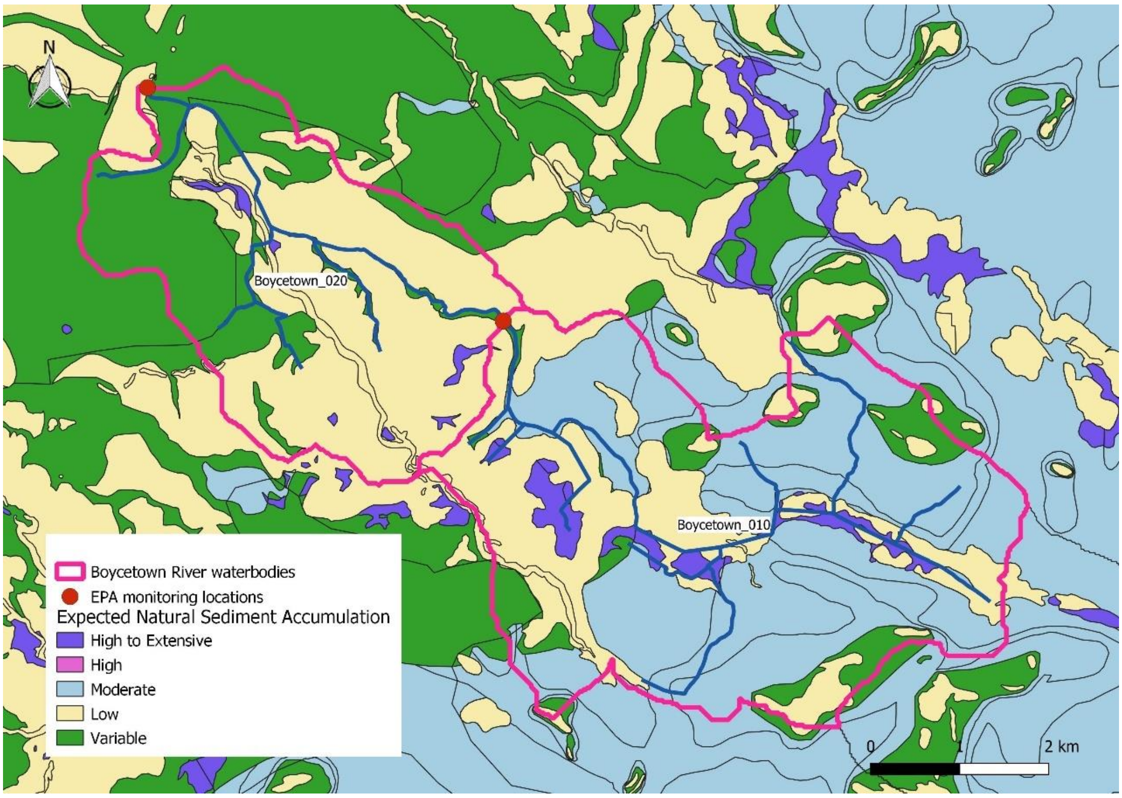


Figure 7-2: Natural Sediment Accumulation map for Boycetown River (in development).

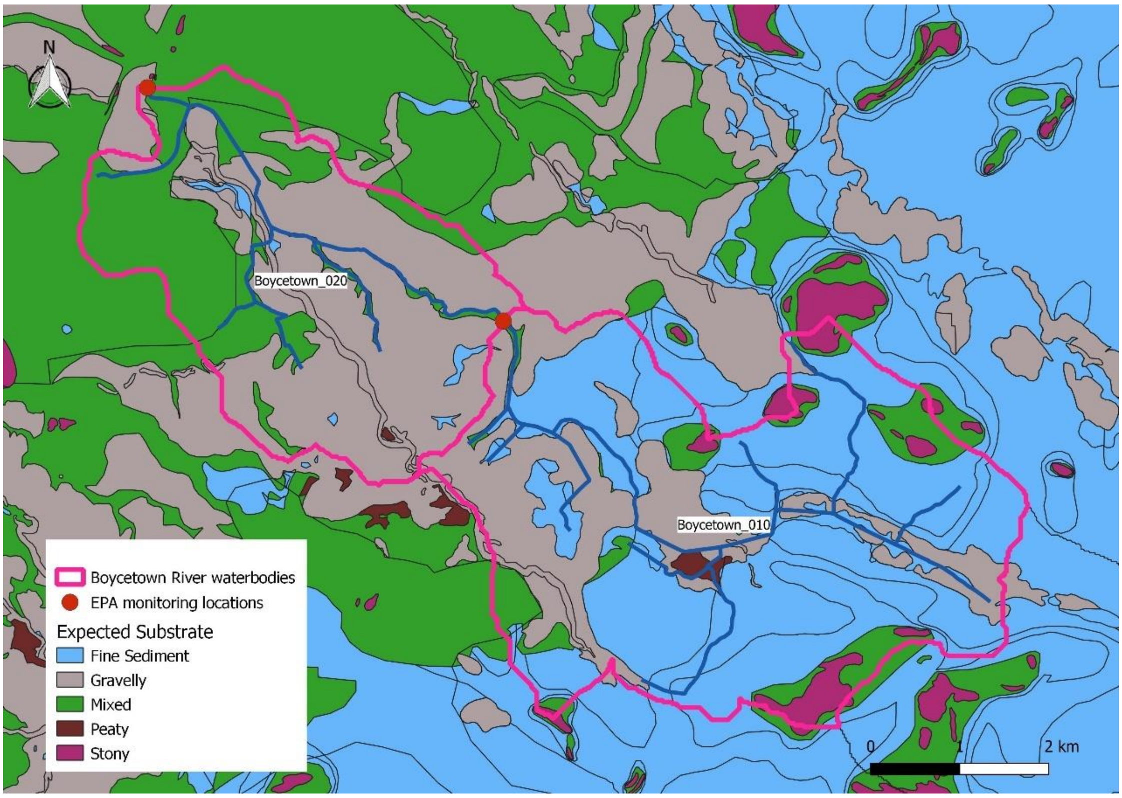


Figure 7-3: Expected substrate settings for Boycetown River (in development).

7.3.2 Thresholds and guidance limits

Note that, at present, **there is no quality standard or objective for suspended and/or deposited sediment under the Water Framework Directive (WFD).**

The Freshwater Fish Directive, which was transposed into Irish law by the European Communities (Quality of Salmonid Waters) Regulations S.I. No. 293 of 1988, included a standard for suspended solids of <u><</u>25 mg/l, expressed as an average concentration over a period of 12 months, but not applying to suspended solids with harmful chemical properties[6]. This Directive was to be repealed and subsumed into the WFD, however at a national level, there are currently no Irish regulations which state an Environmental Quality Standard for sediment for the purposes of WFD assessments.

Annual mean threshold values do not often reflect the complexity of sediment transport.
Setting out meaningful suspended or deposited sediment thresholds can be challenging considering:

(i) different natural backgrounds of sediment production in the catchments (because of different physical characteristics).
(ii) differences in aquatic species present in the catchments (with different life stages and different responses to sediment pressure) and
(iii) high spatial and temporal variations in sediment transport (majority of suspended sediment load is transported within short period of time during storm events, which can be often missed with the surveillance monitoring programme often based on few grab samples a year).

The Ecological Quality Objectives for Freshwater Pearl Mussel set down in the European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations S.I. No 272 of 2009 are more qualitative. They require that there are no artificially elevated levels of siltation present within pearl mussel habitat. This is evidenced by the absence of silt plumes when the substratum in such a river is disturbed. This reflects the sensitivity of this species to sediment impacts, given that the juvenile stages are dependent upon clean well oxygenated substrates to survive their juvenile stage which sees them buried for up to 5 years. Regarding invertebrate monitoring and siltation, the Q rating scheme highlights siltation by appending an asterisk to the biotic index (e.g., Q1*, Q2* etc.).

7.4 Methods of Measurement

This section proposes use of visual methods for deposited sediment (% fine sediment cover and Shuffle Index), which are easy to implement. These methods have been adapted for Local Catchment Assessments. Levels of deposited sediment are often assessed during EPA biological assessments and such measurements can indicate whether sediment is a significant issue at the monitoring location. Measurements of suspended sediments are more challenging to carry out or link with ecological response. However, where required, such measurements can be aided with turbidity measurements and automatic ISCO samplers.

7.4.1 Overview of the substrate conditions

Table 7-1 describes the range of sediment sizes that can be found within a river channel (see **Appendix C** for the Catchment Walk fieldsheet used by LAWPRO). Coarse sediment comprises boulders, cobbles, and gravels, while fine sediment is usually defined as sand, silt, and clay. Silt and clay may be quite problematic when it comes to fine sediment issues. Note that coarser material is more likely to be

[6] S.I. No. 293/1988 - European Communities (Quality of Salmonid Waters) Regulations, 1988. (irishstatutebook.ie)

found in high gradient streams (e.g., more energy for sediment erosion and transport), with finer sediment dominating as the gradient decreases.

When walking along the catchment, it is important to answer several questions:

- What is the range of sediment within the channel? What is (are) the dominate sediment(s) within the channel? Does this change abruptly along the course of the river? Does the range of sediment present in the channel correspond to the physical (gradient) and geological setting?
- Are there notably high levels of siltation along the channel? Within the streambed itself (interstitial siltation), on the surface of the bed (surface siltation) or along the bank margins (marginal siltation)?
- Is the fine sediment deposit composed of predominantly either sand, silt or clay, or a combination of some or all of these?
- Does it appear that the composition of the fine sediment deposit contrasts with the bed sediment that is present naturally?
- Where there are elevated levels of fine sediment or frequent/substantial fine sediment deposits, what activities are present within the reach that may be the reason for these observations (e.g., channel maintenance, cattle access – see Section 7.1 above)? In terms of sediment input from the river banks, are banks naturally eroding (gradually and corresponding to soil, subsoil, or bedrock type)? Or are the banks eroding extensively that could show an issue?

Table 7-1: Range of river sediment sizes based on the Wentworth scale (modified) (see Figure 7-4 for information on how to measure the intermediate axis).

Description of particle size		**Intermediate axis (mm)**
Bedrock	Layer of underlying solid rock	-
Boulder	Larger than a soccer ball	>256
Cobble	Smaller than a soccer ball, but larger than a tennis ball	64-256
Gravel (Pebble)	Pea to tennis ball	4-64
Gravel (Granule)	Matchstick head to pea	2-4
Sand	Loose crumbly material between fingers, smaller than a match head, but larger than flour	0.063-2
Silt	Texture similar to fine white flour, size smaller than flour (not visible to the naked eye)	0.0039-0.063
Clay	Sticky cohesive material, not visible to the naked eye	<0.039

Note: The channel bed substrate can also have peat sediment or artificial material.

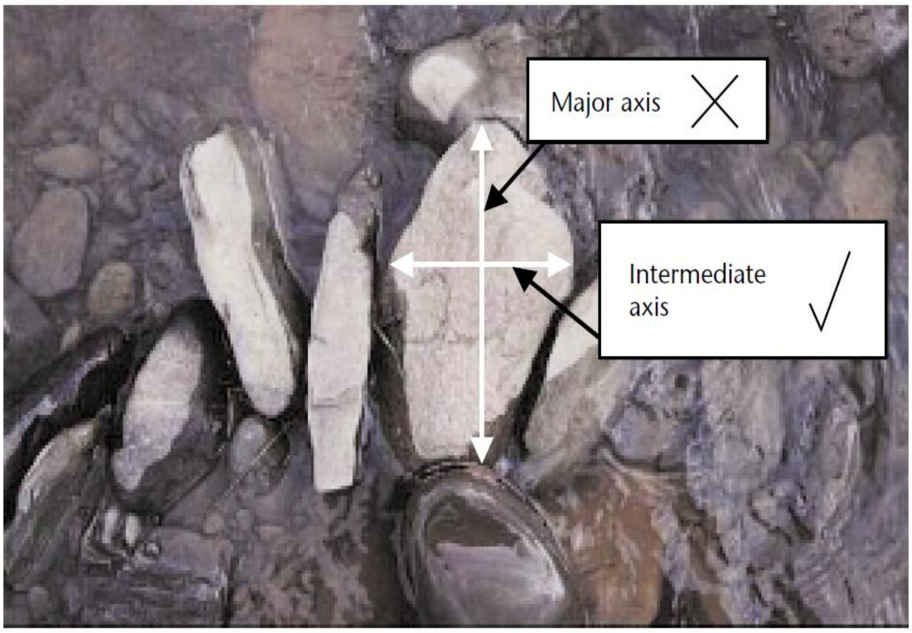


Figure 7-4: Measuring the 'intermediate axis' of river sediment (from the 2003 RHS (River Habitat Survey) Field Survey Guidance Manual).

7.4.2 Visual estimation of the percentage sediment cover

- The assessment is carried out either from the bank or from the stream (water level dependant). Sometimes (e.g., in naturally sandy substrates such as on sand and gravel aquifers), an assessment from the stream may be necessary as it allows for better differentiation between silt and sand (which may be difficult from the river bank). It also allows for identification of the interstitial sediment. Refer to **Appendix C** for Catchment Walk fieldsheet.
  Sand/ silt/ clay may look similar when assessing from the bank. Sand has granules that can be seen, and it can also be felt when rolled in the hand. Silt and clay particles are too small to be seen as separate particles by the naked eye and will be smoother when rolled in the hand. Kicking the river bed may also inform on whether deposition is fine material (silt/clay) or if it is sand. Silt/clay plume will have a characteristic 'smoky' appearance and will stay in suspension longer than sand, which will settle quicker.
- **Determine % riverbed substrate** first. Table 7-1 outlines substrate grain sizes.

- **Length of the stretch:** Assessed length of the river stretch is assumed to be what is visible at the site of assessment – c. 20-50m.

- Assess surface **sedimentation[7] level**: Walk the bank (or stream) and assess % sediment cover visually. Table 7-2 shows sedimentation levels with the proposed % sediment cover. Table 7-3 and Figure 7-12 to Figure 7-16 show examples of different sedimentation levels as observed during EPA field assessments. Actual % sediment cover should always be recorded in the field (e.g., 50% rather than stating 'High' only).

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[7] Sedimentation refers to a deposition or increased accumulation of sediment particles (fine sand, silt, clay, peat) at the river bed. It is often used interchangeably with 'siltation' (used for example on the field sheet) which refers to the deposition of fine sediments (mainly silts). Sedimentation is used here to ensure that all fine sediment particles (fine sand, silt, clay, peat) are considered during the assessment.

Table 7-2: Sedimentation level categories. For reference only. Actual % sediment cover should always be recorded in the field.

Sedimentation level - record % surface cover	XE, X - Extensive (100%)
	E, Extensive (>70%)
	H, High (40-70%)
	M, Moderate (20-40%)
	L, Low (<20%)
	A, Absent
	Dx, Depth of fine sediment (x, cm)

The sedimentation bands (Low – to X-Extensive) were assigned based on available literature and consultation with the EPA.

Note: Impacts at high status sites can be higher with a lower percentage of sediment cover.

Currently, no ecologically linked threshold values have been proposed for Irish rivers. Clapcott *et al.,* (2011) recommends 20% sediment cover as an upper limit that can detrimentally affect biodiversity and fish habitat in New Zealand rivers. These threshold values however are not confirmed for Irish conditions.

- **Habitats:** Assess all flow habitats, but keep in mind that impact will be more significant when found in riffle/run/glide than in pools. Keep in mind that areas with a high density of macrophytes naturally trap sediment. *Apium nodiflorum* for example, is a common macrophyte found in freshwaters, and can be found in both low nutrient and in medium to higher nutrients levels (See Section 10, this Volume). *Apium nodiflorum* can however encroach into a river channel, and expand from bankside vegetation, to become dominant in the main flow of the river channel, when there has been an increase in interstitial sediments, which allows for better establishment of this macrophyte (Figure 7-5). Emergent vegetation can obscure the view of the stream bed. The channel should be entered where possible to check for presence/depth of sediment under vegetation.

Figure 7-5: *Apium nodiflorum* (Fool's water-cress). Often grows in sedimented areas (Photo: Lynda Weekes).

- **Sedimentation depth[8]:** Make a note of deposited sediment depth (if deemed significant). Use the kick net to assess the depth (and take a photo). Be aware that barriers, such as fallen trees, at the outlet of the pool may cause additional deposition.

  Work upstream to avoid disturbing the riverbed being assessed. Note changes in depth of soft sediment along the channel. Does the soft element of the bed seem to be dominated by one of sand, silt or clay, or a combination of one or all of these?

- **Sediment type:** Note whether sediment is of mineral or peat origin (peaty sediments are 'fluffier' in appearance, e.g., Figure 7-6). Also, note if anoxic sediments are present (usually black soggy sediments with bubbles when disturbed and with a distinctive smell, Figure 7-7). This indicates pollutants attached to the sediment. It is useful also to make a note of the sediment colour. Presence of sediments with different colours along the same channel indicate different sediment sources (Figure 7-8 to Figure 7-10). Note situations where the bed is calcified (depending on the geological setting, Figure 7-11, see also Section 10 Macroalgae) or whether the bed is armoured. A distinctive organism, *Phormidium incrustatum* (cyanobacteria, blue-green algae) is frequent in calcareous streams and is the commonest crust forming organism in Irish Rivers (Kelly-Quinn & Reynolds, 2020, Chapter 8). Calcium carbonate deposits are biogenically precipitated in part and can completely cement loose substrate on the riverbed, eliminating habitat for interstitial dwelling invertebrates and spawning fish. In smaller streams, travertine weirs may develop. The extent of concretion varies in response to natural factors such as groundwater chemistry, turbulence and light, and calcification breaks down at high phosphorus levels (Kelly-Quinn & Reynolds, 2020, Chapter 8)). An armoured bed occurs when there is a layer of coarse material on the surface layer of the river bed, trapping fine sediment within the sub-layer. This occurs due to frequent low magnitude flow events that transport fine sediment only. Once the bed is armoured, larger flow events will be required to break up the bed. It occurs naturally in gravel bed rivers but also in rivers downstream of impoundments. It can impede fish spawning activity in some cases.

[8] As a health and safety precaution, check the depth of bed sediments with a stick/pole before entering the river to avoid the risk of losing footing in deep/soft sediments!

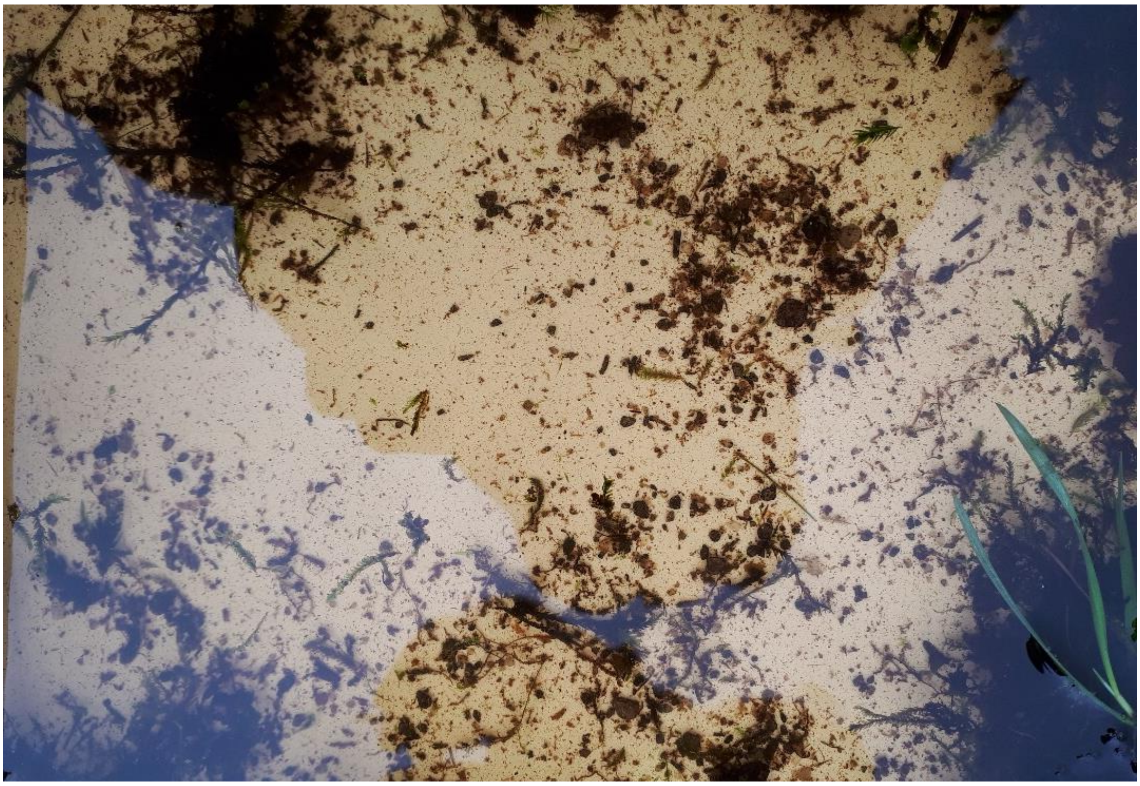

Figure 7-6: Peaty sediment (with plant material) seen in the tray after the kick sample (Photo: Anna Rymszewicz).

Figure 7-7: Anoxic sediment (Photo: Anna Rymszewicz).

Figure 7-8: Dark brown colour sediment (Photo: Stephen Davis).

Figure 7-9: Light colour in the main channel and dark brown sediment in margins (Photo: Stephen Davis).

Figure 7-10: Different types of suspended sediment at the tributary confluences can help identify different sources (Photo: Stephen Davis).

Figure 7-11: Calcified rock with *Phormidium incrustatum* (cyanobacteria) in Boycetown River (Photo: Anna Rymszewicz).

- **Sedimentation type**: i.e. surface or interstitial. Percentage sediment cover estimates levels of surface sedimentation. Interstitial sedimentation can also be assessed at the same time; however, it may not be visible during visual assessment. It is best assessed by observing a sediment plume after a kick (important to pay attention to plumes created during SSIS sampling) or to apply the Shuffle Index method (see Section 7.4.3 of this document). If the bed is dominated by gravel or sand, kick the substrate to find out whether a plume of silt and/or clay is generated or not (i.e. does kicking cause siltation). If there are no artificially elevated levels of siltation present in the gravel / sand dominated riverbed, there will be no visible silt plume when the substratum is disturbed.

  Interstitial sedimentation occurs when fine sediment clogs spaces between stones and gravels. It fills in habitat space for invertebrates and can prevent oxygen circulation within substrates (also very important for fish spawning grounds and juvenile freshwater pearl mussel habitat) where many invertebrates live. **It is important to assess interstitial sedimentation, especially at high status sites, and to always pay attention to the plume created while kick sampling.**

- **Mark channel gradient**. It is important to be aware where the assessment is being done in the catchment. In higher gradient sites, there may be no deposition of fine sediment as water is moving too fast for sediment to deposit out (as the sites are flashy). However, these sites may be still transporting sediment. Sediment could be still originating from the adjacent lands but simply washed off to the lower parts during storm events. Look for evidence of sediment deposition on the banks and note water colour.

- **Note recent rain**. Preceding weather conditions is an important indicator of sediment transport. In high flow conditions and just after storm events sediments can be washed off or can be still in suspension. In such cases assessment of percentage sediment cover can indicate low levels, which can be misleading when drawing the conclusions on significance of the sediment impacts.

Table 7-3: Different sedimentation impacts, and categories (levels) observed during EPA field assessments.

Siltation Impact	**EPA category**	**LAWPRO category**	**Photo**
No visible impact	Clean	Absent	Figure 7-12
Slight impact	Slight	Low	Photo N/A
Moderately Impacted	Moderate	Moderate	Figure 7-13
Heavily impacted	Heavy	High	Figure 7-14
Significantly/Very Heavily impacted	Heavy	Extensive	Figure 7-15 and Figure 7-16


Figure 7-12: Bandon River – No visible impact (source: EPA).

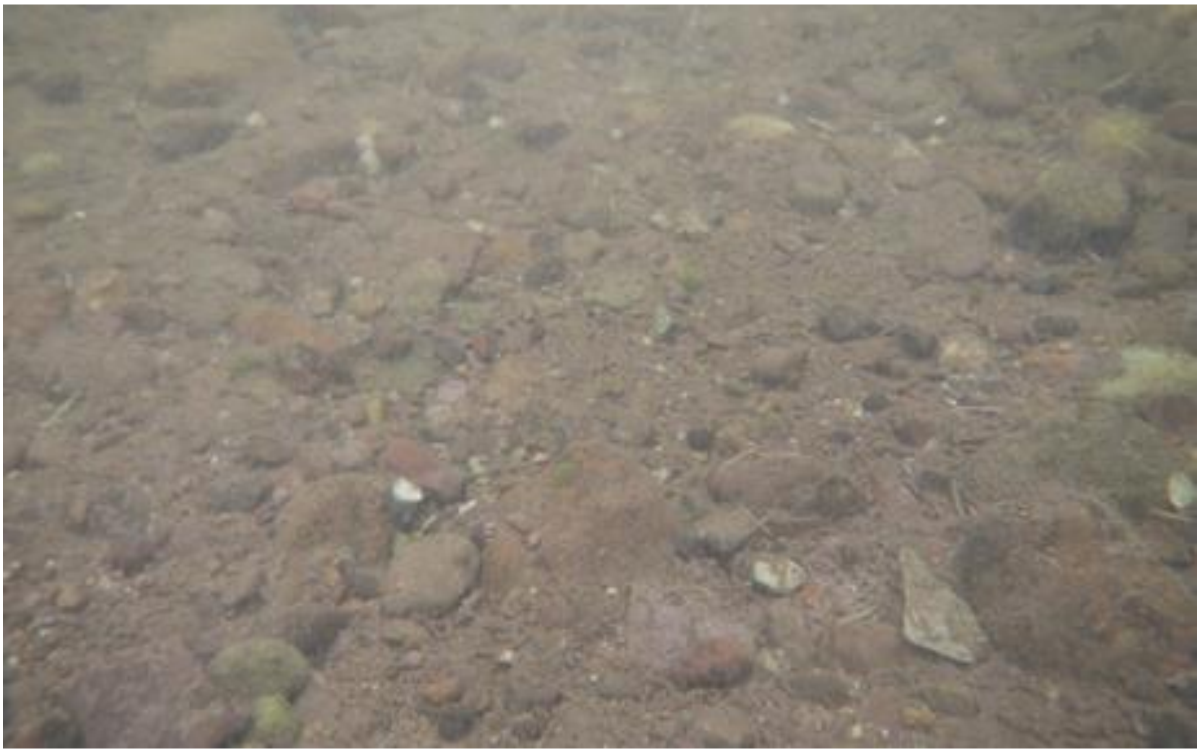
Figure 7-13: Glashaboy River – Moderately Impacted (source: EPA).

Figure 7-14: Mahon River – Heavily impacted (source: EPA).

Figure 7-15: Womanagh River – Significantly/Very Heavily impacted (source: EPA).

Figure 7-16: Allua River – Significantly/Very Heavily impacted (source: EPA).

- **Peaty catchments:** Note in some peaty rivers, visual assessments can be difficult because of the very dark colour of water (e.g., Figure 7-17). In such cases, use an underwater viewer (bathyscope) to help with the visual assessments. The assessment with a bathyscope is done in three transects across the river width (method adapted from Clapcott *et al*., 2011). Four spot checks with the bathyscope should be taken across each transect (at random locations but should represent the whole transect). The number of spot checks per transect will depend on the width of the river. Aim for four spot checks where practicable, however, it is important that spot checks represent the overall substrate across the transect so the number of spot checks may need to be increased in wide rivers to reflect this (number of spot checks should be consistent across all three transects). Estimate percentage sediment cover at each spot check and then calculate an average for all spot checks across the three transects (i.e., all measurements taken). Work from downstream to upstream transects to avoid disturbing the sediment during the assessments.

Figure 7-17: Cloghoge River (Avonmore_010). Sediment cover is not visible due to the dark peaty colours of the river (Photo: Anna Rymszewicz).

- **Ecological significance of sediment deposition** - While no thresholds are provided, the significance of the sedimentation issues will be better understood in time with the experience gained during field assessments. While doing the assessments, it is important to note that:
    - Sedimentation is particularly significant when seen in riffle/ run/ glide (as these are not deposition zones for fine sediment).
    - While pools are natural zones of deposition, if deposition is very deep in pools, it may be significant.
    - Organic-rich sediments such as peat may cause more significant impacts to ecology than the mineral-based sediments (therefore less peat-derived sediment may be needed to cause an issue compared to deposition with mineral sediments).
    - Fine sediments (silts and clays) absorb metals and other pollutants which can pose additional pressure to ecology, it is therefore important to keep in mind any potential industrial or urban diffuse sources upstream of the siltation areas.
    - High status objective sites can be more sensitive to sediment impacts than good status objective sites.

7.4.3 Shuffle Index

Shuffle index (after Clapcott *et al*., 2011) is an assessment technique that may be useful to add to visual assessments in certain circumstances (e.g., when sediment is a suspected issue or if you think there is a large plume while carrying out routine Small Streams Impact Score (SSIS) assessments). It is an indicator of interstitial sedimentation, which can be useful especially when assessing high status sites.

The Shuffle Index method measures how long it takes for a sediment plume to clear over a white tile. Procedure for Shuffle Index:

- Place a white tile on the streambed in a run, and measure/estimate water depth and velocity at this point. Kick sampling tray (held by a stone) may be used instead if there is enough of the water depth.
- Stand 3 m upstream of the tile and disturb the streambed by kicking, moving feet vigorously for five seconds.
- Allocate a score between 1-5 depending on the visibility and duration of the resulting plume in relation to the white tile downstream (see examples in Figure 7-18).
- Take a photo record of the plume, where possible.

7.4.4 Turbidity as a proxy for suspended sediment

Suspended sediment transport is characterised by high temporal variability, which naturally responds to rainfall and increased flow events. Rainfall events increase surface runoff and delivery of eroded particles to the stream network. Increased flows can also re-suspend riverbed sediments or high flows in combination with unstable river banks can cause river bank erosion.

Typically, c. 90% of sediment load is transported during ~10% of the time during or just after storm events. Therefore, to characterise suspended sediment transport, measurements should be concentrated during those events. Measurements of suspended sediment concentrations (SSC) are carried out by a collecting grab water sample which is then analysed for Total Suspended Solids (TSS, APHA method 2540 D)[9]. SSC can be paired with corresponding discharge to derive loads for the storm events or longer periods. Accuracy of the load estimation depends on the SSC and discharge sampling resolution. Turbidity measurements can be used as a proxy for SSC providing an easier and more cost-effective alternative to water sample collection for TSS analysis. This is especially the case if the aim is to characterise suspended sediment transport as in-situ turbidity probes allow for high resolution and continuous measurements. There is, however, no universal conversion from turbidity to suspended sediment concentrations and a site and instrument specific relationship between turbidity and SSC needs to be established.

Turbidity is an expression of an optical property of a water sample, which causes light to be scattered or absorbed rather than transmitted through a straight line. It can be defined as the reduction of transparency in a water sample, which is the opposite of water clarity. It is caused by the presence of suspended and undissolved matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. High water turbidity is therefore directly related to high suspended solids concentration and indicates physical change in water quality.

As opposed to the other water quality parameters (such as, for example, DO, temperature or conductivity) turbidity measurements do not represent absolute scientific quantity, meaning that different turbidity values can be recorded for the same natural water samples using different turbidity instruments[10]. Turbidity readings are specific to the sensitivity of the instrument used and to the physical characteristics of the catchment (as geology and soil type can affect suspended sediment

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[9] Total Suspended Solids (TSS) and Suspended Sediment Concentrations (SSC) are used here interchangeably. U.S. Geological Survey explains difference between these two analytical methods, where TSS analysis normally is based on the subsample of the collected water sample, while in SSC analytical method mass of the entire water-sediment mixture is being filtered. If a sample contains sand fraction total sediment mass can be underestimated when using a subsample for the analysis.

[10] To ensure best practice, it is recommended that the same turbidity instrument (make and model) be used for the measurements during the Local Catchment Assessments. Instrument used, together with the supporting information (such as flow conditions and if possible visual description of suspended matter) should be recorded together with the turbidity reading during the assessment.

optical properties). Turbidity readings cannot be therefore compared between different catchments but should be rather used as an indication of water quality change within the same water body.

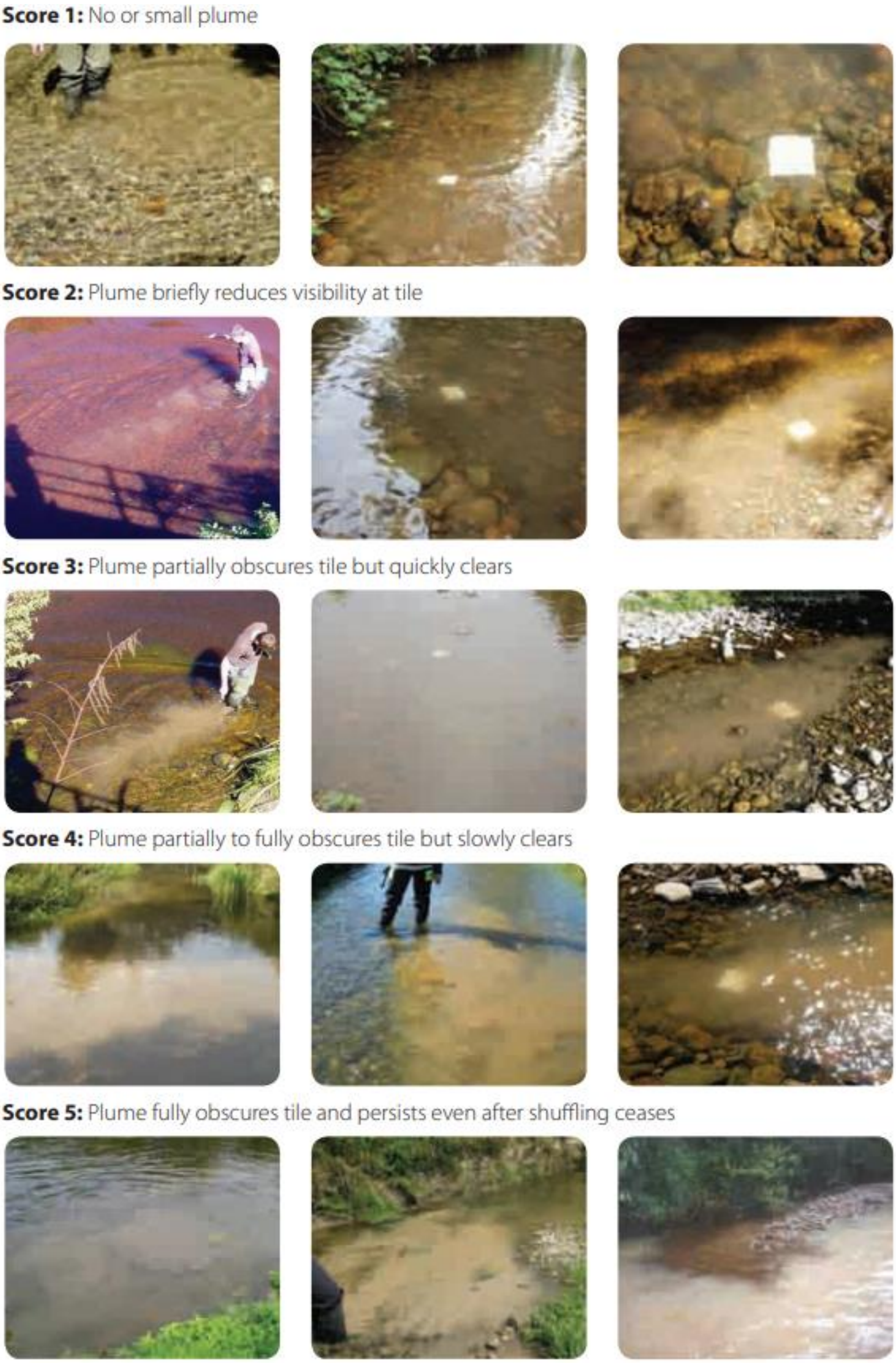

Figure 7-18: Shuffle index examples (source: Clapcott *et al*., 2011, copyrights: Cawthron Institute).

Measurements of turbidity in freshwater environments are typically performed using nephelometers. These instruments are equipped with the light source and light detectors and measure the degree of light scatter caused by the presence of suspended matter in the water sample. A number of different nephelometers are commercially available today and these instruments may vary with regard to their technical design (including different light source and beam configuration together with varying angular range and spectral sensitivity of detectors). An instrument with a light source within infrared (IR) spectrum should ideally be used for the measurements as these instruments are not affected by colour of water caused by the presence of humic substances.

Turbidity can be measured using bench top and portable cuvette style instruments (which require collection of water sample) or with field hand-held instrument operating in-situ.

- Spot measurements

As with the SSC, spot measurements alone are not very informative considering changes in sediment transport with different flow regimes. However, where a number of measurements are carried out on the same day across one waterbody, these measurements can be used for spatial comparison which could indicate areas with sediment issues.

In low flow conditions, if one of the measurements is showing higher values, this could indicate point source pollution upstream of the point of the measurements (or depending on how the sample was taken, could indicate resuspension of fine sediment present at the location).

Measurements during higher flow conditions (following a rainfall event) can be used along the channel to identify tributaries (or specific point discharges) contributing higher sediment inputs. Turbidity measurements could be coupled with flow measurements[11], where sediment loads can be estimated. This would show areas/ tributaries of highest sediment contribution, which could inform further catchment assessment. Catchment walks and field observations of land directly adjacent to the stream during high flow conditions (ideally immediately after rainfall event) can also inform on the possible sediment transport pathway connectivity with the stream network.

- In-situ continuous measurements

Some of the turbidity instruments are designed to record continuously at a high resolution (e.g., 1 or 15 - minute intervals). This can provide a continuous and detailed record of suspended sediment transport. Such measurements require site and instrument specific calibration to SSC (e.g., Figure 7-19). To derive such calibration a number of water samples need to be collected during the full range of flow conditions. Use of automatic samples (ISCO samplers) can help with the sampling during storm events. When the turbidity – SSC equation is derived, it can be used to convert the turbidity record to suspended sediment concentrations (Figure 7-20 shows an example of such a record). Such measurements are often carried out in conjunction with flow measurements and can be used to calculate sediment load for a required period of time. In-situ continuous measurements require site visits for the equipment maintenance and sampling for turbidity – SSC calibrations.

Installation of in-situ turbidity instruments that can record continuously at higher resolution (ideally combined with spot SSC measurements for meaningful turbidity data interpretation) can be useful to monitor temporal variations in suspended sediment transport and to provide accurate estimates of total sediment loadings. These are specialist measurements and would not be routinely carried out during field assessments. They may be useful where more detailed information is required to

[11] For health and safety, flow measurements should not be carried out in higher flow conditions. Modelled flows can be used in this case or where possible flows can be estimated using float method using vegetation/ twigs as floats.

characterise suspended sediment transport or where in-stream works or drainage maintenance works are carried out to monitor effectiveness of the in-stream measures.

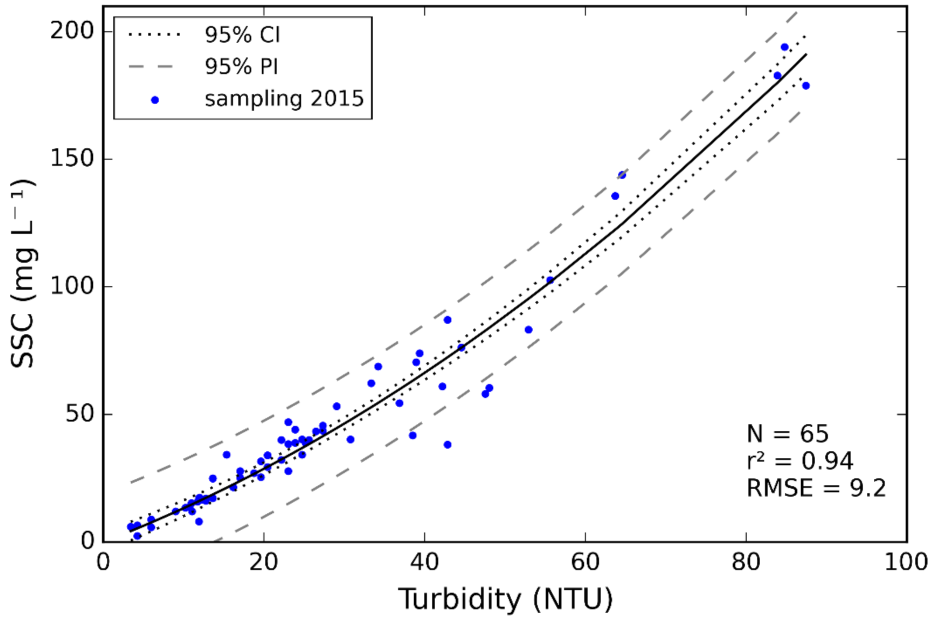

Figure 7-19: Example of turbidity – SSC correlations established for Clodiagh River, Tullamore (OBS 300+ sensor; SSC = $0.0111*T^2+1.2165*T$), Siltflux project (source: Bruen et al., 2017). Note that number of different relationships can be derived depending on the best data fit (i.e., linear, polynomial, exponential). Lower number of samples can suffice for successful turbidity – SSC calibrations, although sampling of both high and low SSC is needed.

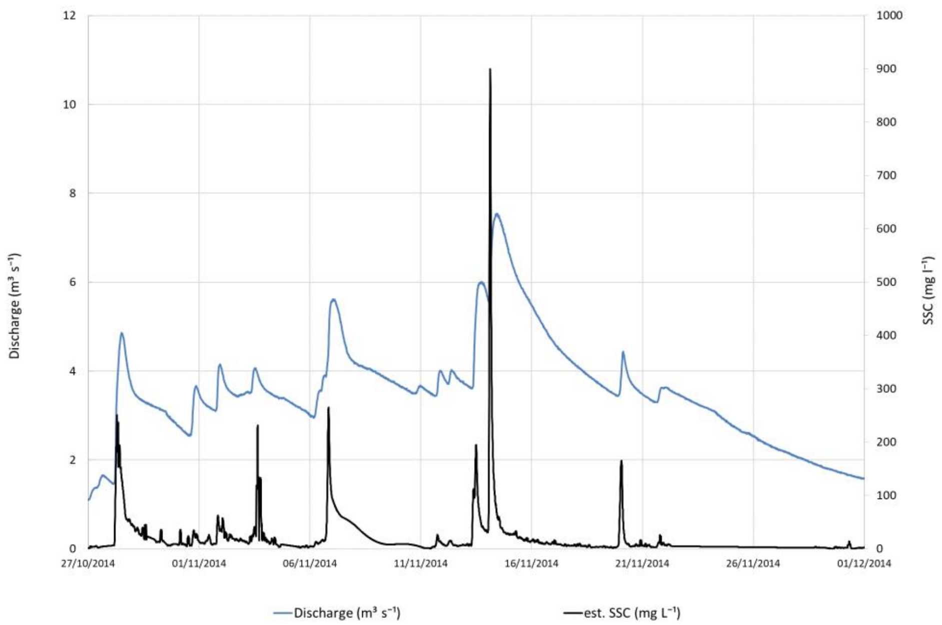

Figure 7-20: Example of SSC high resolution data derived from turbidity measurements with the corresponding discharge data for Camlin River (source: Siltflux project). Note that amount of transported suspended sediment will vary between the storms depending on the sediment supply, storm magnitude and preceding conditions.

7.5 Data Quality

It is important that the desk study carried out before the catchment walk considers catchment-specific factors that could influence the level of siltation observed during a catchment walk (e.g., gradient, land use, geology/hydrogeology, modification to the river channel (e.g., drainage schemes)). As noted above, the production (erosion), transport and deposition of fine sediment within rivers are natural processes, so careful investigation of sources of accelerated erosion/fine sediment inputs is required to determine whether the observed pattern of siltation is natural or artificial. Sediment Accumulation Maps are in development and may be used as a guide at the desk study stage.

7.6 Approaches and Influencing Factors

Key factors to consider:

- Source – Is the fine sediment that is observed of natural origin (e.g., geology/landscape setting, gradual bank erosion, input from a tributary) or the result of human activity? Undertake surveys/observations upstream and downstream of suspected sources. Are seasonal agricultural activities underway? Are there active construction, quarrying, forestry or channelisation/drainage activities in the catchment?

- Transport – Sediment may be temporarily stored and moved downstream between floods; this is a natural process. Consider the time of year and whether there have been rainfall events recently? Is sediment accumulating in a reach that normally transports sediment without problems (i.e., reflecting gradient)? Are there artificial structures causing sediments to accrue (e.g., dams, weirs, bridge abutments/aprons–such structures can trap coarse sediment, but fine sediment can also settle out upstream of the structure due to a reduction in flow)?

- Deposition – Is the area a natural sediment store (e.g., pool habitats or low energy/low gradient setting) or is it accumulating due to an artificial supply from upstream? Larger visible silt beds are more likely to indicate a local source, whereas prominant silt plumes which persist over time may be more likely to indicate a possible sustained diffuse source, particularly if observed during a period where there have been relatively calm antecedent weather conditions. As mentioned above, sediment conditions will vary depending on flow.

- Source ≠ Impact – It is important to remember that at any time of the year deposition in an area does not necessarily indicate that the source is in that area and likewise areas without deposition could be near sources of sediment. Monitoring points that were assigned an asterisk (*) during EPA biological surveys (* usually indicate sedimentation of the river bed) may need to be revisited during summer after measures have been implemented to see if sediment deposition in the area has been reduced. If the site is not improved, other sediment sources may require investigation.

  Seasonality and visual assessments - Temporal variations in sediment transport should be considered. More sediment deposition is expected during low flow conditions in summer. During winter months with higher flows there will be movement of sediment between storms and there may be no evidence of siltation on the day of the assessment. Recent storm events should be noted during the assessment. If we cannot see sediment issues in winter additional visits may be required during summer months where impacts can be more apparent during lower flows. In general, impacts of sedimentation can be seen during summertime (although suspended sediment can also affect ecology), while sediment delivery and/ or active sources can be observed during wintertime following rainfall events.

7.7 Useful References

Bruen, M., Kelly-Quinn, M., O'Sullivan, J., Turner, J., Lawler, D., Conroy, E. and Rymszewicz, A., 2017. *SILTFLUX Project Report: Sediment Flux – Measurement, Impacts, Mitigation and Implications for River Management in Ireland*. EPA Research Report. Available at: https://epa.smartsimple.ie/files/347278/113647/SILTFLUX_End_of-Project_Report.pdf.

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8 Water Quality Indicator – Nutrients

Excessive concentrations of nutrients – Nitrogen (N) and Phosphorus (P) compounds – can lead to eutrophication impacts, including accelerated growth of plants and algae, leading to ecological impacts in rivers, lakes and marine waters, such as reduced oxygen levels and loss of sensitive aquatic species. Eutrophication remains the most significant pollution issue in surface waters in Ireland[12]. In addition, high nitrate concentrations in drinking water pose a threat to human health.

The main phosphorus compounds measured in water are Molybdate Reactive Phosphorus (MRP), also known as ortho-phosphate (PO_4) and Total phosphorus. Nitrogen compounds commonly measured for water quality purposes include Ammonium (NH_4), Nitrate (NO_3), Nitrite (NO_2) and Total Oxidised Nitrogen (TON); TON being the sum of NO_3 and NO_2. Typical concentration ranges for various sources are given in Table 8-1.

Table 8-1: Typical ranges for nutrients from various pollution sources

Sources	NH4 (mg N/L)	MRP (mg P/L)	TON (mg N/L)	BOD_5 (mg/L)
Untreated sewage	22 - 80	5 – 20 (Total P)		150 - 500
OSWWTS (discharge pre-percolation area)	20			20-60
Farmyard soiled water		80 (Total P)		<2,500
Cattle slurry		800 (Total P)		10,000-20,000
Pig slurry		800 (Total P)		20,000-50,000
Silage effluent				30,000-80,000
Landfill leachate	491 (mean)	3 (mean)	2.4 (mean)	>798 (mean)

8.1 Purpose

Measurements of nutrients in water can be used for the following purposes:

1. **Identify potential pollution sources.** NH_4 and MRP concentrations will be elevated where sewage, slurry or soiled water is inputting to waters. Untreated sewage, sewer network overflows, septic tank effluent, animal wastes from slurry or soiled water, landfill leachate will contain elevated NH_4. Drainage from peatland areas, particularly actively worked bogs, can contain elevated NH_4. Jumps in NH_4 and MRP concentrations along stream lengths in rural areas can point to polluting inputs from farmyards or malfunctioning on-site wastewater treatment systems. In addition to organic sources, high MRP can also arise from inorganic fertilizers, particularly if landspread before heavy rainfall. Groundwater discharge to surface waters, in particular in karst areas, can contribute significant levels of MRP.
2. **Seasonal patterns to discriminate between point and diffuse sources.** Domestic wastewater effluent inputs to a stream generally will act as a constant source discharging into flows which vary seasonally. As there will be less dilution available in low flow/summer conditions, then a constant source input can show as a seasonal pattern of highest NH_4 and MRP concentrations in lowest flows, effectively inverse to the seasonal hydrograph. Diffuse sources would not display this pattern either because the source load is not constant over the year or because inputs are mediated by rainfall events.
3. **Chloride as a tracer for domestic wastewater.** Chloride (although not a nutrient) can also be used as a tracer for domestic wastewater inputs, the chloride in sewage arising from dietary intake. Chloride can be included in the analysis suite in surveys with NH_4 and MRP. Where

[12] http://www.epa.ie/pubs/reports/indicators/SoE_Report_2016.pdf

chloride in groundwater is >25 mg/l there is a possible organic waste source (does not apply within 20 km coast due to sea influence).

4. **BOD, Nitrite.** BOD testing is vital to characterise the strength of a wastewater effluent and is an important parameter in discharge licensing and in water quality assessment. However, in stream surveys to locate pollution inputs, it may not be required as in-situ dissolved oxygen and conductivity is measured and in practice many of the inputs that might be indicated by BOD readings will be indicated by NH_4 and MRP measurements. Nitrite (NO_2) is measured in operational monitoring programmes, as a parameter featured in EU Freshwater Fish Directive; however, it's inclusion in nutrients sampling will generally not add much value above NH_4, MRP and TON analysis.

8.2 Significance

8.2.1 Phosphorus/Phosphate

Phosphorus (P) is generally the limiting nutrient in freshwaters and tends to drive eutrophication in rivers and lakes. Most soluble P consists of orthophosphate (also known as molybdate reactive phosphorus) which is readily available for plant uptake. Eutrophication can occur in surface waters with relatively low concentrations of orthophosphate (as low as 0.02 mg/l). Orthophosphate is, therefore, the form of P measured in rivers and compared to environmental quality standards (EQSs). The EQS for orthophosphate in Irish rivers is 0.035 mg/l (Table 8.1). Particulate P is not readily bioavailable, but it can be a long-term source of P for aquatic biota. Total phosphorus, rather than orthophosphate, is considered a critical nutrient in lakes, due to the longer residence time in lakes.

Most of the P in soils (except peats) is inorganic in nature and is predominantly associated with aluminium (Al) and iron (Fe) in acidic soils and calcium (Ca) in alkaline and calcareous soils. The balance of soil P is comprised of organic forms which consist of un-decomposed residues, microbes and organic matter. The organic and inorganic forms of soil P are in dynamic equilibria with orthophosphate ions in the soil solution. Replenishment of soil solution P occurs as P adsorbed to the surface of mineral soils is desorbed (released), as soil organic matter mineralises (decomposes) and as phosphate minerals dissolved. Concentrations of soil solution P typically range from <0.01 to 1 mg P/l. Phosphorus is easily adsorbed by mineral soils and so tends to be primarily transported in overland flow rather than subsurface flows. Excess soil P is highly susceptible to losses in overland flow, particularly if soil P levels exceed crop requirements (P index 4) or P saturation thresholds. Zones where excess soil P coincide with hydrologically sensitive areas (i.e. heavy soils draining via surface flow into watercourses) are called critical source areas. Critical source areas may comprise a small proportion of the total area of the catchment but can contribute a large proportion of total P losses unless measures are put in place to 'break the pathway'. Such measures could include riparian buffers, earthen mounds and wetlands.

Recent Teagasc research (Mellander *et al*. (2015) has shown that well-drained iron-rich soils favour P mobilisation into soluble form and transfer to groundwater. This is a situation that may be present in soils derived from Old Red Sandstone bedrock – a rock type common in Cork and Kerry). Groundwater is an important pathway for the movement of phosphorus from diffuse and small point sources to river, lake and transitional and coastal water (TRACs) ecosystems, particularly in catchments with karstified limestone where there are sinking streams in areas, and where bedrock outcrops at the surface. If phosphorus concentrations in groundwater are elevated in areas where groundwater provides a high proportion of the average flow to surface water, then groundwater may also be a significant contributor to water quality issues in those surface waters.

8.2.2 Ammonium

Ammonium concentrations in unpolluted waters are generally low and elevated ammonium can indicate contamination from sewage, animal slurry, organic waste, leachate or industrial sources. Total Ammonia is the form measured in water quality analysis – this comprises NH_4^+ (ammonium) and

NH_3 (non-ionised ammonia). The majority of the total ammonia in waters will be present in $NH4^+$ form, with the proportions of NH_4^+ and NH_3 determined through equilibrium conditions influenced by pH and temperature. The proportion of NH_3 (form toxic to fish) increases at higher pH and temperature. In this note NH_4 is used to denote total ammonia.

Ammonium has a low mobility in soil and subsoil. Therefore, its presence in groundwater at concentrations greater than 0.15 mg/l indicates a nearby organic waste source and/or vulnerable groundwater conditions (i.e. outcropping or shallow bedrock). While ammonium is mobile in bedrock, it will convert to nitrate over short distances. Ammonia may also be elevated in groundwater where the aquifer is confined or where minerals such as pyrite (FeS_2) are driving reduction processes.

8.2.3 Nitrate

Nitrogen compounds commonly found in freshwater systems include ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Nitrogen is also found in organic compounds such as proteins and protein derivatives e.g. urea. When plant and animal materials decompose, organic nitrogen is biologically converted into other forms of nitrogen. Urea for example is converted to ammonia and carbon dioxide in natural waters, which is readily available for plant uptake. Nitrite is an unstable nitrogen compound which is rarely found in high concentrations. It is formed during the oxidation of ammonium to nitrate (high oxygen environment) or during denitrification (low oxygen environment). If a relatively high concentration of nitrite is found in a flowing river for example, it indicates a nearby source of ammonium which is undergoing oxidation.

Nitrate is the most fully oxidised compound of nitrogen and is therefore the most common form found in freshwaters and at greatest concentrations. In WFD monitoring datasets, total oxidised nitrogen (TON), made up of nitrate and nitrite, is commonly measured. In practice however, the concentration of nitrite is so low, that TON essentially measures nitrate. Oftentimes the term dissolved inorganic nitrogen (DIN) is also used, this refers to nitrate plus ammonium plus nitrite.

Nitrate is an important nutrient for water quality for two reasons:

- It impacts on surface water ecosystems.
- It is an important parameter from a drinking water perspective.

Dissolved inorganic nitrogen (DIN), mainly comprised of nitrate, tends to drive eutrophication impacts in coastal waters, although there are some exceptions. The environmental quality standard (EQS) for coastal waters is 2.6 mg/l as N at the freshwater-saline water interface (Table 8-1). The nitrate ion is not adsorbed on clay or organic matter. Therefore, it is highly mobile and under recharge conditions is easily leached out of the rooting zone and through permeable soil and subsoil. However, denitrification can occur in certain bedrock types, particularly clayey limestones or red sandstones, and in poorly draining soils and subsoils. Therefore, high nitrate concentrations in water are associated with well drained areas, moderate to high permeability soils and subsoils, and transmissive aquifers.

In addition, high nitrate in streams in the presence of relatively low concentrations of MRP can impact on the ecology. *(At the moment, it is unclear what a 'high' concentration is in this context. In the experience of the Catchment Unit, it is between 3.5-4.5 mg/l as N; however, this is a topic for further consideration and discussion.)*

Nitrate concentrations in drinking water are linked with infantile methaemoglobinaemia (IM)[13]. IM occurs when bacteria, either in the soil or in the immature infant gut, convert nitrates to nitrites. Nitrites easily combine with foetal haemoglobin to form methaemoglobin, which cannot carry oxygen

[13] http://www.epa.ie/pubs/advice/drinkingwater/Nitrates%20Position%20Paper%20Flyer.pdf

around the body. The infant presents with central cyanosis (Blue Baby Syndrome), which fails to respond to oxygen.

Groundwater provides the main pathway for nitrate to surface water. Relatively low concentrations of nitrate are found naturally in groundwater, and concentrations higher than 10 mg/l NO_3 are usually indicative of anthropogenic organic or inorganic inputs. Diffuse agriculture (organic and inorganic fertilizers) is the main source of nitrate in water, with point sources having the potential to create small, localised nitrate plumes in groundwater. Given the reactivity of nitrogen compounds in freshwater systems and the complexity of the groundwater pathway, care is needed when interpreting nitrate concentrations, particularly in rivers. This is particularly relevant when analysing seasonal trends in water quality or drawing links between peaks in concentration and source pressures. Some factors to consider when interpreting a nitrogen dataset are:

- While the timing of fertiliser and slurry application can be readily established in a catchment, the effect of this source on stream concentrations depends upon a number of factors.
- From a concentration only perspective, you may typically see higher nitrate concentrations in groundwater pathways during winter. As a rule of thumb, nitrate concentrations are typically higher in the shallow aquifer e.g., the soil and subsoil (in well drained scenarios), the transition zone & the upper fractured zone. As you go deeper into the aquifer, permeability decreases & the likelihood of attenuation increases. The bulk of groundwater flow to small rivers comes from the shallow aquifer with deeper pathways contributing less of the nitrate load to the stream. Considering that the shallow layers (typically) have higher nitrate, whether or not those layers are saturated is important. In winter (or anytime where there is prolonged rainfall), water tables rise. As water tables rise, previously unsaturated, high nitrate groundwater pathways can activate, resulting in the “flushing” of nitrate to the stream. From a concentration only perspective therefore, you could expect to see higher groundwater nitrate in winter.
- The concentration of nitrate in the groundwater pathway is not the only driver of stream concentrations. It is also important to consider the flow and load contribution from groundwater to the stream at the time of sampling. During summer (baseflow) conditions, almost all of the water in stream may come from groundwater. During winter or rainfall event conditions, a proportion of the streamflow will be from groundwater, but there may also be a large proportion from near surface or overland pathways. In a catchment which has a mixture of well-draining soils and poorly-draining soils, while the nitrate concentration in the incoming groundwater may be comparatively high, the stream concentration can be diluted by the overland pathways. These pathways are typically low in nitrate but can be high in phosphate (depending upon source pressures).
- Time lag: Interpreting peaks in stream nitrate concentrations is complicated by the time it takes for leached nitrate to travel through the groundwater pathway before reaching the stream. Travel time for nitrate has two physical components: 1) The vertical travel time of water from the ground surface to the water table through the soil and subsoil. 2) The horizontal travel time of water below the water table, through the aquifer, to the stream.

  Rule of thumb*: As you move further away from the stream, both vertical and horizontal travel times typically increase. Therefore, if you are seeing an immediate peak in stream nitrate concentrations after rainfall, it is most likely a near stream source or near stream field that is causing it. Typically the vertical travel time exceeds the horizontal travel time. As such, thin or absent soils and subsoils can result in a quick stream response to a source pressure.*
- The final consideration in interpreting high stream nitrate concentrations is the mineralisation of organic nitrogen in the soil profile; this can have a dramatic effect on stream nitrate concentrations, as seen on a national scale after the 2018 drought. During the drought period,

mineralisation of organic nitrogen to nitrate in the soil profile was promoted. The following winter, the accumulated nitrate was flushed to rivers, resulting in dramatic increases in stream nitrate concentrations in many river catchments throughout the country.

When interpreting stream nitrate trends and concentrations, a conceptual understanding of the catchment is essential. The above factors should be considered when interpreting the data.

8.2.4 Relevant concentrations

The surface water EQSs for Total Ammonia, Dissolved Inorganic Nitrogen and Molybdate Reactive Phosphorus are given in Table 8-1. The groundwater threshold values for nitrate ammonium and MRP are given in Table 8-2.

Table 8-2: Environmental quality standards for Total Ammonia, DON and MRP in surface water bodies[14]

NUTRIENT CONDITIONS

Nutrient conditions	River water body	Lake[(1)]	Transitional water body	Coastal water body
Total Ammonia (mg N/l)	High status ⩽0.040 (mean) or ⩽0.090 (95%ile) Good status ⩽0.065 (mean) or ⩽0.140 (95%ile)			
Dissolved Inorganic Nitrogen (mg N/l)				Good status (0 psu [(2)]) ⩽ 2.6 mg N/l (34.5 psu[(2)]) ⩽ 0.25 mg N/l High status (34.5 psu[(2)]) ⩽ 0.17 mg/N/l
Molybdate Reactive Phosphorus (MRP) (mg P/l)	High status ⩽0.025 (mean) or ⩽0.045 (95%ile) Good status ⩽0.035 (mean) or ⩽0.075 (95%ile)		(0-17 psu) ⩽ 0.060 (median) (35psu) ⩽ 0.040 (median)	

8.3 Equipment/Instruments

Nutrient compounds are mainly and mostly measured by laboratory analysis of samples collected from the field. This requires following standard procedures (see below). However, PO_4, NO_3, NO_2, and NH_4 can also be tested in the field using test strips, similar to those used for pH measurements. Test strips are one of the easiest methods of testing water quality, and are well suited for use during catchment walks. Test kits for a range of parameters can be purchased at relatively low cost, from vendors such as:
https://www.hach.com/populartestkits
https://hannainst.com/hi3817-water-quality-test-kit.html
http://www.lamotte.com/en/education/water-monitoring

Field test kits are also available for:

- Hardness

[14] http://www.irishstatutebook.ie/eli/2009/si/272/made/en/pdf

- Alkalinity
- pH (see Section 5)
- Iron and manganese

Use of test kits is quick, and results can be obtained in a matter of minutes. Test strips are semi-quantitative and are accurate to +/- one half of a colour block. Quantab strips are accurate to +/- 10 percent. Specific accuracies vary by parameter and are denoted on the product ordering page as well as on the package itself.

Table 8-2: Groundwater threshold values (TVs) for nitrate, ammonium and MRP[15]

"SCHEDULE 5

Groundwater Threshold Values

Parameter	Units	Threshold Values for Chemical Status Tests[1]				Overall Threshold Value Range
		Column 1 Test: Assessment for the presence of saline or other intrusions	**Column 2** Test: Assessment of adverse impacts of chemical inputs from groundwater on associated surface water bodies	**Column 3**[2] Test: Assessment of whether groundwater intended for human consumption in drinking water protected areas is impacted by pollutants and/or is showing a significant and sustained rise in pollutant levels	**Column 4**[3] Test: Assessment of the general quality of groundwater in a groundwater body in terms of whether its ability to support human uses has been significantly impaired by pollution	
Inorganic & Metals						
Electrical Conductivity	µS/cm @25°C	800	-	1875	1875	800 — 1875
Chloride	mg/l Cl	24	-	-	187.5	24 — 187.5
Sulphate	mg/l SO_4	-	-	-	187.5	187.5
Nitrate	mg/l NO_3	-	-	37.5	37.5	37.5
Nitrite	µg/l NO_2	-	-	-	375	375
Ammonium	µg/l N	-	65	-	175	65 — 175
Molybdate Reactive Phosphorus	µg/l P	-	35	-	-	35
[illegible]	[illegible]				[illegible]	[illegible]

8.4 Method of Measurement

Nutrients measured with test strips are measured in-situ. Measurements can be made directly from the water body or by pulling a water sample using a clean jar, bucket or bottle.

8.4.1 How to take measurements

Samples to be analysed by laboratories must be sampled according to standard procedures for sampling, sample preservation and handling, and sample shipment. Guidance and procedures for collecting and managing water quality samples are available in the report entitled "Water Framework Directive – Sampling Manual for Rivers and Lakes" (EPA, 2016).

For use of test kits, simply dip test strips in water, following test kit instructions, and compare the colour of the strip to determine the result (value/concentration) according to a colour guide provided

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[15] https://www.housing.gov.ie/sites/default/files/legislations/si_366_of_2016_-_european_union_environmental_objectives_groundwater_amendment_regulations_2016.pdf

by the test kit supplier (Figure 8-1 and Figure 8-2). Use test strips when a general range is sufficient. Test strips should not be used when an exact measurement is required.

Figure 8-1: Colour guide for test strips (Photo: Joan Martin).

Figure 8-2: Using a test strip (Photo: Joan Martin).

Given the nature of local catchment assessment sampling where samples will be taken at locations not routinely sampled or accessed, care is needed to ensure samples are not compromised by disturbance of stream or bank sediment. It should also be recognised that the purpose in taking any samples is to help investigate, identify and characterise polluting inputs and effects in a watercourse – the data are separate to the dataset for classifying water status.

8.5 Data Quality and Interpretation

The main function of measuring nutrient concentrations during catchment surveys will be to locate the presence of pollutant inputs or confirm pollutant inputs. Surveys in low-flow conditions will be more useful in identifying point source inputs from domestic wastewater.

In assessing stream survey sampling results, the relative changes in concentrations spatially on the same survey day can be more instructive than the absolute values, as nutrient concentrations can vary greatly temporally, particularly in response to rainfall / runoff / overflow events. NH_4 and MRP concentrations in surface waters have much higher temporal variation (or standard deviation) than NO_3.

Standard Deviation: NH4 > MRP > NO3

In considering the concentrations found, take account of the concentrations given in Tables 8-2 and 8-3.

Care is needed in interpreting MRP survey results as MRP is subject to significant biological (plant) uptake in the growing season. MRP can drop to very low concentrations in summer in watercourses with excessive macrophyte growth, the low MRP effectively a reflection of eutrophication impact and plant uptake rather than the absence of significant P inputs. In these cases, this can be confirmed where visual survey would indicate prolific plant growth, daytime Dissolved Oxygen readings would show supersaturation (> 120%) and stream substrate may be calcified. In extreme cases, the oxygen supersaturation may be accompanied by elevated pH (pH > 9).

Changes in nutrient concentrations along streams can also be interpreted alongside conductivity data and temperature to check for indications of significant groundwater contribution to flows.

8.6 Approaches and Influencing Factors

Initial screening survey: an approach is to sample for nutrients at all branches and minor tributaries in a sub-catchment to get information on the relative significance of loads or concentrations coming from each branch. However, it is important to be aware this is just a snapshot of concentrations on the survey day, and subject to the temporal variation influences. Other approaches for initial screening such as macro-invertebrate survey and visual assessment of in-stream conditions at stream branches may be preferred or used alongside nutrient results. It can be more difficult to access groundwater sampling points; however, sample results for background information may be available, for example, from Local Authorities/Irish water/EPA.

Upstream and Downstream: Testing nutrient concentrations (principally NH_4 and MRP) upstream and downstream of a known (or suspected) point source will aid in assessing the impact on the receiving water body.

Confirming pollutant inputs: Testing nutrient concentrations in suspected polluting discharges (or where there are several discharge pipes or drains close together) will confirm strength and significance of inputs. This could be useful where there is not an obvious visual indicator, such as sewage fungus. Disturbing drain sediments to check for malodours, sulphide or blackness (reduced / anoxic sediment) could also be considered for visual clues before nutrient testing.

8.7 Useful References

European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I. No. 272 of 2009). Available at http://www.irishstatutebook.ie/eli/2009/si/272/made/en/pdf

European Communities (Good Agricultural Practice for the Protection of Waters) Regulations 2014 (S.I. No. 31 of 2014). Available at http://www.irishstatutebook.ie/eli/2014/si/31/made/en/pdf

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CEN, 2005. *Small Wastewater treatment systems for up to 50 PT – Part 3: Packaged and/or Site Assembled Domestic Wastewater Treatment Plants.* European Committee for Standardization. I.S. EN 12566-3:2005.

9 Biological Indicators

9.1 Introduction

Field observation of the river channel biota provides critical inputs for the Field-based Assessment process as described in **Volume 1**. The method to be adopted here follows a long-established approach which uses "environmental indicators". Environmental indicators are simple measures of the response of the river or its biological communities to stressors affecting the system. A former example of the approach was the application of the Small Stream Risk Score (SSRS) during the first river basin management planning cycle. This metric used invertebrate indicator taxa to categorise the risk of not achieving the objectives of the WFD (WRBD, 2005).

It is acknowledged that degradation of fluvial ecosystems is often owing to the combined effect of several pressures or "multiple-stressors". Multiple-stressors can interact in complex and unexpected ways and responses of biological communities to combinations of stressors cannot always be predicted based on knowledge of how each individual stressor impacts a particular indicator. Therefore, multiple lines of evidence provide the best opportunity to understand or disentangle the significance of individual pressures in the complex situations where there are several pressures. Observation of semi-independent metrics (e.g. the extent of physical degradation in combination with phototrophic or invertebrate response) improves confidence when the separate elements are evaluated together. Observations on multiple occasions across a number of visits in different seasons is also key to developing a better understanding of complex situations as some stressors may not be active all year round. This approach is fundamental to the process of further characterisation.

For the purposes of this guidance, specific indicators have been chosen to enable assessment of the range of pressures typically encountered in Irish rivers, in a WFD context. This approach was introduced as a new approach in 2018 and has been used by LAWPRO in their Local Catchment Assessments since then. Much of the information to be collected during field assessment is not new. It incorporates well-established physical and phototrophic indicators to support the process. More emphasis is given to recording individual symptoms of degradation (*e.g. the river is channelised, excess interstitial sediment is present, sensitive invertebrates are absent*, *emergent vegetation is extensive*) to progress understanding of "how the river works". It also recognises the greater need to diagnose and isolate causal mechanisms where this information is required.

A new hierarchical assessment approach is outlined, to provide flexible options for the different local catchment assessment questions that arise. For significant pressures that have "acute" or "obvious" effects, simple observations of for example, excess cover of sewage fungus or opportunistic algae, can often be used to validate organic impacts or nutrient enrichment quickly using a Rapid Assessment approach. However, an absence of conspicuous indicators does not necessarily confirm a lack of impact, as visual indicators may be absent for other reasons (natural variability owing to seasonality, changes in water level and additional factors). Also, not all common pressures manifest in this way (e.g. sedimentation or toxic impacts affect interstitial invertebrate communities principally). A rapid instream assessment method to be incorporated with routine river-walks is required in these cases.

Other impacts may be more subtle and require more detailed observation. Sometimes a formal metric score may be needed to enable repeat assessments to be evaluated, or to help assess the significance of an upstream-downstream pressure. A method, adapted from the SSRS methodology, called Small Stream Impact Score (SSIS) incorporates further indicator groups which will prove the most useful option in those cases. The overall approach is intended to bring efficiencies by tailoring the level of assessment to a specific assessment question. Both levels of assessment may be incorporated in a given river walk in different contexts.

Figure 9-1: Physical, chemical and biological processes in river channels are interacting and this is especially the case in a degraded reach (above) or following a period of recovery (below) in this artificially widened stream. A higher interstitial sediment concentration and establishment of a greater biomass of macrophytes than expected for the river type resulted from channelisation. Predictable changes in the invertebrate community were found (i.e. less Heptageniidae and increased densities of Chironomidae) but no de-oxygenation or opportunistic algal cover was recorded here, ruling out nutrient pressure as an often-confounding factor. The succession of marginal re-vegetation helped establish a more natural morphology and habitat heterogeneity and substrate quality improved subsequently. The increased velocity in the narrowed channel favoured more sensitive invertebrates and a lower cover of submerged vegetation. It is important to try to identify the extent of these stressors where they co-occur, so a correct diagnosis for significant pressures can be determined. The “multiple stressor” nutrient enrichment and modification of hydromorphological conditions is the most commonly encountered pressure combination reported for Irish and European waterbodies.

Figure 9-2: Characteristic 'responses' of biological communities become apparent as familiarity with the standard biological indicators develops. A visual assessment of this low gradient reach confirms that it had been physically modified (i.e. banks are re-sectioned but significant re-vegetation has now occurred). Although the channel form was also modified, a diversity of natural substrate remained dispersed over its course (especially important for fish communities). Levels of surface or interstitial fine sediment were not extensive. Sedimentation in slower reaches had resulted in a proliferation of submerged and emergent vegetation (so the extent of change in diurnal oxygen concentration during low water conditions in summer may be important). Increased filamentous diatom growth in shallow glide suggests a possibility of nutrient enrichment, but the condition of this reach was found to be satisfactory for macroinvertebrate communities overall (a rapid assessment of invertebrate indicators could be done to verify this).

9.2 Purpose

The purpose of this section is to provide the field assessor with practical information to recognise and record the biological attributes required for assessment. Further concise information on the significance of selected indicators is outlined below, but more detailed context is given in other volumes of the manual. The sections on hydromorphological pressures (**Volume 2**), biodiversity (**Volume 3**) and water parameters (pH, conductivity, dissolved oxygen) and sediment (both this **Volume 4**) are particularly important for background understanding. Explanatory notes are intended to give a basic outline to enable assessors interpret condition when “less-typical” reaches are encountered, or when undertaking surveys at different times of the year. A series of plates that can be laminated and taken into the field will provide a useful reference for most of the common indicators that will be encountered during river walks. See **Appendix D** for an SSIS identification guide plus a more detailed guide on macrophytes. LAWPROs Biosecurity Protocol is also included in **Appendix E**.

The biological indicators described in this section are as follows:

- Invertebrates;
- Macroalgae; and
- Macrophytes.

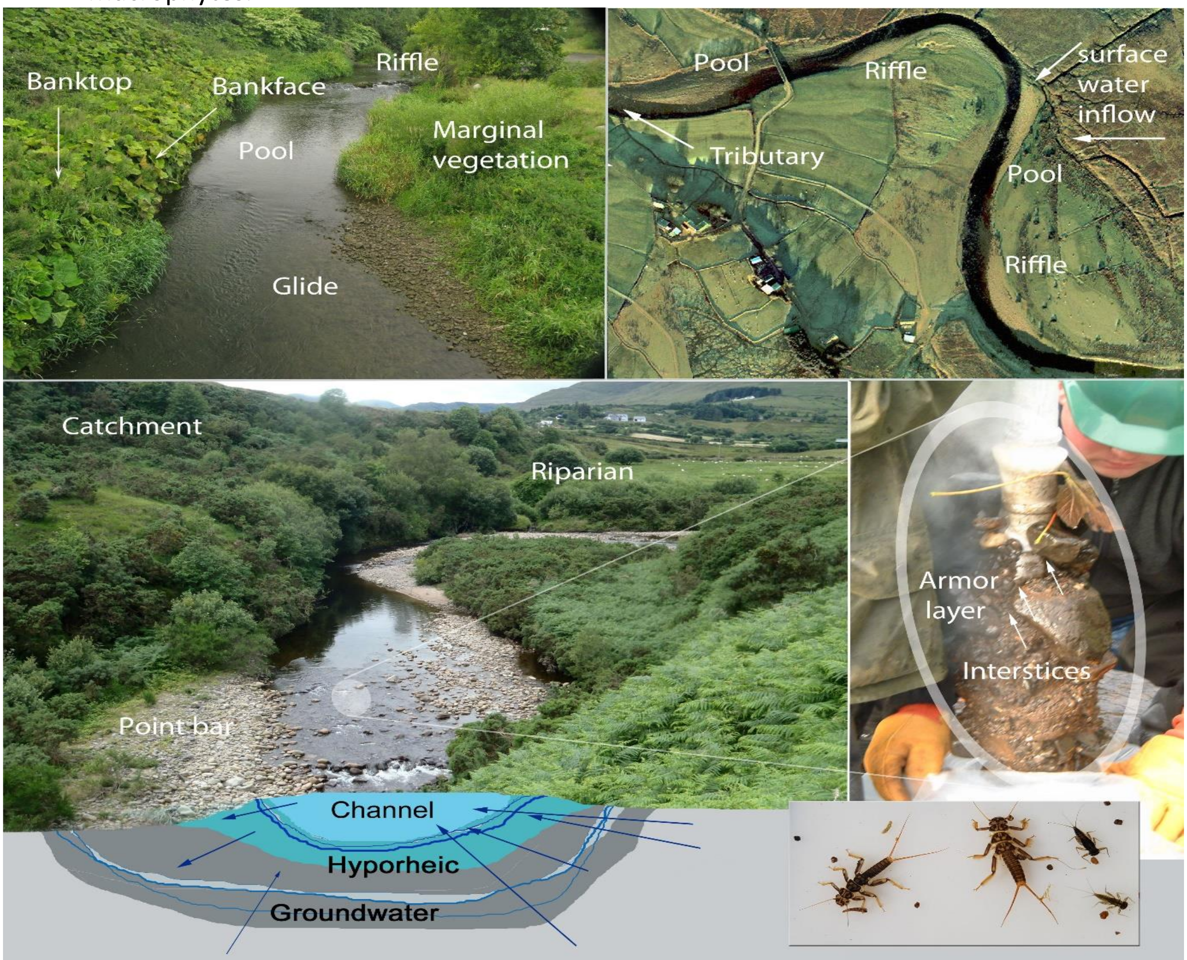


Figure 9-3: Irish rivers commonly have a riffle-glide-pool sequence, or a variation of this channel form, where the most sensitive invertebrate communities are “expected” in gravel interstices. If habitat degradation occurs, it may originate at a local reach scale (e.g. pollution entering from nearby surface water drains) or from catchment wide diffuse sources (e.g. nutrient delivery via groundwater pathways). A desk study which includes a conceptual model for the catchment and its individual waterbodies helps to define the specific assessment requirements before catchment walks are undertaken.

9.3 Hierarchy of survey techniques

The local catchment process is outlined in Figure 1-3 in **Volume 1**. The approach to utilising biological indicators sits within this process and includes a number of key steps:

1. Desk study

Existing information on biological indicators, in particular Q-values and SSIS scores, is assessed in conjunction with other available sources of information (e.g. individual waterbody characterisation and physical and chemical datasets) as part of the collation of receptor information in a deskstudy. This is dealt with in greater detail in Volume 1. It is important that the receptor requirements are well understood before fieldwork plans are determined at deskstudy stage.

2. Small Stream Impact Score (SSIS) and Rapid assessment (RA)

Small Stream Impact Score - Detailed assessment

This level of assessment is based on an adaption of the Small Stream Risk Score (SSRS) with incorporation of further indicators to support identification of significant pressures. This more detailed assessment is beneficial particularly at the start of a survey where there are no Q-value data and in tributaries, by establishing a risk assessment baseline for the waterbody, which can be then followed up with a series of rapid surveys to identify major deviations.

Rapid Assessment

This assessment is designed to enable the assessor to confirm the likelihood that the water quality of a “typical” site is impacted or not impacted, particularly for sites falling at either end of the impact range. When biological condition is at the higher or lower end of a pollution gradient, then representatives of the most pollution sensitive or tolerant forms will dominate the community, respectively. The approach enables the assessor to validate this level of impact quickly with recording of the occurrence of indicator groups in the field sheet. Following a rapid assessment (5-10 minutes duration expected), well documented deviations of biota for some common pressures prevalent in Irish rivers can be established (i.e. organic and nutrient enrichment, acidification or chemical pollution). The survey is intended to be undertaken in conjunction with river walks when recording other field observations and assessing relevant supporting physical and chemical parameters. As it utilises phototrophic indicators, the rapid assessment has most value during summer, when algae and macrophytes are often expected to be most prolific (June – October).

Figure 9-4: An absence of sensitive species (right) in the tray on the left, also with an excessive density of tolerant taxa indicates that this community is impacted by a stressor(s). The significant deterioration in condition in this case can be quickly determined and the clear decline in quality like this forms the basis for a rapid assessment approach.

3. Specialist input

There are additional more intensive metrics for a range of pressures and biological quality elements that may be warranted after some local catchment assessments. Often, a combination of specialist assessments incorporating physical parameters (e.g. sedimentation) in combination with biological quality elements (e.g. fish, invertebrates, macrophytes, diatoms and other algae) may provide considerable value for assessing the full extent of degradation, or loss of beneficial uses in a waterbody. A default requirement for specialist input should not be considered, as the additional precision may not necessarily provide additional insight for a significant pressure. The decision should be made after evaluation of the field assessments in combination with all other available data sources. Questions to guide a decision about further requirements for more specialist input may include:

- How much progress has been made on the original local catchment assessment question – are sufficient data now available to allow the questions to be answered with a reasonable level of confidence?
- Would a repeat catchment walk provide a better option?
- What is the purpose of undertaking additional survey work and what answers will this survey provide?
- What biological quality element and what metric is most suited to answer the specific question and what time of year should the assessment be scheduled for?

9.4 Significance

As outlined in **Volumes 1** and **2** of this Guidance, there are many different activities with the potential to be classed as significant pressures when there is a risk of not achieving WFD objectives. The approach set out below uses some of the more obvious and easier to assess parameters, with a proviso that the indicators selected fulfil one of the following useful criteria:

i) help categorise the "type" of river being assessed.
ii) help to assess the extent of degradation present.
iii) help identify the suspected cause to inform appropriate actions to remedy the significant pressure, where this is feasible.

9.5 Invertebrate Indicators

9.5.1 Indicator value

Invertebrates are the mainstay of bioassessment in rivers owing to their well-known differential sensitivity to a range of environmental stressors commonly affecting aquatic systems, their ease of sampling and identification, and their long-life cycles within waterbodies. Their individual traits and the response of indicator groups has been formalised into WFD compliant metrics to measure the extent of impairment (i.e. for organic and nutrient enrichment, acidification, or more recently using sediment & flow metrics).

9.5.2 SSIS – what is it?

Small Stream Impact Score (SSIS) is based on the SSRS methodology, but the categories have been revised and additional taxa have been added. SSRS was a "*biological risk assessment system for detecting potential sources of pollution in 1st and 2nd order streams*", with the aim "*to support the programmes of measures for the Water Framework Directive (WFD)*"[16]. The outcome was "*a score that assesses the risk of pollution on a watercourse*". "*The assessment is a standardised method that should enable surveyors to produce consistent results*." And based on the macroinvertebrate score, there were three categories of risk; "Probably not at risk", "Stream may be at risk" and "Stream at risk". These categories were used for characterisation for the first river basin management plan. These categories have been updated for the SSIS methodology as the terms *At Risk* and *Not at Risk* have been redefined for the 2nd cycle characterisation and are now 'Probably not significantly impacted', 'Indeterminate evidence of impact', and 'Probably impacted'. The 'score' obtained is based solely on the macroinvertebrates that are present at the sampling point. The field sheets however require field chemistry, stream characteristics and macrophyte and macroalgal cover (including sewage fungus if present) to be entered. Although this information is not used directly to derive the SSIS score, it can be used to interpret the possible reasons for the score obtained. The list of indicator taxa has also been revised and further groups incorporated to help improve diagnostic value of the assessment and help with interpretation where multiple pressure effects are considered to be important.

9.5.3 Outline of SSIS and Rapid Assessment Method

Generally, the macroinvertebrate-based water quality indices used in Ireland utilise a timed kick sampling methodology supported by a timed stone/hand search. Kick sampling involves the disturbance of the streambed substrate with the foot which dislodges invertebrates washing them into a net placed downstream. The stone search is intended to ensure that taxa which are less easily dislodged by kicking are not under represented. Sampling time should be counted as time spent kicking or hand searching and not just the amount of time spent in the river.

The Small Stream Impact Score method requires a 2-minute kick sample a 1-minute stone search. It should be taken predominantly in riffle/run habitat if possible and preferably in cobble substrate

[16] The quotations are taken from the SSRS Training Manual, February 2010.

which is more easily mobilised. If different sub-habitats are present at the site (e.g. different substrate size classes, floating vegetation etc.) it can be useful to spend some time sampling each of these to ensure that the full diversity of macroinvertebrates are captured. The comment section on the SSIS field sheet is extremely useful to add any notable site-specific details or impressions.

The rapid assessment requires a 1-minute kick sample and stone search to assess the relative contribution of sensitive and tolerant macroinvertebrate taxa in a riffle community. The rapid kick sample should be taken in a fast riffle or, failing that, in the fastest flowing section of the stream and ideally, one with a cobble-dominated substratum. Even though sample effort is limited, experience has shown that a small sample like this will contain the dominant taxa in the community (and 80% of that likely to be found in a full 3-minute sample). A more rapid sample also reduces the amount of debris that must be sorted through, thus bringing the efficiencies required for surveying multiple stations during a river walk.

The sample is assessed with respect to a flow chart incorporating streamlined biological attributes in order to help the assessor determine the likelihood for commonly occurring pressures often encountered in Irish rivers. This flowchart is provided in **Appendix D.**

In both SSIS and RA, if the stream is a very slow flowing “Potamon-type”, sampling should incorporate a weed sweep, while taking care to reduce the amount of mud in the sample. Caution should be taken with interpretation of results as the community expected at these sites in reference condition would be quite different to an eroding type stream characterised predominantly by riffle and run habitats. The majority of such sites will have been impacted hydromorphologically through for example OPW arterial drainage schemes, therefore this habitat type may lend itself better to documenting using the Rapid Assessment fieldsheet (**Appendix D**), which will note the observable macrophytes and macroalgae, weed sweep findings, together with documenting the landscape characteristics in the catchment walk fieldsheet (**Appendix C**).

9.5.4 Interpretation of Results

Organic discharges with high B.O.D. will result in a predominance of tubificid worms and *Chironomus*, and sewage fungus may also be prevalent depending on preceding water levels. Where Ephemeroptera-Plecoptera-Trichoptera (EPT) are totally absent and *Asellus*/G.OL.D taxa are plentiful, then organic pollution is the likely cause. If the density of pollution tolerant indicator taxa (e.g. G.OL.D taxa) dominate the sample and cover of trophic tolerant *Cladophora* & *Vaucheria* spp., or *Leptodictyum riparium* and Lemna sp. is high, then nutrient enrichment is an issue.

If interstitial sediments or river bed sediment is greater than that expected for the channel reach, or large plumes of silt emanate from interstitial riffle habitat, then issues such as channel modification, excessive bank erosion, sediment loss from agricultural land or other anthropogenic sediment sources etc., may be suspected to contribute to the declining condition. EPT taxa may be reduced in density with an increase in oligochaetes and chironomidae in these cases (increasing cover of emergent or other macrophyte vegetation may also be observed, particularly encroaching into riffle habitat).

Acidification pressure in some sensitive afforested areas manifests as an absence of *Heptageniidae* and *Baetidae* often with a reduced diversity and density of other taxa (*Gammarus* and snails will also be absent). The invertebrate community will be dominated by Plecoptera, especially *Leuctra* (the diversity of macroalgae and Bryophyta often also declines, but Liverworts may be commonly encountered in the flora).

Chemical pollution from toxic substances (e.g. pyrethroid sheep dip) is increasingly prevalent in some locations in recent years. Typically, invertebrate density is reduced drastically in the most impacted reaches, such that a 10-minute kick sample will be required to obtain a representative sample. The total number of different species of macroinvertebrate (taxa diversity) will often be less than five types.

With biological recovery and invertebrate drift, a given sample may not always fall into such easily defined categories. These intermediate conditions may merit a more detailed assessment. However, the fundamental purpose of this assessment is to enable the major changes in the biota for different river segments to be established. Sampling locations should be strategically located to allow sources of pollution or critical source areas to be pinpointed with greater accuracy. This is best done when surveys are informed by a desk study which will review for example all available monitoring data, pressure locations, potential significant pressures, Pollution Impact Potential (PIP) mapping, and an associated conceptual model for the areas being assessed.

LAWPRO have produced guidance for their catchment scientists in the interpretation of SSIS scores and this guidance is included in **Appendix D**. It should be stressed that kick sampling within Freshwater Pearl Mussel habitat should not be undertaken, and it is recommended to contact the National Parks and Wildlife Service (local ranger or Scientific Unit) in relation to assessments you may wish to undertake in these catchments. LAWPRO have developed a river survey protocol for Freshwater Pearl Mussel rivers, and this is also included in **Appendix D** for information. Guidance is also available in **Appendix D** with case studies on acute toxicity which LAWPRO have encountered and provides additional advice on use of SSIS in these cases.

9.6 Macroalgal Indicators

9.6.1 Indicator value

Useful information on the quality of water can often be directly inferred from the presence of macroalgae and bacterial tufts, particularly when their biomass is high (a higher confidence of impact in this case). However, it must be noted that unlike some indicators, **an absence of macroalgae is not necessarily diagnostic of an absence of pressure**. Conspicuous forms may be missing or reduced in cover due to a range of natural factors (e.g. velocity, scour, depth, shading, seasonality). Equally, the presence of macroalgae is a natural feature of a healthy watercourse and **is not necessarily a diagnostic of the presence of a pressure**. Like all indicators, exceptions to the general statements which follow may be found - nevertheless they are applicable in most situations in all Irish rivers.

Algae are a disparate group of organisms, spanning prokaryotic and eukaryotic kingdoms / domains; they are predominately photosynthetic (not always), have simple reproduction, lack cuticles and are predominately aquatic. As a disparate group, they share similar habitats and there are about 5000 to 6000 species recognised from Britain and Ireland.

Macroalgae specifically are algae that can be recognised, and at least partially identified with the naked eye. They are often a very visible component of aquatic flora, and they have many key functions not least the provision of food to other aquatic life. Algae have had a bad name for some time however it must be stressed that not all algae are 'bad'! The proliferation of green algae is a well-known response to increased nutrients in aquatic systems, however even high status sites have some abundance of macroalgae and indeed some assemblages often contain widely distributed species or rare species (see RIVTYPE project for species lists for various Irish river typologies, Kelly-Quinn et al, 2005).

Algae belong to several different algal groups:

- Cyanobacteria (blue-green algae)
- Chlorophyte / Charophyta (green algae)
- Xanthophyta (yellow-green algae)
- Rhodophyta (red algae)

- Chrysophta (yellow-brown algae)
- Baccillariophyta (diatoms)
- Phaeophyta (brown algae)

When identifying macroalgae, colour, alone is not a reliable characteristic. *Vaucheria* for example is green in colour but is not a green algae rather it is a yellow-green algae. Other diagnostic features which assist in identification in the field include growth forms e.g. filaments, crusts, hemispherical colonies, gelatinous growths; typology e.g. *Cladophora* is characteristic in higher alkalinity environments, and *Stigeoclonium* more so in low alkalinity environments, where *Cladophora* won't be found. The Biological Indicators fieldguide in **Appendix D** provides a useful guide to the main macroalgal assemblages encountered in Irish rivers.

Figure 9-5a: A high cover of opportunistic algae (above) is indicative of elevated nutrients and the individual indicator taxa (Middle L-R) *Cladophora glomerata* (green algae), *Lemna trisulca* (green algae) and *Leptodictyon riparium* (moss) may reach a high abundance with further enrichment. (Lower) *Vaucheria* and *Cladophora* in excessive abundance in the St Cleran's Priority Area for Action (Summer 2019).

Figure 9-5b: Excessive biomass of filamentous green algae (*Oedogonium, Microspora*) in the Owenriff Priority Area for Action (Summer 2021).

9.6.2 Indicators

Presence of a high biomass of bacterial tufts (bacterial slimes, fungus and protozoa) signifies a recent and significant discharge of organic matter to a watercourse. Heterotrophic growths are normally associated with agricultural, municipal and industrial discharges and when extensive should be investigated quickly, as fish kills may occur with de-oxygenation during summer. In some rare cases, burial of large quantities of vegetation (e.g. trees) in waterlogged soils provided sufficient biodegradable organic matter to stimulate excessive growths.

Figure 9-6 Example of sewage fungus found during LCA downstream of a WWTP in the Carricknabraher Priority Area for Action.

Excessive biomass of "blanketweed", a general term which refers to species like *Cladophora*, *Vaucheria* and *Rhizoclonium* is indicative of an excess of nutrients, particularly inorganic phosphorous and nitrogen e.g. in St Cleran's Stream Priority Area for Action (Figure 9-5a). *Cladophora* is intolerant of heavy metals. *Stigeoclonium* sp. replaces these taxa at low alkalinity, where the former taxa will never be found. *Ulva* typically indicates tidal influence - exceptions occur but are rare in Irish rivers and the influence of high conductivity discharges in the vicinity should be confirmed if this taxa is encountered. The trophic optimum of all other filamentous algae is generally lower, but increased cover of some opportunistic taxa (e.g. *Microspora* and *Oedogonium* sp.) are common and indicate nutrient enrichment (when biomass is high) e.g. in the Owenriff Priority Area for Action (Figure 9-5b). In some oligotrophic systems, a naturally high abundance of other filamentous algae may be encountered (typically *Moeugotia, Bulbochaete* & *Zygnema*) particularly in low order watercourses. Confirmation of the occurrence of additional sensitive macroalgae (e.g. *Stigonema*) is helpful to rule out nutrient pressure in these cases.

An excess cover of filamentous diatoms is often an early indicator of slightly elevated nutrients, or a decrease in the extent of invertebrate grazing (indicating a potential imbalance in the system). Other diatoms form distinct mucilaginous colonies and are occasionally prolific with more significant enrichment (e.g. *Gomphonema minutum*). A specialist diatom occurring in oligo-mesotrophic conditions when organic-P is the dominant nutrient source, *Didyomosphenia geminata* is sometimes confused with sewage fungus, but has a more regional distribution in upland areas principally.

Cyanobacterial mats are widespread in many rivers but should never be extensive in cover. When prolific in oligotrophic catchments, it often suggests disturbance events (e.g. extensive drainage activity in a catchment) or general enrichment elsewhere. It can reach very large biomass downstream of drinking water treatment plants when discharges of coagulants to receiving watercourses occurs (flocculants high in iron and/or aluminium salts).

Calcification in many Irish rivers is often influenced by an encrusting cyanobacteria *Phormidium incrustatum* agg. which is the commonest crust-forming organism in Irish Rivers (Kelly-Quinn & Reynolds, 2020)(Figure 7-11). It is reported to have a relatively low optima for orthophosphate, and calcification breaks down at high phosphorus levels (Kelly-Quinn & Reynolds, 2020). It may become more extensive and compacting with increased nitrogen, but other natural factors aside from water quality are equally relevant (carbonate saturation index, gradient, morphology, turbulance and shading). It may commonly be encountered in particular regions of the country (e.g. midland and western limestone influence catchments), especially in low order tributaries.

Some macroalgae e.g. *Nostoc* have specialist cells (heterocysts) which manufacture nitrogen when the ambient concentration of this essential nutrient is low. Other less conspicuous macroalgal forms are often overlooked or may only be regionally important. They occur mainly in oligotrophic streams where inorganic nutrient concentration is sufficiently low to provide a competitive advantage over more generalist filamentous forms. Confirmation of other taxa (e.g. *Chaetophora* & *Drapnaraldia* sp.) may be particularly useful in specific circumstances (e.g. groundwater influenced rivers).

9.6.3 Sampling detail

The group is best assessed during summer (May through to end of September) after a period of stable flow, but some species will reach maximum cover earlier in the year. Sewage fungus may be regularly encountered at all times of the year and thrives at relatively low water temperature. However, it is easily scoured with modest increases in water level, so checking under larger substrate (boulder-cobble) and marginal vegetation for the presence of slimes is important when organic discharges are suspected.

A river with a high biomass of a trophic tolerant form (e.g. *Cladophora*) annually, will undoubtedly be found to be nutrient replete when water chemistry samples are taken and analysed. Therefore, it is important that the coverage and density of the algal assemblages is documented and photographed as evidence of enrichment. Where significant variation in the extent of cover occurs, repeat visits to the same locations can be a useful approach, to document where breaks in the algal biomass occurs within the water body. This may assist in the narrowing down of the pressures and sources where nutrients are being lost via landuse activities. Establishing the extent of a seasonal succession for algae may also provide additional insight. A temporal succession of forms (e.g. species indicating lower trophic status followed by *Cladophora* & *Vaucheria* in summer) suggests seasonal variability of nutrients, but temperature and light may be equally important factors for some reaches. Therefore, repeated visits to the same sites over the course of a summer period, in order to document the succession, will be invaluable information to build your issues profile before refining LCA conclusions.

Increased macroalgal cover along a single bank of a river may lead to the location of a discharge point. Where an equivalent biomass is observed subsequently, further downstream across the width of a channel, this extent indicates the end of the mixing zone. When algae are restricted mainly to faster flowing reaches (e.g. riffle only, or in higher velocity areas of the channel) then it can be inferred that nutrients are elevated (depending on the species present) but not to a concentration that would enable colonisation of the entire reach.

9.6.4 How to sample

A visual assessment of the general macroalgal forms can be quickly done in the river when conditions are suitable (season & water level). In extensively riffled areas, a bathyscope is indispensable for accurate assessment of cover. For more intensive surveys, an efficient way to confirm the presence of specialist indicators is to check the tops of larger boulder-cobble substrate (~6+ cobble-boulders) in areas of intermediate velocity of the channel, as these areas are less likely to scour during floods.

The extent of cover and density for the basic assemblages (see **Appendix D** Biological Indicators Fieldguide) can be routinely reported, when encountered. A more intensive survey may be done in conjunction with an SSIS survey when the information is useful to help establish if the reach is impacted. An absence of opportunistic algal cover should also be noted during low water conditions in Spring and Summer. Confirmation of the presence of more specialist forms is optional, as they have a more irregular distribution.

Appendix D provides both the SSIS and RA fieldsheets used by LAWPRO. For macroalgal cover (MAL cover) the following indicative % cover and density categories are used:

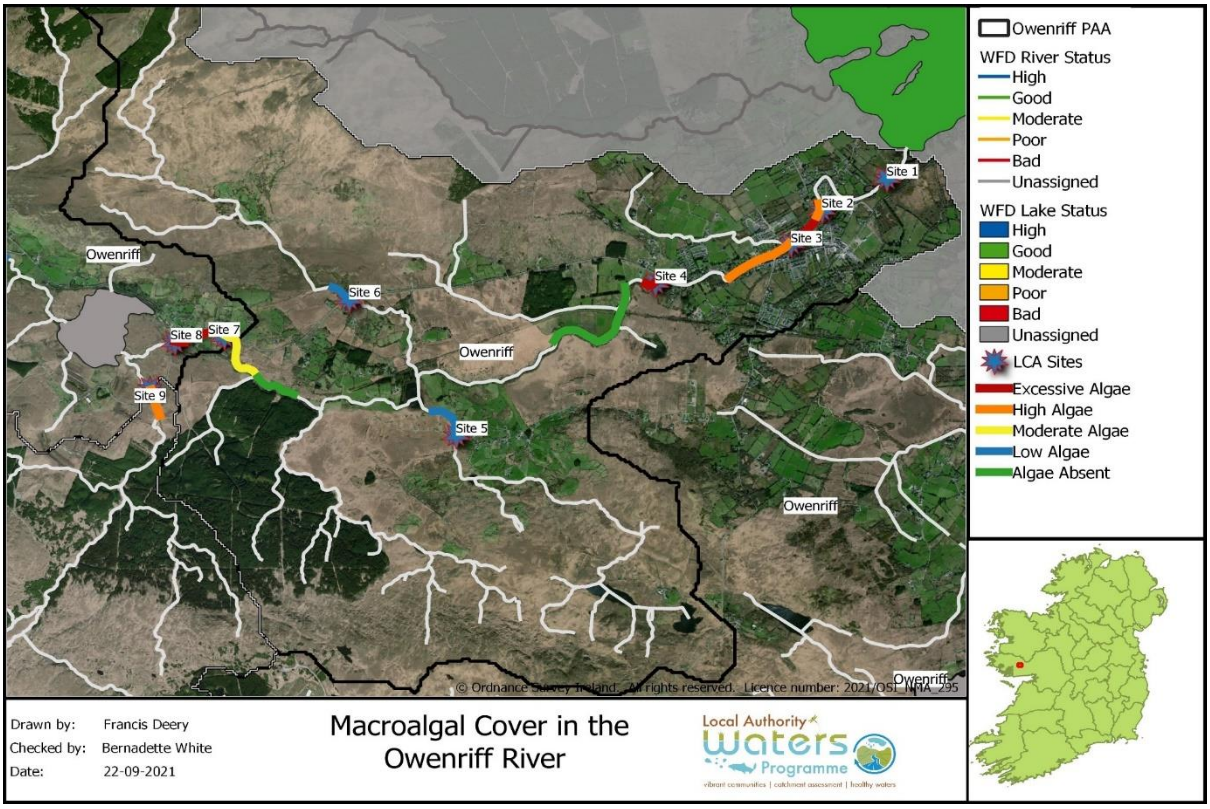
Channel vegetation cover: Dominant – Abundant – Frequent – Occasional – Rare – Absent – Not Visible

Density: Excessive (>75%) – Dominant (>50% - ≤75%) – High (>25 - ≤50%) – Moderate (>10% - ≤25%) – Low (<10%) – Not Visible

Total vegetation cover can be estimated using DAFOR scale abundance categories. **Density** estimates will assess the biomass of macroalgae present in a channel. It is important to note both. At certain times of the year, under certain conditions, the biomass of macroalgae can increase dramatically in a river stretch e.g. extended period of low flows, and sufficient nutrient availability. It is important to document the cover the density through several site visits to the same stretches to compare, and to understand whether your river stretch has an ongoing nutrient impact or it was exacerbated by low flows only occasionally. Ongoing nutrient impacts will become obvious over time and should be documented with photographs, fieldsheet recordings, and mapping of cover/density. An example for the Owenriff PAA is provided below. Breaks in algal cover above and below tributaries, or along certain stretches will assist in the refinement of referral areas which critical source areas may be located which are contributing nutrients into the river channel.

Sampling equipment

- Hand lens.
- Field guide.
- A freezer bag can be helpful to take a small sample of plant for later identification if a microscope is available.
- A bathyscope can aid in observing macroalgae on the river bed directly.
- A grapnel hook can be useful for identifying macroalgae in lakes (photic zone) or in deep unwadeable rivers (algae at the river surface).



9.7 Macrophyte indicators

9.7.1 Indicator value

Macrophyte communities in rivers provide useful indicators for assessment and are influenced primarily by the physical character of the river (light availability, altitude, slope, substrate, flow rate, depth), and secondarily by nutrient levels.

Depending on the location in the river system, expect to find different macrophytes according to the physical nature of the habitat. In the upper reaches there will be bryophytes that can withstand strong currents and the erosive nature of a channel. Vascular plants are absent here as the substrate is too dynamic. In the middle reaches, trailing mosses such as *Fontinalis antipyretica*, liverworts such as *Chiloscythus polyanthos* begin to occur, and again few vascular plants if any. Further downstream, where sediment begins to build, vascular plants are common as they can root into the substrate, flows are more stable, and depth is greater. Few bryophytes are found in the lower reaches. At the very low reaches, slow water enables broadleaved emergent plants to grow such as *Apium nodiflorum* and broad leaved floating plants such as *Nuphar lutea* and *Lemna minor*.

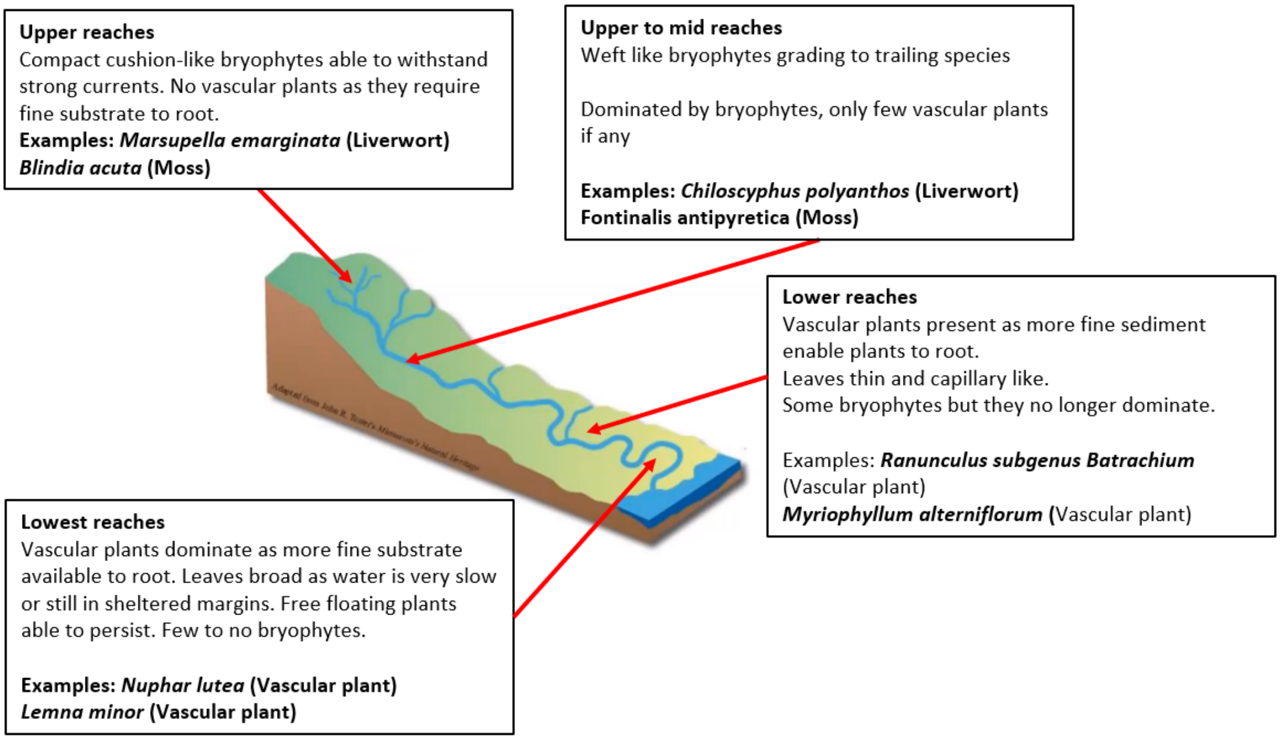


Figure 9-7 Longitudinal aquatic plant zones

In a transverse direction from river, lake, or pond shores to deep waters, emergent plants such as *Sparganium erectum* are found in the shallows, leading to floating leaved plants such as *nuphar lutea* and then fully submerged plants such as *Potamogeton crispus*.

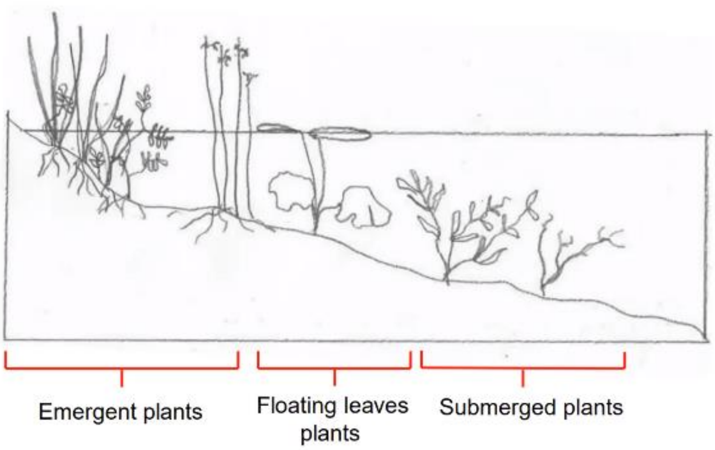


Figure 9-8 Transverse aquatic plant zones

Nutrient levels, especially phosphorus (because it is the limiting nutrient) can affect the community of plants found at a site. Elevated levels of phosphorus can cause accelerated growth of plants. Macrophyte observations may be particularly useful when taken up and downstream of a known discharge.

Excessive plant growth can also occur when there is a hydromorphological and or sedimentation pressure, especially in lowland channels. Extensive stands of emergent taxa in former degraded channels can significantly modify flow and sediment dynamics in a reach. When prolific, macrophytes are a primary cause of de-oxygenation with nutrient enrichment. Marginal plants such as *Sparganium* *erectum* and *Apium nodiflorum* need silty, fine gravely substrates and are examples of plants found in these conditions. High nutrient levels can encourage lush growth.

In oligotrophic systems, increasing cover of submerged forms in gravel-bed rivers can indicate increasing trophic status or a sedimentation pressure.

Some bryophytes (mosses & liverworts) when combined with other metrics provide information on the potential sensitivity to acidification for waterbodies in sensitive areas.

In cases of toxic impact from insecticides, the macrophytes will be unaffected.

9.7.2 Indicators

Macrophyte species and species assemblies can give a crude indicator of nutrient conditions (particularly when nutrients are either low or high). Example macrophyte indicators can be seen in detail in the [Indicator Field Guide, **Appendix D**] and in the table below.

High water quality	**Good water quality**	**Moderate/Poor water quality**
Callitriche brutia	*Apium nodiflorum*	*Myriophyllum spicatum*
Myriophyllum alterniflorum	*Berula erecta*	*Nuphar lutea*
Juncus bulbosus	*Rorippa nasturtium aquatica*	*Elodea nuttallii*
Potamogeton polygonifolius	*Ranunculus subgenus Batrachium*	*Potamogeton crispus*
	Elodea canadensis	*Potamogeton pectinatus*
		Potamogeton lucens
		Sparganium emersum
		Sparganium erectum
		Zannichellia palustris

Consider the physical conditions of a site and the catchment when assessing macrophytes. A site may be naturally high in nutrients for example, due to the geology of the catchment, soil type or due to being in the lower reaches of a river. Lowland rivers would normally be expected to be naturally more enriched than upland rivers. Many macrophytes can exist in poor/moderate quality water, it may be that a particular species is more dominant where anthropogenic enrichment is occurring. A combination of evidence (SSIS, macroalgae, sediment, macrophytes together with water chemistry analysis) will help determine water quality. For instance, there may be macrophytes present that indicate Good water quality but they are being outcompeted by macroalgae and in this case algal cover (e.g. *Cladophora, Vaucheria*) is the overriding evidence for nutrient enrichment.

Figure 9-9 The moss *Fontinalis antipyretica*, is an indicator of Good water quality but when smothered by diatom algal growth as seen above, this scenario indicates less than Good water quality.

9.7.3 Sampling detail

As the diversity of macrophyte species is high and identification of some taxa challenging, a simplified list of basic forms is referred to. Two sampling approaches are proposed here. Total estimates of the areal extent of cover and density can be routinely observed, where relevant. Accuracy in deciding on cover and density can be improved through discussions with other Catchment Scientists while on site.

As with SSIS, macrophyte comparisons can be made between sites, and when used alongside other evidence can help build a picture of water quality. When comparing sites, care should be taken to ensure they are within the same river and are physically similar (shade, habitat, substrate and underlying geology) as these conditions can affect the vegetation pattern. Although most macrophytes can be seen throughout the year, summertime (June-September) is the most suitable time as most plants are visible and or flowering. Before survey seasons begin, it is beneficial to refresh plant identification knowledge with training material.

Observing macrophytes is best done in low flows rather than after spates as this can affect water clarity and reduce the density of some macrophytes. As with macroinvertebrate and algal surveys, macrophyte surveys should be done at the same time if comparing between years. Bear in mind that in very shaded or dark, peaty streams, light availability will be the limiting factor and low macrophyte growth may be observed, regardless of water quality.

Tips on identification: Macrophytes adopt different forms depending on their environment; generally a narrow leaf indicates faster flow whereas a broader leaf indicates slower flow. Plants may have different floating leaves to their submerged leaves, for example, *Ranunculus* has capillary shaped submerged leaves and broad floating leaves. Many marginal plants, for example *Oenanthe* have very different submerged leaves compared to their emergent leaves.

Tips on moss identification: Look at the overall form of the moss on the rocks and limit your survey to the wetted zone. A hand lens is necessary to identify moss. Pick up a frond and bend the frond over so that a leaf pops up. Hold frond and leaf up to the sunlight and use the hand lens to observe the leaf shape and mid rib/nerve if it has one.

Figure 9-10 Mid rib/nerve of the moss *Platyhipnidium riparioides*

9.7.3.1 How to Sample

Some of the more widespread and easier to identify indicator taxa are illustrated in **Appendix D** Macrophyte ID Guide. More detailed assessment of cover for these taxa can be done if warranted (e.g. if biomass exceeds a threshold expected for the type of channel, or observed to be significantly different upstream-downstream of a pressure).

Channel vegetation cover: Dominant – Abundant – Frequent – Occasional – Rare – Absent – Not Visible

Density: Excessive (>75%) – Dominant (>50% - ≤75%) – High (>25 - ≤50%) – Moderate (>10% - ≤25%) – Low (<10%) – Not Visible

Total vegetation cover can be estimated using DAFOR scale abundance categories. **Density** estimates will assess the biomass of macrophytes present in a channel. Some easy to identify indicator taxa are illustrated in plates and their individual abundance can also be recorded when biomass is higher than anticipated (>20% cover as a general recommendation). However, lower relative changes in cover between reaches of the same channel may also have a diagnostic value.

- Bryophyta (mosses & liverworts)
- Emergent broad-leaved
- Emergent reeds/sedges/rushes
- Floating-leaved (rooted)
- Free floating
- Amphibious
- Submerged broad-leaved
- Submerged linear-leaved
- Submerged fine-leaved
- Opportunistic algae

Sampling equipment

- Hand lens.
- Field guide.
- A freezer bag can be helpful to take a small sample of plant for later identification.
- A bathyscope can aid in observing submerged macrophytes.

- A grapnel hook can be useful for identifying macrophytes in lakes or in deep unwadeable rivers. However, stringy species such as fine leaved *Potomogetons* can be missed using this method and care must be taken when rare plants may be encountered (see below).

9.7.4 Species of conservation concern

Care must be taken not to uproot species of conservation concern, for example Najas flexilis, a macrophyte found in lakes mostly on the west coast. Najas flexilis is a small, annual, submerged macrophyte of freshwater lakes that is listed on Annex II and Annex IV of the EU Habitats Directive. In Ireland, the species is also protected under the Wildlife Acts (1976 and 2000), being listed on the Flora (Protection) Order, 2015 (Statutory Instrument No. 356 of 2015). A search on www.Biodiversity.ie will help identify locations where you may encounter such plants, for example when surveying Unassigned lakes.

9.8 Typological Factors in Stream Ecology

The following section briefly introduces some further "typological" factors that assessors will undoubtedly encounter when sampling the diverse range of stream habitats that exist. When undertaking assessments using metrics or indices, investigators are evaluating how far aquatic communities have departed from their ideal 'reference state' (i.e. the natural situation that would exist in the absence of anthropogenic pressure (pollution or physical/hydromorphological)). The various indics and risk scores are based on an expected natural range for 'typical' stream conditions found in Irish rivers generally. However, all streams are not ecologically equivalent and will not respond in a standard way in all circumstances. Their biological communities (flora and fauna) may respond in a less predictable way to pressures and occasionally negate threshold values provided for assessing typical streams. In these cases, the relative change in metric score between reaches may provide a useful attribute to determine the significance of a pressure. In practice, a continuum of stream types may be encountered for each waterbody or river walk. Direct comparison of metric scores without reference to natural habitat differences is not always recommended. This is further outlined below for some of the more widespread types that may be encountered. Other criteria that are important for assessment are also briefly referred to.

The main criteria for consideration include the following:

- Gradient
- Flow regime & substratum quality
- Seasonality
- Diurnal Variation
- Groundwater Influence
- Brackish Influence
- Lake Outflows
- Intermittent Flow Rivers
- Tunnelling

Figure 9-11: Examples of the different categories of Irish rivers that may be encountered during catchment walks – a small stream in a near-pristine upland catchment (upper left), a naturally slow flowing "Potamon-type" (middle left), a calcified reach with high base-flow index (upper right) and a High status calcareous lowland river channel during low summer water level.

9.8.1 Gradient

Gradient is inextricably linked with flow regime and substratum. In the national WFD typology devised for Irish rivers, slope and geology were the two dominant factors used to separate the communities of 12 major river types. This was done on the basis that gradient interacting with geology will dictate the substratum and the energy of the river's discharge and thus habitat for macroinvertebrates, aquatic plants and fish – the major biological quality elements of the WFD.

In very high gradient, high energy areas, physical conditions of the habitat may be so severe that the overall density of macroinvertebrates is restricted. Longer sampling times may be required to enable a realistic assessment and some of the typical Riffle-Glide-Pool (RGP) species may be naturally absent. Similarly, aquatic plants, if present, may be confined to the mosses and liverworts that can withstand severe flow conditions.

9.8.2 Flow regime & substratum quality

Flow interacts with geology and soils in determining the nature of the substratum that will be present in a river channel. Substrate availability at the reach scale is dependent on each combination of gradient, flow-regime and geological setting, but can be classified into bedrock, boulder-dominated, cobble-gravel, finer sands or silts. Bedrock and sandy substrates provide homogenous (simple) habitat and a lower diversity of invertebrates occurs naturally for these classes. Gravel-bed streams are widespread. They are shallow, frequently have elements of a riffle-glide-pool sequence, and have larger cobble substrate providing essential habitat for many of the sensitive stone-clingers expected there e.g. *Heptageniidae*. Other adjacent reaches may have typological factors outside the typical RGP sequence (e.g. slower flowing Potamon-type). In lower gradient areas, the substratum will (naturally) have a much greater proportion of sands, fine sediments and silts due to natural deposition. The macroinvertebrate communities will be quite different to the communities of RGP reaches – with more silt dwellers such as *Ephemera danica*, damsel fly and dragon fly nymphs and a greater preponderance of cased caddis flies. Macrophyte growth will be greater in slow-flow reaches and higher density of *Simuliidae* may be present on vegetation. Emergent plants such as *Schoenoplectus* and *Sparganium erectum* typically occur along river margins in unmodified channels and are prolific in degraded ones. In low gradient streams mud and silt may accumulate on the stream bed. This can cause difficulties for kick-sampling, especially in degraded reaches. A 3-minute kick sample in such a case may result in a sample tray full of mud making it very difficult to identify and enumerate the macroinvertebrates. In such situations, shorter samples, weed sweeps and sub-sampling may be required to properly assess the sample's contents.

9.8.3 Seasonality

It is important to be aware of the natural seasonal differences that regulate biota expected in rivers at different times of year. In an unpolluted, near-pristine watercourse, the macroinvertebrate community will vary quite significantly, with more taxa expected in winter than in summer. This is primarily due to the life cycles of the invertebrates, with many species emerging from the stream during the summer months to complete their adult life stages. There is then a period of time when the adults have emerged and before the next generation of eggs have hatched, where particular taxa may be completely absent from stream faunal communities. The timing of these absences depends largely on stream water temperatures in a given year and the length of the absence varies by species (see **Appendix D**). Species naturally absent in summer include some of the highest scoring taxa when metrics are considered. Essentially this means that we must take **temporal** reference conditions into account just as importantly as we take substrate conditions into account for the main river types. Summer scores are generally expected to be lower than corresponding winter scores for unimpacted situations. While the absolute score will be lower in summer, this does not mean that the water quality or ecological status is somehow poorer in summer. It is necessary to compare like with like when comparing metric results.

In planning local catchment assessments, it is important to compare results for the same site at the same time of year when monitoring the same waterbody interannually. A two to three-week window is suggested for year-to-year comparisons. For catchment walks that are aimed at, for example, pinpointing sources of pollution in a catchment, it is essential to undertake the surveys within a tight timeframe of several weeks or less, so that meaningful comparisons can be made, eliminating seasonality as a source of variation.

If metrics produce low scores in winter this is particularly significant because of the seasonal expectation of a full complement of high scoring *Ephemeroptera* and *Plecoptera* during winter that should maximise the score. Therefore, absence of these taxa during winter implies quite a serious impact on the stream. However in many cases it will not be possible to survey for invertebrates in winter due to higher water levels, flooding etc., and alternative methods of assessment may be more valuable for this time of year. For example, LCAs undertaken in the October to May period, typically our wetter months, is the most effective way of pinpointing diffuse sources of pollution in catchments, flow paths and associated critical source areas.

9.8.4 Diurnal Variation in Dissolved Oxygen

In faster flowing turbulent reaches an equilibrium concentration of 100% saturation should occur in streams. In eutrophic watercourses, dissolved oxygen saturation levels may vary considerably from day to night, especially during the growing season, due to the influence of nutrient enrichment on aquatic plant biomass. The amount of oxygen produced by aquatic plants during daylight via photosynthesis will exceed that consumed by respiration and this can lead to supersaturation in the water column. Dissolved oxygen saturations greater than 120% saturation are a sign of eutrophic conditions. Supersaturation during daylight hours may provide an indication of the occurrence of oxygen depletion at night owing to respiration. In these cases dissolved oxygen levels will be lowest at dawn following a night of respiration. In eutrophic conditions dissolved oxygen concentrations will follow a curve, increasing throughout the day and decreasing throughout the night. If diurnal fluctuations in dissolved oxygen are the suspected cause of impact it can be useful to measure the dissolved oxygen concentrations just before dawn to assess how saturation levels drop. In-stream dissolved oxygen loggers are particularly useful in these cases to prove the presence of diurnal fluctuations, or dawn surveys. In a situation where low day time concentrations are observed, even in the presence of aquatic plants, this indicates that oxygen consumption is dominated by sediment uptake, except in the case of some groundwater influenced streams.

Organic matter depositing and infiltrating the substratum causes an additional draw on dissolved oxygen levels, especially in the interstitial spaces where invertebrates are found. It is important to note that low dissolved oxygen saturation in rivers and streams is predominantly due to sediment oxygen demand and/or macrophyte and algal respiration. The BOD demand in the water column itself can only account for a small proportion of the total observed demand – the dominant demand is from deposited organic matter in and on the substratum.

9.8.5 Groundwater Influenced Streams

Sampling close to groundwater inflow points may yield seemingly poor metric results. Some groundwater sources have naturally low dissolved oxygen saturation (see section 4). If such a source forms a significant part of a stream's discharge, then the oxygen levels in the stream may also be quite low. In this case the reference condition may not support high-oxygen demanding mayfly or stonefly taxa and the equivalent metric threshold values may be lower than those cited for shallow riffled streams.

Not all groundwater sources have naturally low dissolved oxygen concentrations, however, and this further complicates the interpretation. If such a groundwater source is contaminated by organic matter, this will result in further low oxygen saturations with bacterial degradation – which needs to be distinguished from the category of aquifers having naturally low oxygen described above. It will be useful to examine all other supporting data in these cases – macroalgal assessment (particularly the absence of opportunistic algae, or recording specialist forms if present), and chemical or microbiological data for the groundwater body may help with interpreting the significance of metric scores. Establishing the temporal pattern and daily variation in DO in conjunction with water level may help to separate the influence and effect of groundwater for high base-flow rivers.

9.8.6 Brackish Water Influence

Freshwater macroinvertebrates are impacted by salt as if it were a pollutant – many of the most sensitive taxa will quickly disappear in brackish conditions. Thus, sampling a river or stream in the vicinity of transitional waterbodies requires consideration of the possibility that high salinity water intrudes regularly, or occasionally, in the sampling reach.

A spring high tide may push salt water upstream further than a neap tide (lower) twice during the monthly lunar cycle, such that an apparent recovery is observed. This may be accounted for by invertebrate drift occurring during the neap tides part of the cycle, only for impact to occur again during the saline phase.

Brackish reaches are usually easily recognised by the presence of excessive densities of ‘shrimps’. Flounder or other marine species may also be found, although flounders can tolerate freshwater quite well and may be found many kilometres inland in certain rivers (especially in south eastern ‘sunken’ rivers such as Suir, Nore, Barrow and Blackwater systems). The presence of *Ulva* may also indicate more permanent brackish conditions. Essentially such reaches are transitional waters and a different set of assessment tools and metrics is required to assess them.

9.8.7 Lake Influenced Rivers and Streams

Invertebrate communities near lake outflows generally respond to the increased concentration of phytoplankton from the lake – typically filter feeding macroinvertebrates *Hydropsyche* and *Simuliidae* will dominate the macroinvertebrate fauna of these communities.

If the upstream lake is in poor condition (increased trophic status or de-oxygenation) this will be reflected in the outflowing river or stream by a greater preponderance of filter feeders and detritivores such as *Asellus* and *Gammarus*. A complete absence of sensitive EPT fauna is likely to indicate that the lake is in poor condition and is impacting the outflowing river or stream. An outflow from a good- or high-status lake, while still yielding a lower score than a ‘normal’ or ‘typical’ RGP reach, will support at least some of the high-scoring mayflies such as *Heptagenia.*

Impoundments or water abstraction from lakes may cause hydromorphological pressure as evidenced, perhaps, by a complete lack of flow in the outflowing river or stream or by an abnormally low flow - for all or part of the year. The former will result in a very impoverished fauna and the latter, while not as severe, will cause a reduction in the ecological status of macroinvertebrate, aquatic plant and fish communities to a level below the expected reference condition for the water body.

9.8.8 Intermittent Flow Rivers

Rivers and streams in karst areas may run completely dry in the summer months – resulting in a severe pressure on macroinvertebrate, fish and aquatic plant communities. When sampling these water bodies in the winter when flows return, it may not be immediately obvious that the cause of the less than good macroinvertebrate or aquatic plant communities is owing to the fact that they dry out completely in the summer. Examination of hydrometric records or confirmation of an absence of flow (in the absence of significant abstraction pressure) will help to identify natural karst systems.

9.8.9 Tunnelling

Extensive tunnelling of channels may occur by excessive development of a single year class of an individual tree species after a management intervention (e.g. Alder in some cases). Stream reaches that are heavily shaded will have low primary production and hence have limited occurrence of macrophytes, filamentous algae or bryophytes. This in turn affects the entire food chain with reduced food supply demonstrated to be a major factor impacting fish communities (reduced salmonid abundance has been observed in 'tunnelled' reaches). Thus, heavily shaded reaches must be critically assessed when interpreting their faunal or macrophyte communities. The 'typical' reference condition may not always apply there, and a restricted community may not be due to pollution or other impact – just owing to the fact that it's extensively shaded.

9.9 SSIS in high status objective rivers

The number of freshwater high ecological status water bodies (and monitoring sites) has been in decline for several decades. As a means of halting this decline, the Phosphorus Regulations of 1998 set the 1995-1997 Q values as the statutory baseline for improvements to water quality. At that time there were 153 river sites with Q5 reference conditions and 666 with Q4-5 – a total of 819 high status sites. These Regulations prohibited any deterioration of sites at Q5, Q4-5 or Q4 and set a target of incremental improvement of sites with water quality at Q3-4 or less. However, there has been significant deterioration for both Q5 and Q4-5 river sites since then.

The protection and restoration (if required) of High Ecological Status (HES) waterbodies has been identified as a priority objective in both the 2nd cycle river basin management plan and the draft 3rd cycle plan. The first step required was the identification of the remaining waterbodies that were still at High ecological status. The second step was to identify those waterbodies that should be at High status but have very recently declined and can be considered to have deteriorated since the WFD monitoring programme began. The third step was then to consider how the waterbodies that have not been at High status for some time can be returned to High status over the longer term. The first two steps were undertaken in 2016 in the preparation of the 2nd cycle River Basin Management Plan and are outlined further in a separate note on the Blue Dot Catchments Programme. For a river waterbody to be assigned a high status objective (HSO) it should:

- follow a pattern whereby high status has been achieved regularly throughout its monitoring history, and
- if deterioration has occurred, it will only have only occurred recently, i.e. since WFD monitoring commenced (2007 – 2009).

In these rivers, good status is considered unsatisfactory. Therefore, tools such as the SSIS that have been developed with the intention of assessing rivers with a good status objective must involve careful interpretation of results. High status rivers will generally have a greater diversity of sensitive taxa than those at good status. Therefore, when carrying out SSIS to determine if a Blue Dot river is probably impacted, it is important to consider not just the score but the diversity and abundances of sensitive taxa present.

A guidance note on the interpretation of SSIS in Blue Dot Rivers has been prepared by LAWPRO and is included in **Appendix D**. It should be noted that this guidance is considered a first iteration and may be conservative, and it is the intention of LAWPRO to further refine this guidance with the assistance of the EPA and subject matter experts. The SSIS guidance requires at least 2 Group A taxa with each accounting for at least 10% of the abundance and combined at least 30% of the of the total abundance of the sample. Group D and E taxa combined must make up less than 10% of the abundance.

In addition to the above consideration the guidance also requires additional consideration of the seasonality of the sample and the sampled location. All considerations are outlined below.

- The most important consideration is the time of year when the sample is collected. In a Blue Dot river, the sample **must** be collected in the summer (June to September inclusive) to have a reasonable indication if it is probably impacted. This is due to the tendency for there to be fewer sensitive taxa in the river during the summer due to seasonality in the life cycles of certain sensitive taxa (see **Appendix D**).

- The habitat must be suitable. In Blue Dot rivers it is particularly important that the sample is taken in a suitable riffle that would provide well aerated habitat for sensitive taxa. If samples are collected in glides or other habitats you are more likely to capture fewer of the most sensitive taxa and erroneously identify a probable impact.
- Bear in mind the substrate type when sampling also. For example, bedrock may provide less favourable habitat than boulders/cobbles for sensitive taxa. Refer to EPA taxa lists for the site where available to get an idea of what to expect.
- When looking at the sample determine roughly the percentage of the community that are Group A taxa. These taxa combined must make up at least 30% of the invertebrate abundance. This is just a guide percentage, you are not expected to count all individuals, but to get a reasonably accurate estimate from the tray.
- There must be at least 2 Group A taxa cumulatively making up 30% of the total abundance while each of these should make up no less than 10% of the population each (i.e. 25% of the abundance made of 1 Group A taxa with 5% made up from 2 others would not suffice while three Group A taxa that account for 10% of the abundance each (total 30%) would suffice).
- Class D and E taxa (the most tolerant groups) should make up less than 10% of the abundance when combined.

9.10 Useful References

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10 Appendix A: Streamflow Measurements – Further guidance and practical examples

10.1 Introduction

There are many methods to either estimate or measure stream flows, however, there is a hierarchy of likely accuracy versus practicality. The general order of accuracy is:

1) **Measured flows** in the field are most accurate (essentially irrespective of how they are taken) once the method is carried out accurately and reliable field records have been kept.
2) **Hydrometric stations** (verified and checked).
3) **Modelled outputs** (Hydro-tools or Rainfall Area Method).

The choice of which method to employ largely depends on the degree of accuracy you require and the equipment that you have to hand. At the desk study stage, hydrometric data or modelled flows should suffice to get a feel for the catchment. This is particularly useful in calculating nutrient load reduction targets at WFD monitoring points or estimating the relative load contribution from different water bodies in a large study area. Note: the application of modelled flows depends upon the suitability of the catchment.

For local catchment assessment, such as assessing the impact of a WWTP, bridge hop assessment, or piped discharges, manual flow measurements are recommended.

Measured flows

Methods to manually measure streamflow are ranked below in terms of accuracy.

1: In-stream flow measurements (taken with current meter, Acoustic Doppler Current Profilers (ADCPs).

2: Bucket and stopwatch – where there is sufficient fall and a small enough flow to catch all the flow.

3: In-stream estimates using a float to measure velocity over a relatively uniform river reach (approximately 50m) with measurements of the cross-sectional area at upstream and downstream locations.

4: Dilution gauging –not covered in this document, however guidance is available in the urban catchments online training and associated video presentations.

Methods 2-4 have been covered in the main body of Volume 4. In this Appendix, more information is provided on method 1: the use of a current meter to estimate stream-flow. This method depends upon the availability of a current meter, which can vary in cost substantially.

Hydrometric Stations

Hydrometric data can be a useful resource to understand how your catchment reacts to rainfall. The combination of daily hydrometric flow data with a time series of nutrient chemistry at a WFD monitoring points can be extremely effective in understanding the interplay/difference between stream concentrations versus stream loads. This is particularly relevant comparing the pressures which act upon river ecology vs. the pressures in a lake or estuary with incoming rivers. When utilising hydrometric data, it is important to recognise and understand the potential limitations of the data. Depending upon the operator of the gauging station, the data may be immediately downloadable as a CSV, or it may have to be requested through the Hydro-net website (links provided in subsequent sections). In either case, it is recommended to contact the operator to get practical advice on the use and limitations of the dataset prior to interpreting. The following considerations have been cited by the EPA hydrometric unit:

1. How accurate is the rating curve at low, medium and high flows – OPW stations are sited where high flows can be accurately estimated and the reverse is true for EPA stations and low flows. Many locations suit the accurate estimation of one, but not the other.
2. Is the device at the station a direct measurement device (e.g. an ultrasonic), or is a stage discharge relationship used?
3. In either case, how often are calibration gauging's taken. Weed and gravel build up impact rating curves and weed can make ultrasonic devices unreliable.

Modelled flows

Modelled estimates such as *Hydro-tool* or the Rainfall-Area method should always be used as a last resort and in the knowledge that they can be wholly unreliable in karst areas, and downstream of abstractions and discharges.

10.2 Manually measuring river flow

The following section details how to utilise the velocity-area method, using an impeller type flow meter. The section is written from a practical standpoint and from personal experience. As such, while the general method is well established, many of the subtleties in the exact way in which the method is carried out are subjective and should be treated as such. Figure 1 shoes an example of the equipment commonly used by LAWPRO during local catchment assessment.

The equipment you will need to carry out the flow meter method are:

- Flowmeter.
- A meter stick.
- A marked builder's line (or a measuring tape).
- Steel fence posts.
- A shovel (optional but useful).

Figure 1: Example of LAWPRO equipment for flow measurements: budget flow metre, metre stick and builders' line with increments and fence poles.

10.2.1 Site selection

Site selection is extremely important when estimating stream flow in the field. Concrete bridges or culverts are an ideal place to do flow measurements. In this scenario:

- All of the flow is focused through a single area.
- The flow is typically less turbulent than natural channels.
- There is less scope for a loss of streamflow through channel sediments.

- There are typically less obstructions to flow or rocks on the streambed, which can inhibit an accurate depth measurement.

Where possible, therefore, flows should be carried out in the above scenario. *Note: make sure all the river flow goes through the bridge (e.g., no side channels).*

If the cross section of the river is not appropriate at a bridge, then walk up-stream or downstream to a section that is appropriate. When considering a non-bridge location for flows, such as a natural channel, the following should be considered when assessing a potential site:

- Look for relatively smooth or laminar flow rather than turbulent flow (Figure 2). Flow meters typically give an average of the stream velocity over a period such as 30 secs to a minute. In turbulent flow, there are eddies etc, so that the stream velocity at particular points in the river is ever fluctuating. The calmer the section you choose is, the more representative the velocity you measure will be.
- Some more primitive flow meters only give you a spot measurement of velocity. In this scenario, it is essential to take multiple measurements of velocity over at least a 30 second period.
- Try not to measure downstream of a waterfall or a large convergence of flow (this promotes turbulent flow).
- Avoid choosing a site, which is immediately upstream of a large obstruction, i.e., large rocks, trees, or sudden widening of the channel.

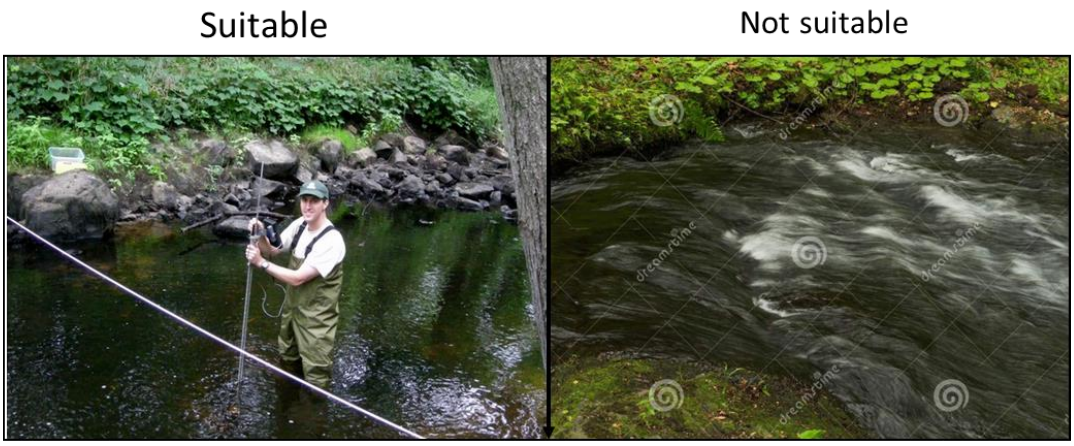


Figure 2: Suitable cross-sectional profile vs. unsuitable.

- Once you have found a relatively calm site (it does not have to be and rarely will be perfect), it is essential to ensure that all the flow in the river goes through that cross section. You do not want a side channel running parallel that you are missing in your stream-flow measurement.
- The next point cannot be emphasised enough: clean out your cross section to make it suitable. Remove any large debris or boulders from the cross section, so that when you do your depth measurements with the metre stick, you are measuring the depth of the water surface to the streambed, rather than from the water surface to the top of a boulder. Note: this is where the optional shovel comes in handy.
- If there are any boulders or moveable obstructions directly upstream of where you are doing your measurement, remove those, too.
- Often-times the edges of your river cross section will be obstructed by vegetation. In this scenario, clear out the vegetation in so far as possible. If there is a large amount of flow going through the vegetation, then the site probably isn't suitable.
- In terms of workload, five minutes of cross section preparation goes a long way.

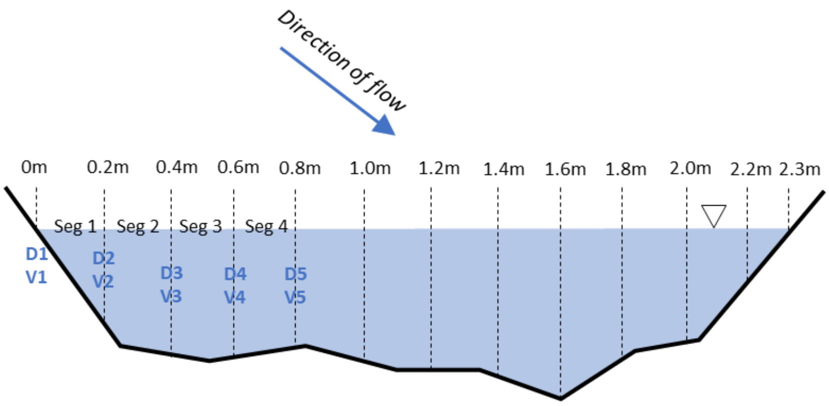
10.2.2 Theory

The velocity area method spits a stream cross section into segments. The flow in m^3/sec is calculated through each segment, with the total flow equal to the sum of the flows through each segment. Flow in any channel is equal to the cross-sectional area in m^2 (depth x width) multiplied by the velocity in the channel in m/sec. So the rule is:

Q = VA

- Where: Q = flow (m^3sec)
- V = velocity m/sec
- A = cross sectional area (m^2)

Conceptually, the Q = VA relationship makes sense. Take a scenario of a large pipe versus a small pipe, with an identical flow of water being pumped through both. The flow through both pipes is identical, but it will be significantly faster in the smaller pipe, i.e., the area through which the water can flow is much smaller, so is speeded up. The “V” in that equation gets greater as the “A” decreases. The Q = VA formula forms the basis for all the 1D, 2D and 3D groundwater flow equations also & can be used to estimate how fast water moves through the groundwater pathway (essential in travel time/timelag estimations). For measuring stream flow, you are dividing the stream up into segments (Figure 3) each of which has a width of 20cms (0.2m)



Width (m)	Depth (m)		Velocity (m/s)	
0	D1	0	V1	0
0.2	D2	0.2	V2	0.07
0.4	D3	0.35	V3	0.12
0.6	D4	0.36	V4	0.13
0.8	D5	0.3	V5	0.15

Figure 3: Example of segmented cross section with depth and velocity measurements.

Starting at point 0 and facing into the direction of flow, you measure the depth from the top of the water to the stream-bed, and also the velocity going through that point. Note: point 0 should always be the same side of the river for each of your assessments. I always have point 0 as my first increment on river right (RR). You then repeat the process going across the stream. So, at width 0.2m, you measure a depth and a velocity; at 0.4m you measure a depth and a velocity, etc. until you get to the other side of the stream. The flow through each segment of the river is equal to the cross-sectional area of that segment multiplied by the average velocity of the segment. The total flow is the sum of the flows in each segment. The calculated flow through Seg 2 is shown below as an example:

Flow through Seg 2

Cross sectional area of Seg 2 = $\frac{(D2 + D3)}{2} \times W = \frac{(0.2m + 0.35m)}{2} \times 0.2m = 0.055m^2$

Average velocity in Seg 2 = $\frac{(V2 + V3)}{2} = \frac{0.07 + 0.12}{2} = 0.095m/s$

Q = VA; therefore the flow through Seg 2 = $0.055m^2 \times 0.095m/s = 0.0052m^3$/sec

Or, **5.2 litres/sec** (1000 litres in a m^3)

10.2.3 Setup

Once you have found and cleaned a suitable stream cross section, the following steps insure an accurate flow measurement:

- Pin the fence posts into each side of the channel & stretch out your incremented builders' line across (Figure 4), with the line as taut as possible. The increments on your builders' line should be 20cm intervals. On streams <3m total width, you take measurements every 20cms. On streams >3m total width, with a relatively smooth flow, you could do 0.5m increments.
  Note: Alternatively, a measurement tape could be stretched out across the channel, however, this is difficult to get taut and also difficult to anchor to the sides of the channel.
- Measure the total width of your channel and record on the field sheet.
- Facing into the flow, starting from river right, use the metre stick to measure the depth from the water surface to the stream-bed across the channel. So, begin at W=0m, measure and record the depth. Then go to W=0.2m, record the depth. W=0.4m, record the depth etc till you get to the far bank.

  Note: I find measuring all the depths across first and then returning to W=0 and doing each velocity measurement across more practical than trying to measure both at once. This choice largely depends on your flow meter. The higher end flow meter will have cm increments on it which you can use to measure depth, followed by velocity.
- Next you go back to start, i.e., facing into the flow, starting from river right & repeat the process at each width increment. Now, instead of measuring the depth, you measure the velocity with the flowmeter. So, begin at W=0m, measure and record the velocity. Then go to W=0.2m, record the velocity. W=0.4m, record the velocity, etc till you get to the bank.
- Record all measurements and calculate flow according to Section 2.2.

Note: In streams, stream velocity is faster at the surface and toward the middle of the channel, and slower along the sides and bottom of the channel because of differences in friction. The average velocity is usually at 0.6 times the total depth from the water surface, or 0.4 times the total depth from the bottom of the channel. The higher end flow meters will have a plate on them, allowing you to measure the exact depth the flow meter impeller goes to. If you don't have this and get the impeller of the flowmeter half way between the water surface and the streambed, you should be fine.

Figure 4: Streamflow measurement being carried out in the Rogerstown Estuary Priority Area for Action.

10.2.4 Hydrometric data

There are approximately 1032 hydrometric gauging stations throughout the country. The bulk of these sites (approximately 70%) are operated by either the OPW or the EPA. Hydrometric stations and associated CSV data can be downloaded/requested at the below link:

https://www.epa.ie/hydronet/#Flow

If there is a current or historical hydrometric station in your catchment, you may be able to use this data to estimate flow at the WFD monitoring point. *Note this is subject to the cautionary note re: high and low flows provided in Section 1.* If the hydrometric station is at or close to the WFD monitoring point, the 30th percentile flow can be combined with annual average nutrient data to carry out a high-level nutrient loading analysis. The 30th percentile (or any percentile) can be calculated easily on excel using the daily timestep data.

The daily flow data can also be utilised to better understand the temporal occurrence of nutrients at the WFD monitoring points. Figure 5 shows an example of this approach from the Broadmeadow river, as carried out during the LAWPRO Broadmeadow desk study. The chart can be used effectively to differentiate between high concentrations during both low and high flow. Phosphate peaks during low flow often represent a lack of stream dilution and exacerbation of point source impacts, e.g. misconnections, septic tank discharges, farmyard sources or wastewater pressures. Phosphate peaks during high flow conditions may represent sources which are mobilised during heavy rainfall, such as storm water overflows, pumping station issues or widespread losses of phosphate through agricultural critical sources areas. The phosphate load lost during these high flow events greatly exceeds that of low flow. In the context of the transitional waterbody into which the Broadmeadow River flows, targeted these high loading events is critical to improving water quality.

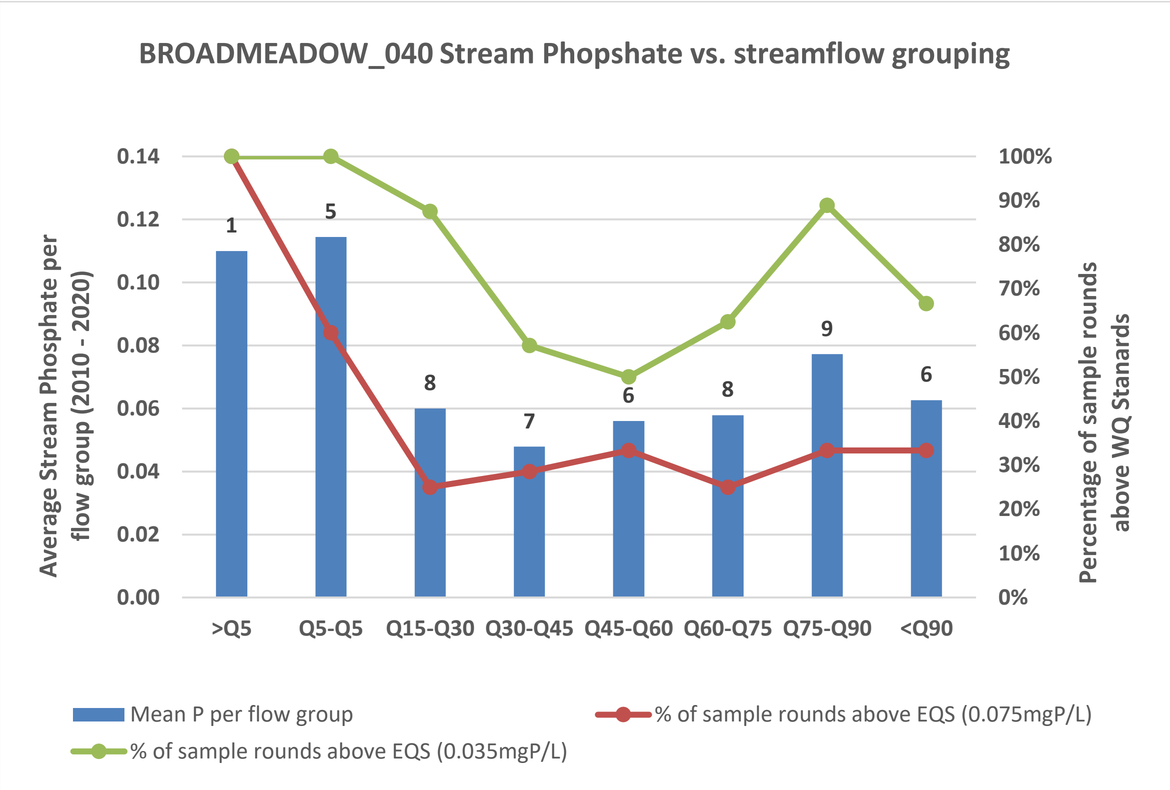


Figure 5: Stream phosphate at the EPA monitoring point on the BROADMEADOW_040 from 2010 to 2020, grouped according to flow on the day of sampling (as measured at BROADMEADOW OPW hydrometric station). The blue bars represent the average stream phosphate concentration within each flow grouping with >Q5 representing the highest flow condition. The green line shows the percentage of occasions where the 0.035mgP/L EQS exceedance, the red line shows the percentage 0.075mgP/L

Upscaling hydrometric data

If your hydrometric station is a significant distance upstream of your EPA monitoring point, then you may need to upscale the results. This approach is advised with caution as you are assuming that stream flow increases in a linear fashion with an increase in catchment area. This assumption forms the basis of the rainfall-area method, which will be described in subsequent sections. Both approaches are useful, particularly at the high level desk study stage. It is important, however, to bear in mind the limitations of the assumption and site them within the report text.

In order to carry out the approach, it is often necessary to define the catchment area of the hydrometric station and your monitoring point. The WFD waterbody catchment areas are readily available, whereas the catchment areas of additional supplementary monitoring points, hydrometric stations, or tributaries may have to be defined. Methods to define catchment areas include:

- Manual approach: catchment boundaries defined using contour maps, via GIS or by hand.
- Automatic approach: OPW subcatchment tool (FSU Portal).

For convenience, the FSU portal provides an excellent tool to estimate the catchment area of any point within your catchment. The catchments can be viewed online via the FSU website and are also available to download as .SHP files which can be integrated into your GIS files. The below provided a link to the portal, while specific instructions on how to setup and use the tool are provided at the end of this document. https://opw.hydronet.com/

Worked example

A hypothetical catchment has been drawn to show the approach (Figure 6). The “Made-up“ river catchment has two tributaries and an EPA monitoring point at its base. The main channel has been broken up into 3 sub-catchments. The dashed lines here represent the boundaries of the sub-catchments. For this exercise, the tributaries can be ignored as they are not relevant. The hydrometric station is shown by the purple star at the base of sub-catchment 2 (MC_SC 2) and an EPA monitoring point is shown by the red circle at the outlet of the river. The 2019 30th percentile flow at the hydrometric station in the example was **0.33m^3/sec.**

To upscale or downscale river flow data, you look at the catchment area of the hydrometric station relative to the catchment area of the EPA monitoring point.

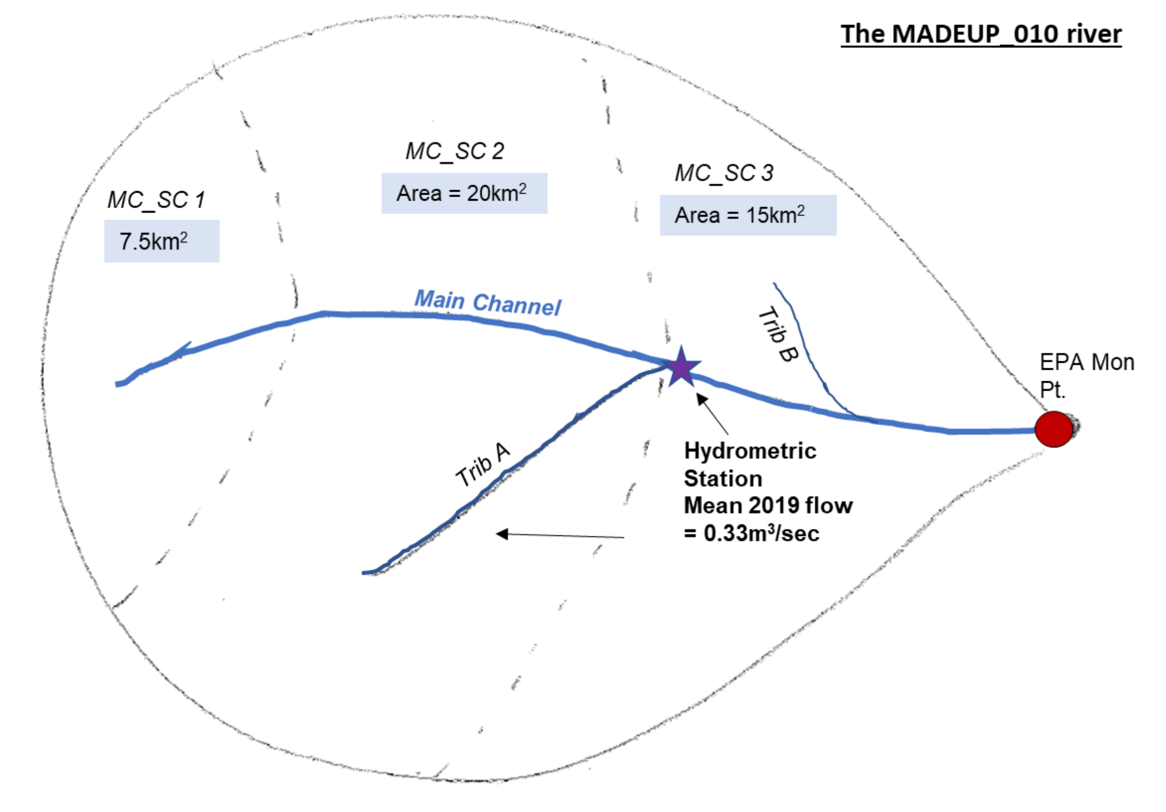
Therefore:

- The total catchment area contributing to the flow at the hydrometric station is equal to:
  MC_SC 1 (**7.5km^2**) + MC_SC 2 (**20km^2**) = **27.5km^2**
- The catchment area contributing to the flow at the EPA monitoring point is equal to:
  MC_SC 1 (**7.5km^2**) + MC_SC 2 (**20km^2**) + MC_SC 3 (**15km^2**) = **42.5km^2**

The catchment area contributing to the flow at the EPA monitoring point is therefore 1.55 times (i.e. 42.5/27.5) the size of the catchment area contributing to the flow at the hydrometric station.

- Your upscaled flow for the EPA monitoring point therefore equal to:
  0.33m^3/sec x 1.55 = **0.51m^3/sec**

  Or if you want to express in litres per sec = **510l/s** (i.e. there are 1000 l in a m^3)



- The dashed lines divide the main channel into three subcatchment areas (which in practise would be delineated using topography, note: this is easily done on GIS also)
  These are subcatchment 1 *(MC_SC1)*, subcatchment 2 *(MC_SC2)* & subcatchment 3 *(MC_SC3)*.
- The total catchment area of the EPA Monitoring Point is equal to MC_SC1 + MC_SC 2 + MC_SC3

Figure 6: Hypothetical catchment with main channel and three sub-catchments: MC_SC 1 - MC_SC 3.

10.2.5 EPA modelled flows

The EPA has produced an updated data set of modelled river flows across Ireland. This data set is available through the EPA map viewer: HydroTool application. The new modelled outputs provide estimates of the *Naturalised* stream flow at a given point. The naturalised flow is the flow that would be in the river if there were no human induced abstraction or discharge related impacts on the flow. It does not therefore estimate the actual real-world flow in the channel downstream of such influences. At all data points, flow percentiles and catchment descriptors (e.g. catchment area, average precipitation, average evapotranspiration, etc.) are available. Nationally, the model results are estimated to have a 95% Factorial Standard Error (FSE) of +/-16% at the Q30 (approx. average flow) and +/-56% at the Q95 (low flow) level. Flow estimates are not available for catchments underlain by conduit karst, or in controlled catchments, as the modelled results are unreliable in such areas. The accompanying detailed description and disclaimer should be read before model outputs are used.

(Donal Daly, 2019)

- A user-guide for the hydro-tools model is provided below:
  [Monitoring & Assessment: Freshwater & Marine Publications | Environmental Protection Agency (epa.ie)]
- The model itself can be accessed and used via the EPA Maps website (Link below)
  https://gis.epa.ie/EPAMaps/Water

The hydro-tools website output (Figure 7) is useful is you are compiling a table of flows or if you are using those flows in load reduction calculations. If you are carrying out a mapping exercise where, for example, you are mapping the P or N load per unit area for a waterbody sub basin, then you will need to use the hydro-tools in a way that is compatible with QGIS. As with the FSU portal, the catchment areas from the hydro-tools model are available as .SHP files.

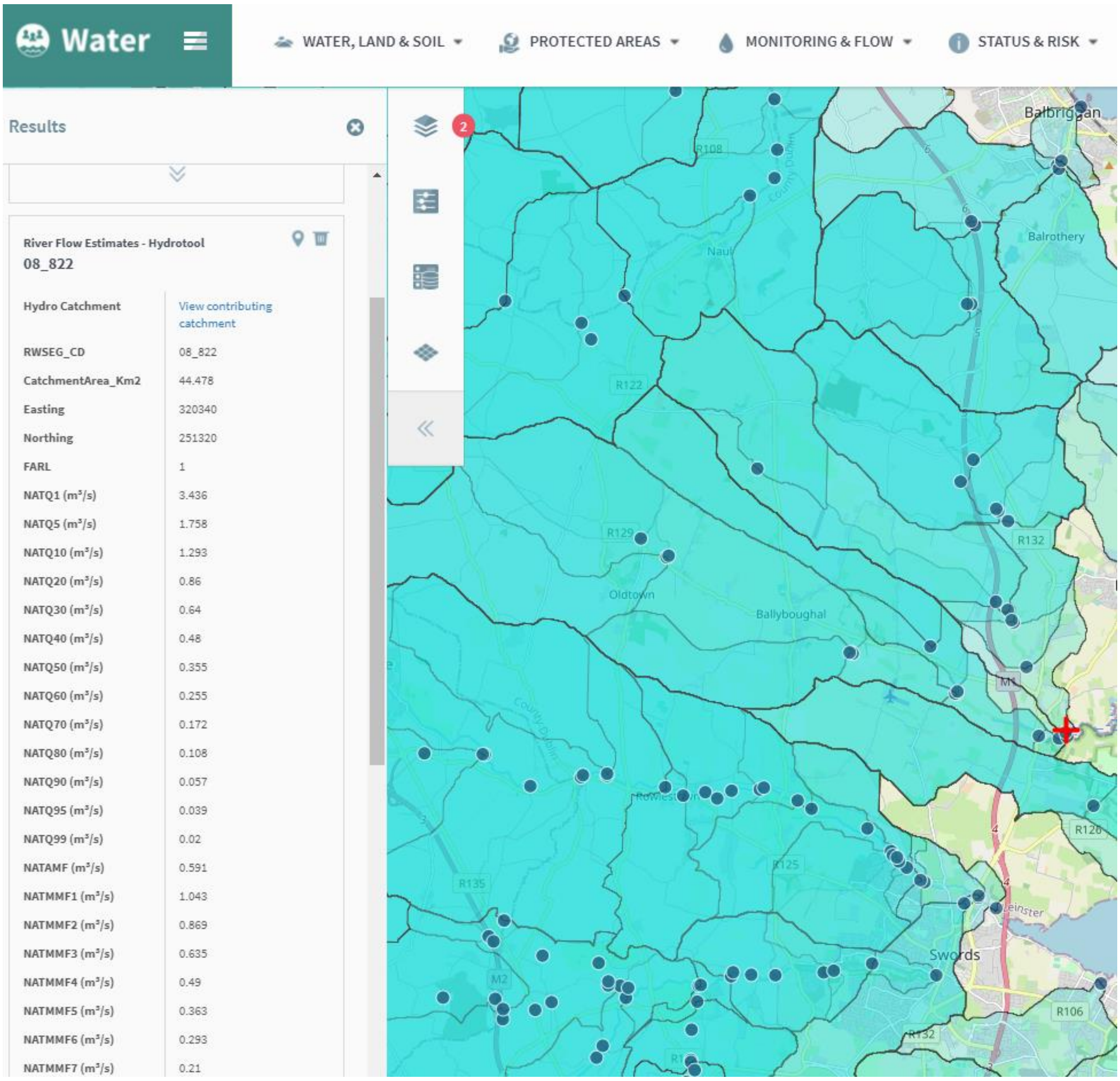


Figure 7: Example of EPA hydro-tools output.

10.2.6 Calculating flow data (Rainfall Area Method).

There are a number of ways to estimate streamflow using the rainfall-area method. The method assumes that streamflow increases linearly with an increase in catchment area and an increase in effective rainfall. In addition, the method assumes a closed system, e.g., that all rainfall which falls within the catchment (minus evapotranspiration) ends up in the river. The method is perhaps the most coarse method outlined in this document and should only be used in the connection with “back of envelope” calculations. The method offers the following advantages:

1) It is quick and easy.
2) In contrast to Hydro-tools, you can estimate monthly streamflows, which vary according to effective rainfall at a given location.

Getting the catchment area

For an EPA waterbody, the catchment areas are readily available. If applying the approach to a tributary or defined subcatchment on the main channel, you can use any of the methods highlighted in Section 2.4.1. The FSU portal (automatic catchment generation tool) is very useful for this purpose.

Getting the rainfall data

Historical and current rainfall data are available at the below link. Here you can search through the map and see what rainfall station is closest to (or in) your catchment and download the data as a CSV. The quality of the data will depend on where you are, with bigger stations collecting more meteorological parameters.

https://www.met.ie/climate/available-data/historical-data

Ideally, the rainfall-area method should use calculated effective rainfall.

- Effective rainfall (R_{eff}) = the proportion of rainfall that either gets converted to run-off or that recharges to groundwater.

Often, however, only total rainfall is collected. As such, there will be two scenarios when carrying out the approach:

Scenario 1) You have a suite of analytes, i.e. Total Rainfall, Evapotranspiration & Soil Moisture Deficit (SMD).

If you have this data, you can calculate effective rainfall with the following Eq.

- **Effective rainfall (R_{eff})** = Total Rainfall – Evapotranspiration– SMD

Do this in daily time steps and add up the sum of daily R_{eff} values for whatever year you are looking at.

Scenario 2) More often than not (particularly in more rural settings) you will only be able to download total rainfall data.

In this scenario, you can assume that the proportion of rainfall that gets converted to run-off or recharges to groundwater is 50% of the total rainfall, possibly 60% in more western, wet catchments.

In this scenario, therefore:

- **Effective rainfall (R_{eff})** = Total Rainfall x 0.5 (or 0.6 in the West)

Example calculation

In Section 2.4.1 (Figure 5) the Made-up river catchment was used to show the upscaling of hydrometric flows. Using the same catchment scenario here, the rainfall area method is applied. It is assumed that a rainfall station was located close to the catchment and that only total rainfall was collected (no SMD or evapotranspiration data available).

- Total catchment area = 42.5km^2
- Total rainfall = 800mm
- Estimated effective rainfall (R_{eff}) = 400mm (i.e. 800mm x 0.5)

- River flow (Q) = catchment area (42,500,000 m^2) x effective rainfall (0.4m) = 17,000,000m^3/year

The key thing to note when you are doing this calculation is that you use consistent units. I have converted Km^2 to m^2 (i.e. 1,000,000 m^2 in a Km^2) and also converted mm to m (1000mm in a m).

Therefore:
The annual average flow at the EPA monitoring point for 2019 is **17,000,000m^3/year**. There are 365 days in a year, so that is **46,575m^3/day**. There are 86,400 seconds in a day, so that's **0.54m^3/sec.**

- Finally, convert m^3 to litres (1000 litres in a m^3), so your average annual daily flow is **54.4 litres/sec.**

A cheat…
In the above example, it was shown how calculate effective rainfall & convert between units to arrive at your average annual flow in litres/sec. Understanding these units and using correct conversations is important, but there is a quick cheat you can use. The equation below will do the conversions for you, but just be careful with it as it works only for a catchment area expressed in Km^2 and a rainfall expressed as **total** rainfall in mm/year. The equation is:

- **Flow** (litre/s) = **A x R x 0.5 x 0.032** where:
  A = catchment area of the monitoring point (km^2)
  R = Total annual rainfall (mm)
  0.5 = factor converting total rainfall to effective rainfall
  0.032 = conversion factor to litre/sec

So let's repeat the calculation from the previous page where:

- Total catchment area = 42.5km^2
- Total rainfall = 800mm

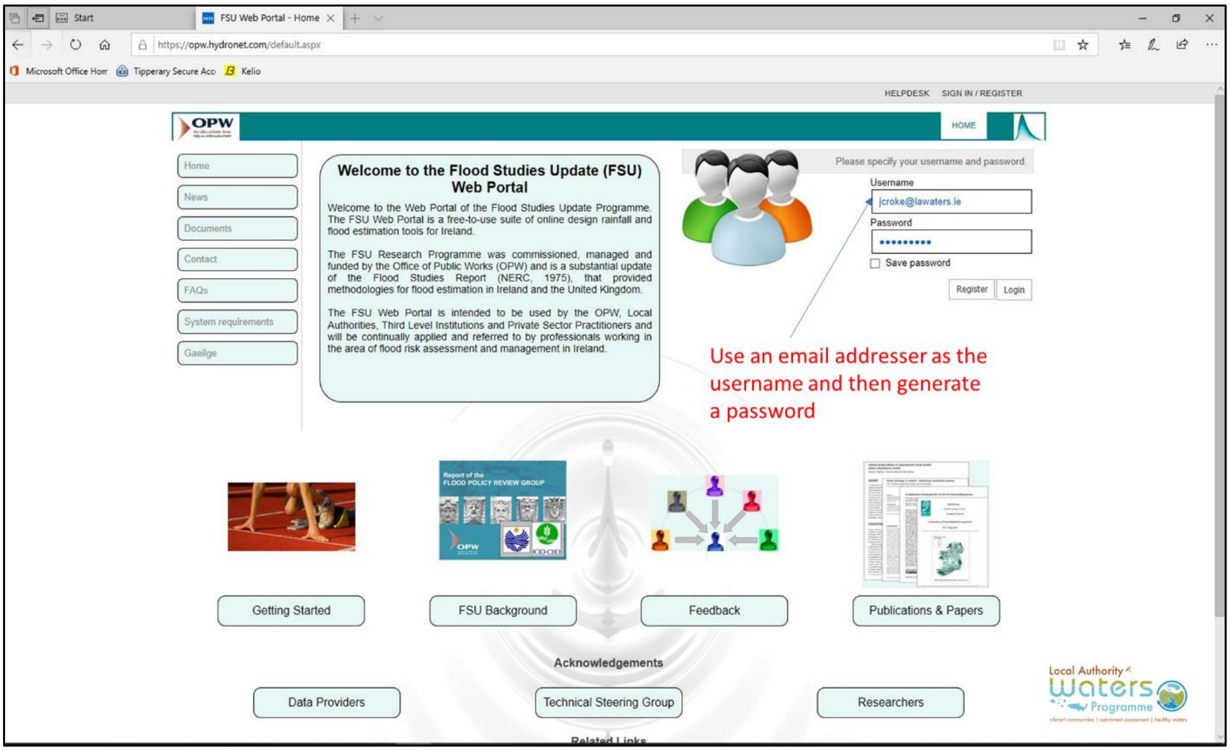
  Flow (litre/s) = A x R x 0.5 x 0.032
  Flow (litre/s) = 42.5 x 800 x 0.5 x 0.032
Flow = 54.4 litres/sec

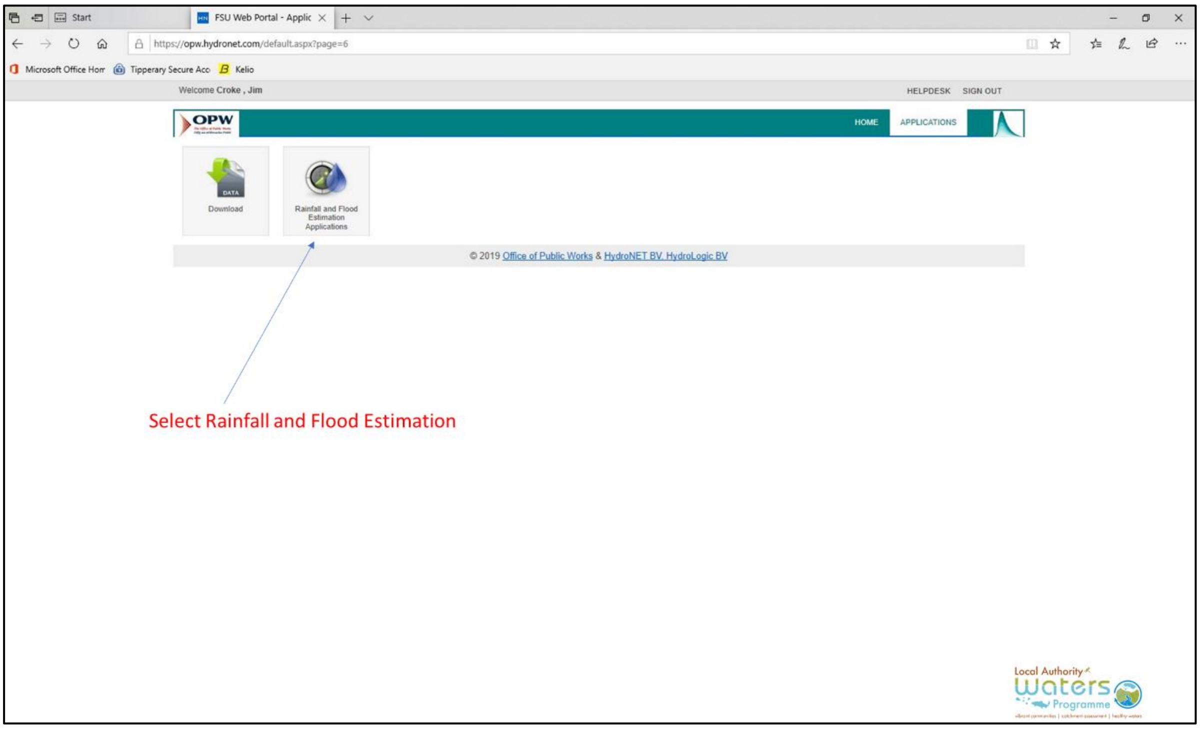
10.3 The FSU Portal

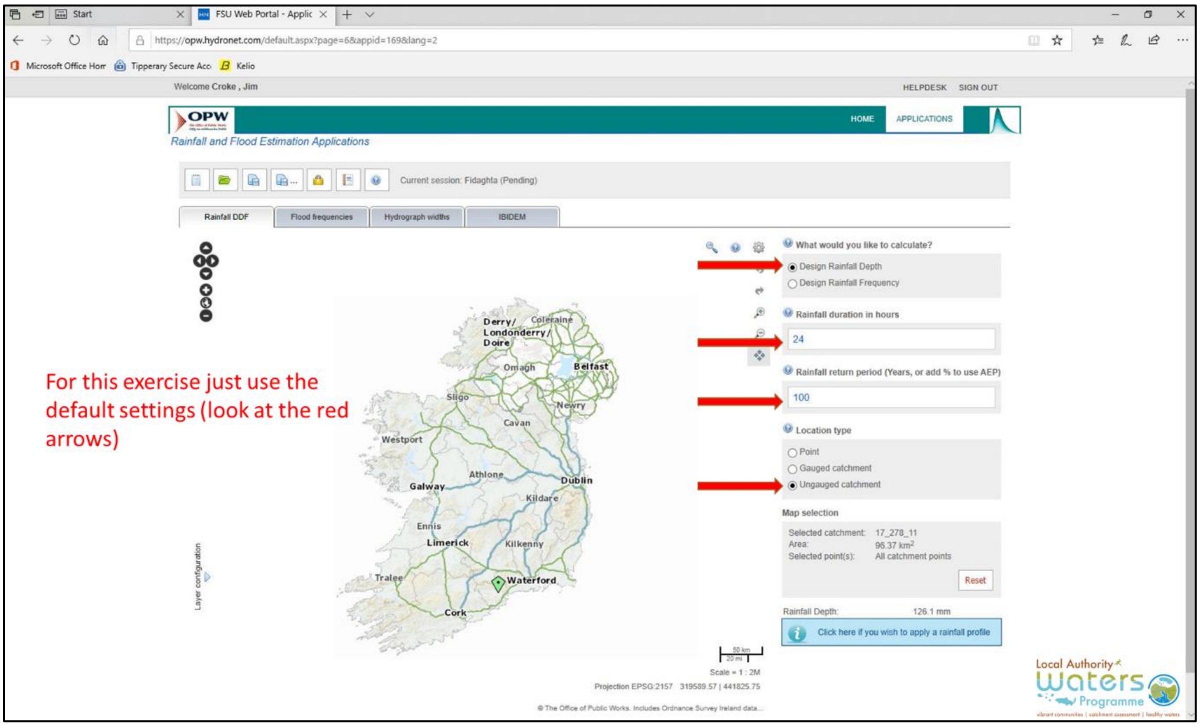
OPW FSU Portal

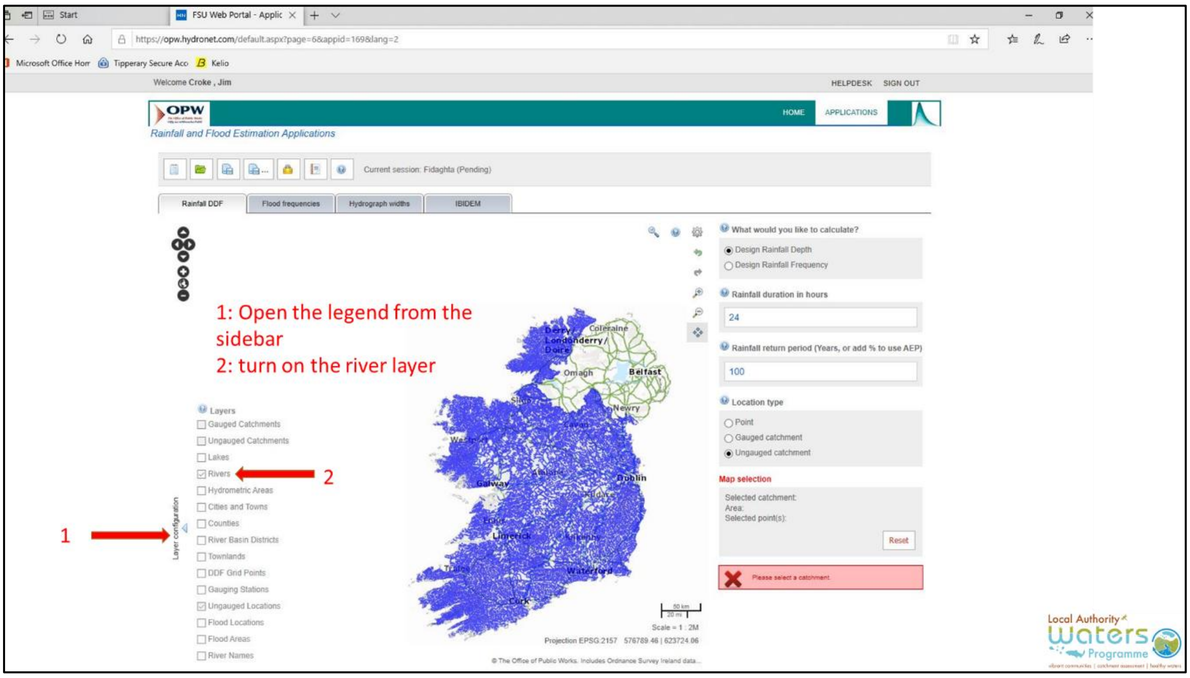
- Use to get the area of a specific location on a river or stream when working out load concentration
- Can be used to identify an catchment area of a overland flow point source
- Can be used to highlight an area of interest to ASSAP

Go to:
https://opw.hydronet.com/

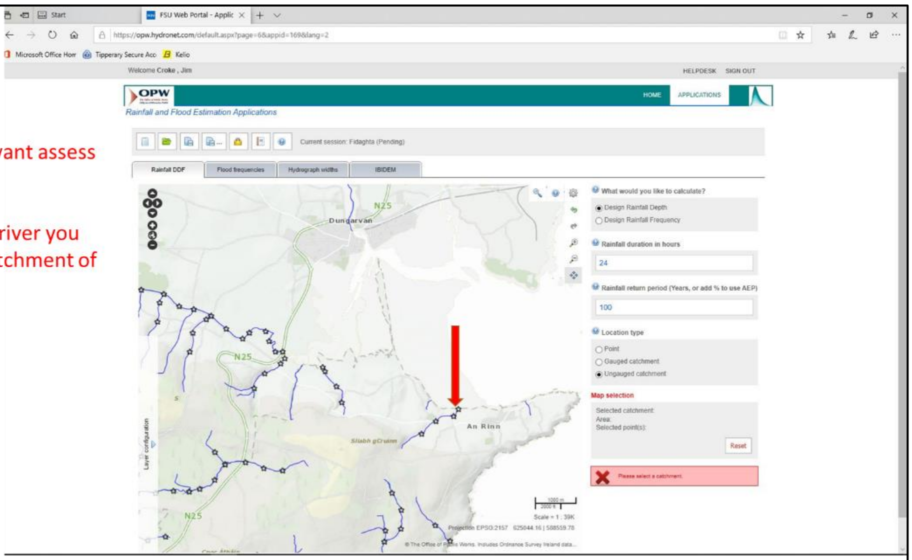

FSU Web Portal - Home
https://opw.hydronet.com/default.aspx
HELPDESK SIGN IN / REGISTER
HOME
Home
News
Documents
Contact
FAQs
System requirements
Gaeilge
Welcome to the Flood Studies Update (FSU) Web Portal
Welcome to the Web Portal of the Flood Studies Update Programme. The FSU Web Portal is a free-to-use suite of online design rainfall and flood estimation tools for Ireland.
The FSU Research Programme was commissioned, managed and funded by the Office of Public Works (OPW) and is a substantial update of the Flood Studies Report (NERC, 1975), that provided methodologies for flood estimation in Ireland and the United Kingdom.
The FSU Web Portal is intended to be used by the OPW, Local Authorities, Third Level Institutions and Private Sector Practitioners and will be continually applied and referred to by professionals working in the area of flood risk assessment and management in Ireland.
Please specify your username and password.
Username
jcroke@lawaters.ie
Password
Save password
Register
Login
Use an email addresser as the username and then generate a password
Getting Started
FSU Background
Feedback
Publications & Papers
Acknowledgements
Data Providers
Technical Steering Group
Researchers
Local Authority Waters Programme


FSU Web Portal - Applic
https://opw.hydronet.com/default.aspx?page=6
Welcome Croke , Jim
HELPDESK SIGN OUT
HOME
APPLICATIONS
Download
Rainfall and Flood Estimation Applications
© 2019 Office of Public Works & HydroNET BV, HydroLogic BV
Select Rainfall and Flood Estimation
Local Authority Waters Programme


Rainfall and Flood Estimation Applications
Current session: Fidaghta (Pending)
Rainfall DDF
Flood frequencies
Hydrograph widths
IBIDEM
What would you like to calculate?
Design Rainfall Depth
Design Rainfall Frequency
Rainfall duration in hours
24
Rainfall return period (Years, or add % to use AEP)
100
Location type
Point
Gauged catchment
Ungauged catchment
Map selection
Selected catchment: 17_278_11
Area: 96.37 km²
Selected point(s): All catchment points
Reset
Rainfall Depth: 126.1 mm
Click here if you wish to apply a rainfall profile
For this exercise just use the default settings (look at the red arrows)


Rainfall and Flood Estimation Applications
Current session: Fidaghta (Pending)
1: Open the legend from the sidebar
2: turn on the river layer
Layers
Gauged Catchments
Ungauged Catchments
Lakes
Rivers
Hydrometric Areas
Cities and Towns
Counties
River Basin Districts
Townlands
DDF Grid Points
Gauging Stations
Ungauged Locations
Flood Locations
Flood Areas
River Names
1
2
What would you like to calculate?
Design Rainfall Depth
Design Rainfall Frequency
Rainfall duration in hours
24
Rainfall return period (Years, or add % to use AEP)
100
Location type
Point
Gauged catchment
Ungauged catchment
Map selection
Selected catchment:
Area:
Selected point(s):
Reset
Please select a catchment.

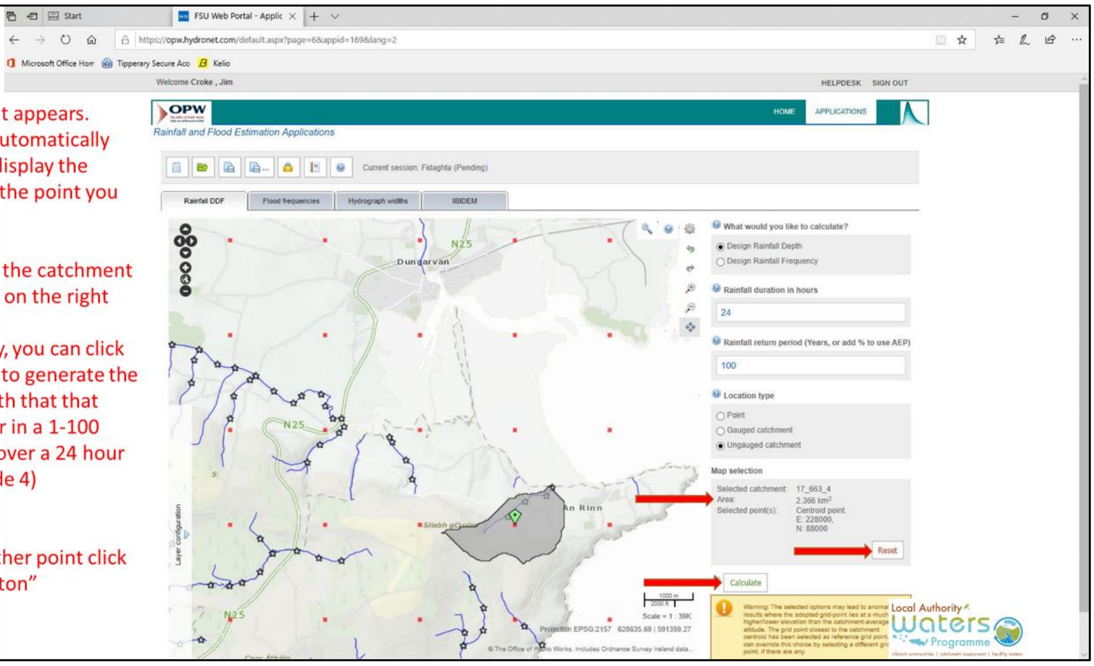
- Zoom into the area you want assess
- Click on the point on the river you want to get the area / Catchment of



Ok, This is what appears. The program automatically generate and display the catchment for the point you have chosen

- The area of the catchment is displayed on the right
- Additionally, you can click "Calculate" to generate the rainfall depth that that would occur in a 1-100 year event over a 24 hour period (Slide 4)

To look at another point click the Reset "button"



11 Appendix B: Electrical Conductivity – A useful tool for investigating catchment hydrology.

As environmental hydrology continues to grow in importance, both researchers and practitioners remain on the look-out for investigative techniques to help better understand where aquatic pollutants come from and how they reach water courses. Despite being routinely employed in some disciplines, specific electrical conductance (SEC) remains a relatively underutilised tool for Irish hydrological investigations. This is unfortunate, as the method has been shown to provide a rapid and inexpensive, yet reliable means of measuring water quality in the field, provided certain constraints are taken into consideration. The following short article is the first of two presented in the Catchments Newsletter that examines the utility of SEC for Irish hydrological studies.

Before undertaking SEC surveys, certain technical matters need to be considered to ensure that maximum benefit can be obtained from data collected. Readings are typically taken in the field using a handheld electrical conductivity meter, of which there are many brands on the market of contrasting quality and reliability. In general, the maxim “you get what you pay for” applies, with those models at the upper end of the price range typically proving more resistant to instrument drift. However, regardless of what meter is employed, routine calibration is essential. This should typically be done at least once a day, using standards having SECs approaching those anticipated in a survey area; it is generally considered good practice to calibrate immediately before and immediately after a survey each day to ensure instrument reliability.

Once the above precautions are considered, measurements in the field can provide a valuable insight into hydrological processes, particularly when data are collected in a catchment under contrasting hydrological regimes and/or at different times of the year. However, as electrical conductivity is temperature dependent, variations in how warm (or cold) different water samples need to be accounted for; this is achieved by standardising all measurements to 25 degrees C to give Specific Electrical Conductance (SEC). Note that not all models of conductivity meter provide an SEC readout, under these circumstances temperature must be recorded and corrections to yield SEC retrospectively applied. Indeed, even where SEC is provided, it is generally considered good practice to measure temperature, as it can provide valuable supplemental information about hydrological processes, such as the location of upwelling groundwater.

In the natural environment the SEC of water can vary enormously, from values around 5 microsiemens per cm (μS/cm) encountered in some rainwater samples, to levels one million times higher in saline waters. In unpolluted freshwater systems, SEC reflects the presence of substances present in the soils, subsoils and bedrock that water encounters along hydrological flow paths which form ions when dissolved. These can vary dramatically from one geological setting to another. For geological units typically encountered in Ireland, SECs can range from 10s of μS/cm in water samples collected from poorly decomposed raised bog peats to values over an order of magnitude higher in samples collected from units such as calcareous subsoils and carbonate bedrock. (Natural SECs above 1000μS/cm are rare in

Box and whisker plots contained in Figure 1 summarise the SEC of bedrock groundwater samples contained in the EPA’s Groundwater Quality Monitoring Database. The plots provide an idea of anticipated ranges for each aquifer type and demonstrate more consistent median SECs in limestone aquifers, compared to non-carbonate and mixed aquifer types. The slightly lower median SEC and greater range of variation observed in non-carbonate aquifers partially reflects the influence of geochemistry. These aquifers are typically less reactive than limestones, giving lower SECs. However, their signature may be overprinted by carbonates present in the overburden, which then dominate ionic content in underlying aquifers, particularly in units with short residence times. In all aquifer types the range of variation remains relatively high. Given the level of variation observed, direct measurements of groundwater SEC in a catchment should be sought out to build confidence in interpreting catchment-specific data and the role of different hydrological flow paths

At the catchment scale, where significant geochemical differences exist along various hydrological flow paths, SEC measurements can act as a useful screening tool for constraining potential processes. Mapping the results of these measurements across a catchment allows us to examine spatial variations in water quality and attribute responses observed to processes operating within subcatchments. Alternatively, use of automated SEC loggers permits large numbers of measurements to be collected in time at fixed points and thus provide a means of characterising (integrated) temporal variations in water quality (Figure 2).

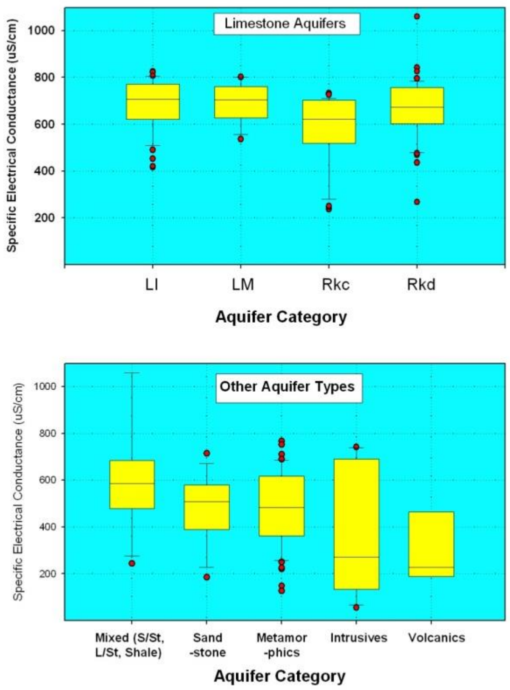


***Figure** 1: Box and Whisker plot of median specific electrical conductances for major Irish bedrock types, analysed as part of the EPA's groundwater monitoring programme. (Above) Limestone aquifers, (Below) Non-carbonate and mixed aquifer types. (Data provided by A. Mannix, EPA)*

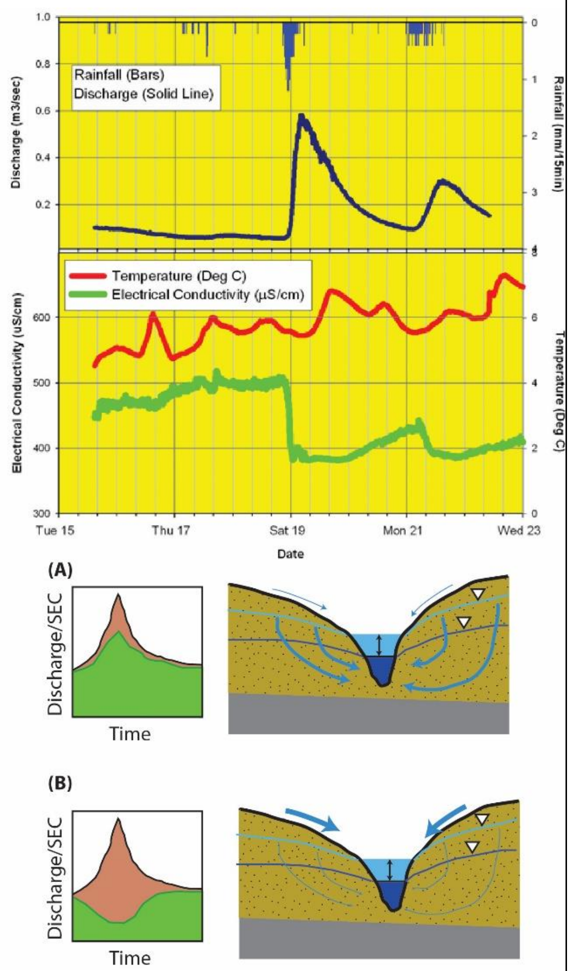


***Figure 2:** (Above) Multiple parameter plot illustrating the change in discharge, water temperature and SEC observed in river water at the outlet of the Glen Burn Test Catchment, Co. Down –February 2011. SEC helps discriminate between possible hydrological pathways. (Below) In Example (A) a*

SEC can also prove useful in detecting pollution, particularly where high concentrations of ions are present in source effluent, examples of which include landfill leachate, septic tank effluent and some agricultural wastes. In many cases the conductivities of these liquids prove significantly greater than background levels, thus permitting SEC to be employed as a screening tool for targeting samples for laboratory analyses. At the same time, examining trends in SEC levels along water courses allows us to identify potential sources of surface water pollution and the relative contributions they make to total pollutant load (See Lower SEC stream (400 μS/cm) receiving sustained inputs of 700μS/cm water (1m^3/sec/100m).

A. Input of 700μS/cm water (and doubling of discharge) between 900m and 100mm downstream.
B. Response observed with an equivalent increase in SEC but with a flow increase of 0.1m^3/sec over the same interval; the spike in the data (not simulated) reflects incomplete mixing of waters.

While measuring SEC can prove a very valuable investigative tool, it is essential that data be interpreted while considering catchment land use and physical setting. What's more, there can often be considerable temptation to relate SEC to the concentration of specific pollutant concentrations. Although this may be appropriate, one needs to remember that not all ions (, even at equivalent concentrations,) will generate the same SEC response. Consequently, SEC should be used, and compared to the results of laboratory-based analyses to establish links (if any) with pollutant levels. As a corollary to this point, samples that do not have SECs differing significantly from pristine waters may still be polluted since many pollutants are not ionic and thus do not contribute to measured SEC responses. Furthermore, some pollutants, although ionic, may impact water quality at concentrations below levels that permit them to be confidently measured using field SEC meters. Finally, when interpreting results remember that profiling provides a snapshot of conditions and that water quality varies depending on hydrological processes operating at the time of measurement.

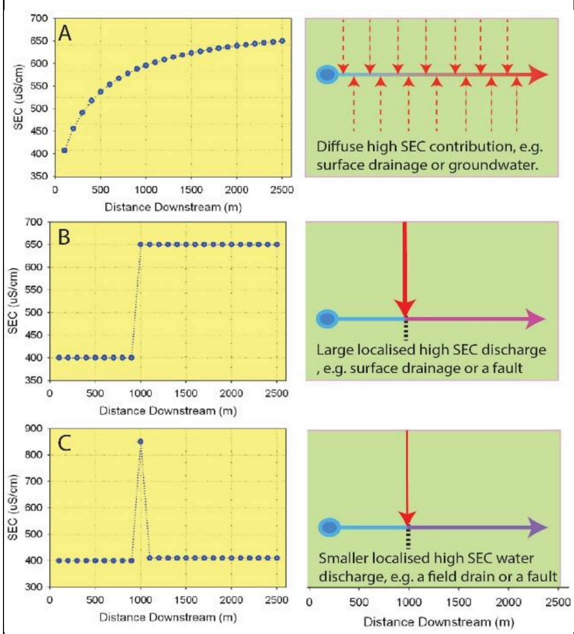


Figure 3: *Modelled examples of typical water quality profiles along a river reflecting responses to inputs of elevated SEC water under contrasting physical settings (right).*

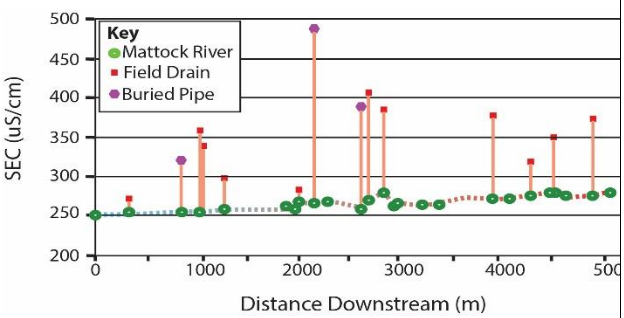


Figure 4: *Specific Electrical Conductance profile measured along the course of the Mattock River (Co. Louth/Co. Meath), April 2012. The gradual increase in the SEC of river water reflects minor contributions of elevated SEC water discharging from numerous field drains and buried pipes discharging to the Mattock along its course. (Data P. Rafferty, DkIT)*

Despite these limitations, SEC can prove a very useful investigative tool for environmental hydrologists. Maximum benefit can be obtained by combining its use with other routinely measured parameters, including with the results of laboratory water quality analyses, and with physical hydrological data. Moreover, repeated measurements of SEC in the same catchment, particularly during periods of contrasting hydrological conditions, build confidence in interpreting survey results. Although still relatively underutilised in Ireland, continuous monitoring of SEC with discharge during the recently completed EPA-funded Pathways Project demonstrated the value of the parameter for distinguishing between potential hydrological delivery mechanisms. SEC surveying deserves further consideration as an investigative technique in the Environmental Hydrologists tool kit. Experience to date across Ireland suggest that it can act as a useful method in helping identify pollution sources and characterising the pathways by pollutants can reach surface water receptors. This in turn can assist decision makers on taking suitable courses of action to maintain environmental quality.

Ray Flynn (Queen's University Belfast) and Jenny Deakin (EPA Catchments Unit)

12 Appendix C: Catchment Walk Fieldsheet

Appendix C Catchment Walk Field Sheet

Date:	**Waterbody Type:**			**Assessors:**		
Time:	**Waterbody Code:**					
Recent Rain:	**Waterbody Name:**					
Site ID.						
Grid Coordinates						
EPA Station Code (If applicable)						
Physico-chemical Parameters	**DO (% and mg/l)**					
	Temp (^{o}C) (use DO meter reading)					
	Cond (µs/cm)					
	pH					
	TDS (ppm)					
	Water colour					
Hydro-morphological/ Physical characteristics	**Gradient**					
	Channel bed substrate (%)	BE / SA	BO / SI	CO / CL	GP / PE	GG / AR
		NV				
	Channel bed substrate (natural setting)					
	Siltation (Level, Type)					
	Bank					
	Shading (Low, Moderate, High)					
	Risk of nutrient/sediment input (buffer)					
	Riparian	**LB:**		**RB:**		
Biological Assessment	**Wet Width/depth**	**Width (m):**		**Depth (m)**		
	Velocity (m/sec) | Flow (m^3/sec)					
	Habitat					
	Assessment Outcome					
Landscape features	**Geology/Hydrogeology**					
	Vegetation	**LB:**		**RB:**		
	Surrounding Drainage Density (H,M,L)					
Hydro-morphological pressures	**Channel modification**					
	Channel maintenance					
	Bank modification					
	Level of damage to the bank (livestock/ vehicular access)					
	Drains					
	Barriers					
Invasive Species	**Invasive Species**					
	From and to (grid co-ordinates)					
Biodiversity Observations						
Other	**Thermal Imaging Code**					
	N strips					
	P strips					
	Water Sample ID.					
	Level (m)					

Comments:
Site sketch
Other Observations:

Hydromorphology Lookup	
Gradient	H, High (e.g. >2%)
	M, Moderate (e.g. 0.3-2%)
	L, low (e.g. <0.3%)
Channel bed substrate (record %)	BE, Bedrock
	BO, Boulder (> 25 cm) - Larger than a soccer ball
	CO, Cobble (6.4 - 25 cm) - Smaller than a soccer ball, but larger than a tennis ball
	GP, Gravel - pebble (4 mm - 6.4 cm) - Smaller than a tennis ball but larger than match heads
	GG, Gravel - granule (2-4 mm) - size of a match head to half of the match head
	SA, Sand (63 µm - 2 mm) - Smaller than a match head, but larger than flour
	SI, Silt (4 - 63 µm) - Smaller than flour (not visible to naked eye)
	CL, Clay (< 4 µm) - Not visible to the naked eye
	PE, Peat
	AR, Artificial
	NV, Not visible
Channel substrate correspond to natural setting?	Y, Yes
	N, No
	NV, Not visible
Siltation level - record % surface cover	XE, X - Extensive (100%)
	E, Extensive (>70%)
	H, High (40-70%)
	M, Moderate (20-40%)
	L, Low (<20%)
	Dx, Depth of fine sediment (x, cm)
	A, Absent
Siltation type	S, Surface
	I, Interstitial
	CW, Covers the entire channel width
	BM, Along bank margins
	SA, Sand
	SI, Silt
	CL, Clay
	PE, Peat
	DP, Deposition - pools
	DR, Deposition - riffle, glyde, run
	DO, Deposition - obstractions
	AS, Anoxic sediment
	SIx, Shuffle Index x = 1, 2, 3, 4, 5 (recorded for High Status), where **Score 1** = No or small plume; **Score 2** = Plume briefly reduces visibility at tile; **Score 3** = Plume partially obscures tile but quickly clears; **Score 4** = Plume partially to fully obscures tile but slowly clears; **Score 5** = Plume fully obscures tile and persists even shuffling ceases
Bank	NP, Natural profile

	MP, Modified profile
	BC, Bank collapse
	BE, Berms along banks
	GE, Gradual erosion (particularly at meanders)
	AE, Accelerated erosion
	BV, Bank vegetated
	UV, Bank unvegetated
Sediment input (elaborate in notes if artificial)	A, Artificial
	B, Bank
	T, Tributary
	NK, Not known
Riparian	F, Fence present Bx, Buffer present (x, distance in metres to bank top) G, Grass (circle if dominant) S, Scrub/Shrub (circle if dominant, * if continuous) Td, Deciduous trees (circle if dominant, * if continuous) Tc, Coniferous trees (circle if dominant, * if continuous) I, Invasive
Shading	L- Low, M- Moderate, H - High
Risk of nutrient/sediment input (buffers) *	High - Absence of functional buffer zones from Watercourses/ drains. Bank Erosion, slumping and poaching likely to be observed.
	Moderate - Buffer zones are absent or have been breached and there are pathways by which nutrients/ sediment can enter watercourses and drains visible at some locations.
	Low - Pathways by which nutrients/ sediment can enter watercourses are present but only minor pinch-point or pathways to natural watercourses impeded.
	None - No visible pathways by which nutrients/sediment can enter watercourses and drains. No visible bank erosion, trampling or poaching.
Channel modification	CH, Channelisation/Drainage
	AD, Arterial Drainage scheme
	DD, Drainage District scheme
	OD, Overdeepened
	OW, Overwidened
	ST, Straightened
	N, Narrowed
	RS, Resectioned
Channel maintenance	Y-V, Yes based on visual assessment
	Y-D, Yes based on channel maintenance database
	EX, Exposed bank
	Rs, removal of bed sediment
	Rav, Removal of aquatic vegetation
	Rbv, Removal of bank vegetation
	Rrv, Removal of riparian vegetation
	R, Recent (<1 year)

	P, Previously (1-5 years)
	H, Historically (>5 years)
Bank modification	CA, Cattle access
	P, Poaching
	EM, Embankment
	RR, Riprap
	GB, Gabions
	BO, Boulder protection
	Wc, Wall (concrete)
	Wb, Wall (brick/stone)
	WP, Wood piling
	BIO, Bio-engineering material
Level of damage to the bank (livestock/ vehicular access)*	High - Evidence of trampling and dunging in river. Presence of eroded banks and disturbed waterways. Direct pathway to natural watercourses.
	Moderate - Evidence of some poaching and trampling. Direct pathway to natural watercourses.
	Low - Access to drains evident but pathway to natural watercourses impeded.
	None - No evidence of damage to watercourses as a result of livestock access.
Drains*	RC, Recently Cleared - Drains have been recently cleared or created flowing directly into natural watercourses.
	FF, Free flowing - Drains are un-vegetated and/or free flowing and follow direct pathway to natural watercourses.
	RF, Reduced-flow - Drains are partly blocked and vegetated and/or pathway to watercourse is impeded.
	NF, Non-functional; - All drains are fully blocked and/or vegetated.
Barriers	Bax, Bridge with arches (x, number of arches)
	Bapx, Bridge with an apron (x, height of apron lip)
	D, Dam
	Wx, Weir (x, height of weir)
	FP, Fish pass measure
	S, Sluice
	F, Ford
	Fa, Ford with artificial material
	CV, Culvert

* Based on the ‘Whole Farm Assessment’ scoring system, Pearl Mussel Project.

LANDSCAPE FEATURES	
Geological	**Lookup Code**
Soil - well drained	SWD
Soil - poorly drained (gley)	SPD
Soil - peat (high OM)	SPT
Iron pan	IP
Made ground	MG
Subsoil High permeability (sand/gravel)	SSHP
Subsoil Moderate permeability (silty)	SSMP
Subsoil Low permeability (clayey subsoil, clay, peat)	SSLP
Mottled soil/subsoil	MS/SS
Preferential flowpaths	PFP
Exposed bedrock - weakly fractured	EBWF
Exposed bedrock - highly fractured	EBHF
Exposed bedrock - solution conduits	EBSC
Vegetation Indicators of Natural Drainage	
Indicator Species of Poor Drainage	ISPD
Indicator Species of Good Drainage	ISGD
Indicator Groundwater Plants	IGP
Hydrogeological	
Springs, seeps and upwellings	SpSU
Karst spring	PSp
Precipitated calcium carbonate (Tufa)	CC
Calcification	Cl
Iron staining	IS
Gaining flows in stream from GW (stream -gw interaction)	G-SW-GW
Losing flow in stream to GW (stream - gw interaction)	L-SW-GW
Loss of stream to swallow hole	LSSH
Enclosed depression (karst subsidence feature)	K-ED
Swallow hole/sinkhole	K-Sh
Turlough	TH
Dry valley	KDV
Limestone pavement	KLP
Conduits/caves	KCC
Biodiversity	
Otter	MOR
Mammal- Other	MO
Birds - Dipper	BDR
Birds - Kingfisher	BKR
Bird - Sandmartin	BSN
Freshwater Pearl Mussel	FWPM

INVASIVE SPECIES	
Invasive Species - Terrestrial	**Lookup Code**
Giant hogweed	GH
Japanese knotweed	JK
Giant knotweed	GK
Himalayan balsam	HB
Himalayan knotweed	HK
Giant Rhubarb (Gunnera)	GR
Winter heliotrope	WH
Invasive Species - Aquatic	
Asian clam	AC
Creeping water primrose	CWP
Curly waterweed	CW
Floating pennywort	FP
Killer shrimp	KS
New Zealand flatworm	NWF
New Zealand Pigmyweed	NWP
Nuttall's waterweed	NW
Parrot's feather	PF
Signal crayfish	SC
Slipper limpet	SL
Water fern	WF
Zebra mussel	ZM

IMPACTS	Lookup Code
Nutrient pollution	NP
Organic pollution	OP
Chemical pollution	CP
Saline pollution/intrusion	SP
Acidification	AD
Elevated temperatures	ET
Altered habitats due to hydrological changes	AH
Altered habitats due to morphological changes (includes connectivity)	AM
Litter (an impact under the MSFD)	LR
Microbiological pollution	MP
Diminution of quality of associated surface waters for chemical / quantitative reasons	D
Damage to gw dependent terrestrial ecosystems for chemical/quantitative reasons	DP
Alterations in flow directions resulting in saltwater intrusion	ASI
Abstraction exceeds available GW resource (lowering water table)	ABLGW
Other Significant Impacts	OSP

13 Appendix D: Bioindicators Supporting Documentation

SMALL STREAM IMPACT SCORE (SSIS)

v1.1

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

*circle entry if single specimen

* tick box for selected taxon if 2+ generations observed

Site Name:________________________________

Date : ___________________________________

Time: ___________________________________

Habitat sampled: __________________________

Wet width (m):____________________________

Avg. sample depth (m):______________________

Coordinates

E______________________ **N**_________________________

%Substrate

Bedrock _____ Boulder______ Cobble______ Gravel_______

Sand _______Silt_______Clay________Marl______ Peat____

Shading

>75%

50-75%

25-50%

<25%

1: EPHEMEROPTERA	**Ab**	**RA***
Ecdyonurus ○ *A* ☐		
Heptagenia ○ *A* ☐		
Rhithrogena ○ *A* ☐		
Ephemera danica ○ *A* ☐		
Paraleptophlebia ○ *B*		
Ephemerellidae ○ *C*		
Caenis ○ *C*		
Other ________________		
Baetidae ○ *C (not SISS) Ab___ RA____*		
Total no. SSIS Ephemeroptera		
sum RA		
Index score A		

2: PLECOPTERA	**Ab**	**RA***
Perla ○ *A* ☐		
Dinocras ○ *A* ☐		
Isoperla ○ *A*		
Chloroperla ○ *A*		
Amphinemura ○ *A*		
Brachyptera ○ *A*		
Protonemura ○ *A*		
Leuctra ○ *B*		
Other ________________		
Total no. Plecoptera taxa		
sum RA		
Index score B		

3: Trichoptera	**Ab**	**RA***
Limnephilidae ○ B		
Sericostomatidae ○ B		
Glossosomatidae ○ B		
Lepidostomatidae ○ B		
Goeridae ○ B		
Hydropsychidae ○ C		
Polycentropodidae ○ C		
Rhyacophila ○ *C*		
Other ________________		
Total no. Trichoptera taxa		
sum RA		
Index score C		

4: G.Ol.D	**Ab**	**RA***
Radix balthica (G) ○ D		
Potamopygrus (G) ○ *C*		
Planorbis (G) ○ *C*		
Ancylus (G) ○ *C*		
Physa (G) ○ D		
Lumbriculus (OL) ○ ------		
Eiseniella (OL) ○ ------		
Tubificidae (OL) ○ E		
Simuliidae (D) ○ C		
Ceratopogonidae (D) ○ C		

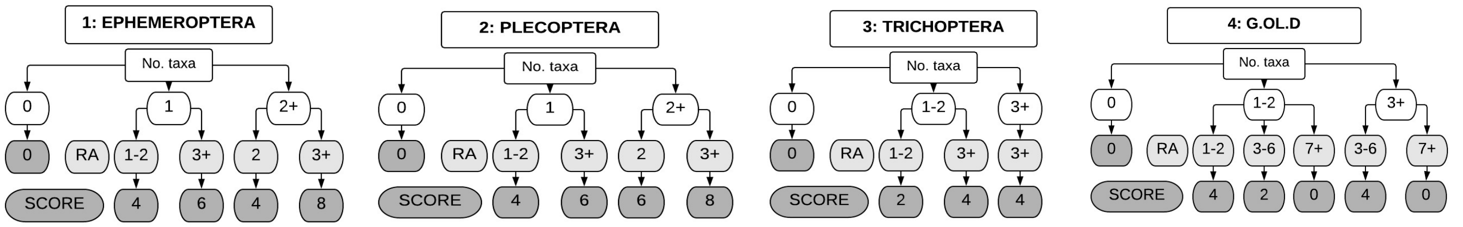
G.OL.D	**Ab**	**RA***
Dicranota (D) ○ *C*		
Tipulidae (D) ○ C		
Chironomidae (D) ○ C		
Chironomus (D) ○ *E*		
Other ________________		
Other ________________		
Other ________________		
Total no. G.Ol.D taxa		
sum RA		
Index score D		

OTHER TAXA (not SSIS)	**Ab**	**RA***
Gammarus ○ *C*		
Crangonyx ○ *D*		
Riffle beetle ○ C		
Leech ○ D		
Flatworm ○ C		
Odonata ○ B		
Crayfish ○ C		
Other ________________		
Other ________________		
Other ________________		

ASELLUS INDEX SCORE	
Asellus ○ *D* if absent tick box (score = 4)	
Asellus ○ *D* if few (1-20) tick box (score = 2)	
Asellus ○ *D* if common (> 20) tick box (score = 0)	
E: *Asellus* index score (4 or 2 or 0)	

Total Index Score (A+B+C+D+E)		
Average Index Score (Total IS / 5)		
SSI Score = (Average IS) x 2		
SAMPLE TAXON NUMBER		

> 7.25 Probably not significantly impacted		
> 6.5-7.25 Indeterminate. Evidence of impact		
< 6.5 Probably impacted		
INVERT. DENSITY (E / A / M / L / S)		



Macrophyte	Cover
absent?	

Macroalgae	Cover
Cladophora	
Vaucheria	
Bacterial tufts	
absent?	

Proportion of sample (inverts)	***EDNCFP***
Here indicate if Excessive, Common…	
Class A	
Class B	
Class C	
Class D	
Class E	

Channel vegetation % Cover : Excessive (>75%) - Dominant (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

Invert proportions : *Excessive (>75%) - Dominant (51-75%) - Numerous (21-50%) - Common (6-20%) - Few (1-5%) - Present (1-2 individuals)*

general comments:

Rapid assessment. Noted important Taxa in the comment box
Circle answers and use the results to follow the RA flow chart

Site name__________________	**Date**_____________	**Time** ________	**Coordinates**______________________________		
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

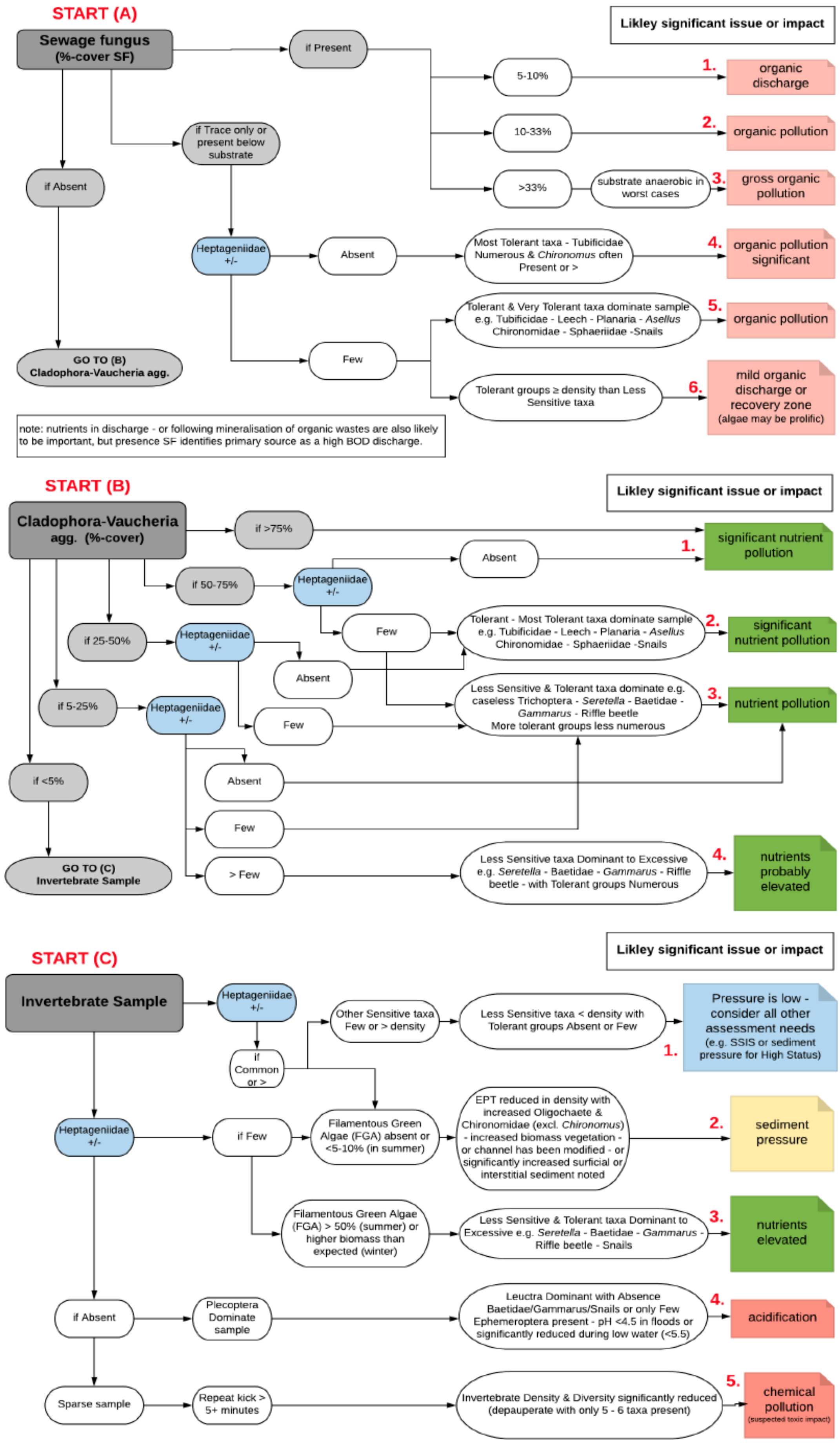
Site name__________________	**Date**_____________	**Time** ________	**Coordinates**______________________________		
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

Site name__________________	**Date**_____________	**Time** ________	**Coordinates**______________________________		
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

-This flowchart is intended to be used in conjunction with Rapid Assessment (RA) to quickly identify categories of significant impacts using the well-known response of key biological indicators.

-Start at (A) and follow arrows that best describe the observed situation, while recording the final result of the field assessment.

-If the situation is **not well described by the available options**, then the flowchart result should **not be used** and dominant biological indicators should be recorded or an SSIS may also be considered.



Briefing Note	Ecology Working Group Guidance Note No. 1
Topic	Interpreting the Biological Significance of SSIS Scores, Version 2
Prepared by	Steve Davis, Paul O'Callaghan, Cormac McConigley & Bernie White
1st issue Date	23rd May 2019
2nd issue Date	5th October 2021
Reviewed by	Bernie White, Catchments Manager
For Circulation to	LAWPRO Catchment Assessment Team

Introduction

The Small Stream Impact Score (SSIS) provides a methodology to help determine if a waterbody is ***Probably not significantly impacted, Indeterminate*** or ***Probably Impacted***. This level of assessment is based on an adaption of the Small Stream Risk Score (SSRS) with incorporation of further indicators (e.g. macrophytes, macroalgae) to support identification of significant pressures. (see Section 4.2.1 of **Volume 1 of Local Catchment Assessment Guidance Manual**).

It is important to note that the SSIS cannot be used to determine status. However, it is not appropriate to state that a river is at any status class as SSIS is not a status tool. The SSIS is an assessment of the probability of impact not status. It is important that we are clear in the language we use to describe our findings. Additionally, the score itself does not indicate the degree of impact i.e. an SSIS score of 12 does not necessarily mean that the waterbody is of better quality than one with a score of 8, it is merely that both are determined to be Probably not significantly impacted in both cases.

The Ecology Working Group first developed this guidance in 2019 to supplement the training provided in 2018 (Local Catchment Assessment Training Course) and aid in interpretation of macroinvertebrate communities observed during Local Catchment Assessment. Since 2019, the Ecology Working Group has been supporting catchment scientists, with additional training, in particular during the Summer of 2020 and 2021. This updated guidance on interpretation of SSIS findings, is building on the training delivered and lessons learnt during that process, plus supplements LCA Manual Vol. 4 Section 10.

Interpreting the Macroinvertebrate Community

A good source of information on the relative sensitivities of the different groups of macroinvertebrates to organic pollution is provided below, replicated from Toner et al. 2005. The table is based on the Q-value system used to support the determination of status for rivers. For LAWPRO, the most important information relates to the grouping of the invertebrates into Group A *Sensitive*, Group B *Less Sensitive*, Group C *Tolerant*, Group D *Very tolerant* and Group E *Most Tolerant*.

There are a few things to note in this table:

- Not all stoneflies and mayflies are equally sensitive to organic pollution even though they all score the same in the SSIS. For the stoneflies, they are all considered to be very sensitive except for *Leuctra* (Table 2). The flat-bodied mayflies (*Ecdyonurus, Rhithrogena* and *Heptagenia*) and *Ephemera danica* are the Group A sensitive mayfly taxa while all other mayflies are considered to be Group B less sensitive or Group C tolerant (Table 1 & 2). You will note that our updated SSIS fieldsheet now includes information beside each taxa to indicate which of the sensitivity groups it belongs to based on Toner et al, 2005.
- Although they do not score under SSIS, it is very important to note the presence and abundance of the Baetidae (Group B/C depending on specific species) as they are less sensitive

to organic pollution and can often dominate in somewhat polluted conditions. They are grazers (i.e. feed on algae) and enriched conditions lead to greater food availability, along with less competition from more sensitive taxa.

- Additionally, it is important to note the presence and abundance of the 'Other Taxa' as although they do not score under SSIS, taxa such as *Gammarus* (Group C) can often become abundant under polluted conditions.
- Though not a requirement of the SSIS the presence of at least one group A taxa (in "reasonable" numbers) is needed to indicate a site is *Probably not Significantly Impacted*. If none are present, then the site is highly likely to be impacted.
- Group C, D and E taxa should not be dominant in an unimpacted water body (Table 2). Therefore, if any of the GOLD taxa or other taxa in these Groups are dominant (or possibly abundant) coupled with an absence (or very low abundance) of Group A taxa then your site is Probably Impacted).

Table 1. SSIS Ephemeroptera. Those above the red line are sensitive (Group A) to organic pollution while those below the red line are less sensitive (Group B) or Tolerant (Group C).

1: EPHEMEROPTERA			Ab	RA*
Ecdyonurus	○ *A*	☐		
Heptagenia	○ *A*	☐		
Rhithrogena	○ *A*	☐		
Ephemera danica	○ *A*	☐		
Paraleptophlebia	○ *B*			
Ephemerellidae	○ *C*			
Caenis	○ *C*			
Other ________________				
Baetidae ○ *C (not SISS) Ab___ RA____*				

Diversity and balance in the macroinvertebrate assemblage & interpreting your SSIS Score

When interpreting a macroinvertebrate community, it is important to bear in mind that you need to consider the relative proportion of each group to the overall community rather than their absolute abundance. In unimpacted / pristine conditions (i.e. high status), the community will be a diverse balance of taxa from all sensitivity levels with no taxon unusually abundant. When the WFD environmental objective of good status is achieved, this balance is typically slightly off with lower abundances and/or diversity of sensitive taxa. It is worth recording all taxa found on the SSIS sheet (even if they do not score) as well as their approximate abundances at lower diversity is often a good indicator of more impacted conditions and very low diversity may even indicate toxic conditions (See guidance on Acute Toxicity here - LAWSAT - Documents\44.0 Catchment Science Templates and Guidance docs\44.8 Ecology docs).

SSIS deals in absolute abundances while Q-value deals in relative abundance. It is important to note the contribution of each taxon to the overall community when assessing impact.

For example:

Scenario 1 (Probably not significantly impacted)

- An overall abundance of 200+ invertebrates in a tray
- 20 of these are tubificid worms
- 20 are Baetidae
- But there are a number of sensitive taxa present in high numbers
- SSIS returns Probably not significantly impacted

Scenario 2 (Probably impacted)

- An overall abundance of 50 invertebrates in a tray
- 20 of these are Tubificid worms
- 20 are Baetidae
- Other ten invertebrates include a single specimen of Ephemerellidae, Caenis, Leuctra and remainder are caddisflies
- No Group A taxa present
- SSIS returns Probably not significantly impacted

The above scenarios both return “probably not significantly impacted” but the second is misleading and in fact is likely to be impacted due to the absence of Group A taxa and the dominance of less sensitive taxa. This highlights the need to examine the macroinvertebrate community thoroughly, rather than relying on the score alone and in particular to critically assess the relative abundance of each taxon in relation to their sensitivity to pollution. It is highly likely that other indicators such as macroalgae or sediment assessments will support this interpretation when several lines of evidence are reviewed together.

It is important to collect all specimens while sampling. For example, do not count caddisfly cases on stones. Wash the cases off the stones and count them in the tray. Many of the cases will probably be empty. A single specimen of any particular taxa can be ignored as they may have drifted from upstream. Taxa should only be counted towards the SSIS score if two or more individuals are present in the sample, though you should record their presences and indicate that there was a single specimen, the updated SSIS field sheet has a space where you can indicate abundance.

It is especially important to critically assess the macroinvertebrate communities when assessing SSIS samples in Blue Dot rivers. See SSIS in Blue Dot rivers guidance document for further information on how to interpret these samples (LAWSAT - Documents\44.0 Catchment Science Templates and Guidance docs\44.8 Ecology docs).

Table 2. Macroinvertebrate groups used under the Q-value system ranked by their sensitivity to organic pollution (Toner et al. 2005).

Macroinvertebrates grouped according to their sensitivity to organic pollution					
TAXA	**Group A**	**Group B**	**Group C**	**Group D**	**Group E**
	Sensitive	*Less Sensitive*	*Tolerant*	*Very Tolerant*	*Most Tolerant*
Plecoptera	All except *Leuctra* spp.	*Leuctra* spp.			
Ephemeroptera	Heptageniidae Siphlonuriidae *Ephemera danica*	Baetidae (excl. *Baetis rhodani*) Leptophlebidae	*Baetis rhodani* Caenidae Ephemerellidae		
Trichoptera		Cased spp.	Uncased spp.		
Odonata		All taxa			
Megaloptera				Sialidae	
Hemiptera		*Aphelocheirus aestivalis*	All except *A. aestivalis*		
Coleoptera			Coleoptera		
Diptera			Chironomidae (excl. *Chironomus* spp.) Simuliidae, Tipulidae		*Chironomus* spp. *Eristalis* sp.
Hydracarina			Hydracarina		
Crustacea			*Gammarus* spp. *Austropotamobius pallipes*	*Asellus* spp. *Crangonyx* spp.	
Gastropoda			Gastropoda (excl. *Lymnaea peregra* & *Physa* sp.)	*Lymnaea peregra* *Physa* sp.	
Lamellibranchiata	*Margaritifera margaritifera*		*Anodonta* spp.	Sphaeriidae	
Hirudinea			*Piscicola* sp.	All except *Piscicola* sp.	
Oligochaeta					Tubificidae
Platyhelminthes			All		

Table 3. Q-value table for use in eroding (i.e. riffle-glide) river stretches (Toner et al. 2005).

Biological Assessment of Water Quality in Eroding Reaches (Riffles & Glides) of Rivers and Streams*						
Biotic Indices (Q Values) and typical associated macroinvertebrate community structure. See overleaf for details of the Faunal Groups.						
Macroinvertebrate Faunal Groups**	**Q5**	**Q4**	**Q3-4**	**Q3**	**Q2**	**Q1**
Group A	At least 3 taxa well represented	At least 1 taxon in reasonable numbers	At least 1 taxon Few - Common	Absent	Absent	Absent
Group B	Few to Numerous	Few to Numerous	Few/Absent to Numerous	Few/Absent	Absent	Absent
Group C	Few	Common to Numerous *Baetis rhodani* often Abundant Others: never Excessive	Common to Excessive (usually Dominant or Excessive)	Dominant to Excessive	Few or Absent	Absent
Group D	Few or Absent	Few or Absent	Few/Absent to Common	Few/Absent to Common	Dominant to Excessive	Few or Absent
Group E	Few or Absent	Few or Absent	Few or Absent	Few or Absent	Few / Absent to Common	Dominant
Additional Qualifying Criteria						
***Cladophora* spp.** Abundance	Trace only or None	Moderate growths (if present)	May be Abundant to Excessive growths	May be Excessive growths	Few or Absent	None
Macrophytes (Typical abundance)	Normal growths or absent	Enhanced growths	May be Luxuriant growths	May be Excessive growths	Absent to Abundant	Present/Absent
Slime Growths (Sewage Fungus)	Never	Never	Trace or None	May be Abundant	May be Abundant	None
Dissolved Oxygen Saturation	Close to 100% at all times	80% - 120%	Fluctuates from < 80% to >120%	Very unstable. Potential fish-kills	Low (but > 20%)	Very low, sometimes zero
Substratum Siltation	None	May be light	May be light	May be considerable	Usually heavy	Usually very heavy and anaerobic

Note occurrence/abundance of groups in above table refers to some but not necessarily all of the constituents of the group. The Additional Qualifying Criteria apply in virtually all circumstances. Single specimens may be ignored. Seasonal and other relevant factors (i.e., drought, floods) must be taken into account.
* Macroinvertebrate criteria do not apply to rivers with mud, bedrock or sand substrata, very sluggish or torrential flow, head-water or high altitude streams and those affected by significant ground water input, excessive calcification, drainage, canalisation, culverting, marked shading etc.
** See Further Observations overleaf.

Other things of note

- The SSRS and SSIS were designed as risk assessment tools, and were not designed to provide a full ecological status assessment for macroinvertebrates such as can be obtained with the EU intercalibrated Q-Value system [1]. This caveat should be borne in mind at all times, including when concluding on your assessment findings in Step 5 Further Characterisation (Tier 3).
- Q-value and SSIS are designed to detect organic pollution. Macroinvertebrate sensitivities to other types of pollution can be very different, however Q-values have also been found to be statistically related to water quality measures such as BOD, ammonia, nitrate and phosphate. Similarly, Q-Value is linked to land use pressures in a statistical manner – urban cover, tillage and grassland cover within catchments are linked to Q-Value on a national basis (O'Donohue et al 2005[2]). Research has also shown that Q-Value is statistically linked to fish populations in Irish rivers – high Q-Values have fish populations comprised almost entirely of salmon and trout whereas heavily polluted rivers may have no fish or a small population of tolerant sticklebacks (Kelly et al., 2007)[3].
- Stoneflies are generally quite tolerant of acidity which can be particularly important in episodically acidic afforested areas (e.g. parts of Wicklow, or naturally acidic systems).
- Most macroinvertebrates are sensitive to deposited fine sediment. However, some are more sensitive than others. For example, Baetidae are particularly sensitive as they are unable to dig themselves out of thick layers of deposited sediment and generally would not be found in heavily sedimented areas. Chironomids and Oligochaeta like sediment and will often dominate in these conditions.
- High suspended sediment loads can have a particular effect on filter feeding organisms e.g. Hydropsychidae and Simuliidae as it damages and clogs filter feeding organs and structures. Therefore, their absence may indicate sediment issues even if little sediment is evident on the bed at the time.
- Distributions of macroinvertebrates vary throughout the country. Not all taxa will be present in all streams. The National Biodiversity Data Centre has distribution maps but records are patchy (http://www.biodiversityireland.ie/). Also refer to Characterisation of Reference Conditions and Testing of Typology of Rivers (Kelly-Quinn et al. 2005) in relation to expected communities at different river types (see Reference Library[4]).
- The Q-value is designed to be used in eroding rivers i.e. rivers which follow the typical riffle-glide-pool sequence that can generally be expected naturally in most rivers. It is not intended to be used in Potamon habitats (slow flowing habitats characterised by macrophytes including Potamogeton taxa) or in very small streams (e.g. drains or very small tributaries). As LAWPRO catchment scientists routinely sample these habitats during LCA, extra care should be taken

[1] McGarrigle, M. (2014) Assessment of small water bodies in Ireland. Biology and Environment: Proceedings of the Royal Irish Academy 2014

[2] Donohue, I., McGarrigle, M. & Mills, P. (2006) Linking catchment characteristics and water chemistry with the ecological status of Irish Rivers. Water Research 40(1): 91-8.

[3] Kelly, F., Champ, T., McDonnell, N., Kelly-Quinn, M., Harrison, S., Arbuthnott, A., Giller, P., Joy, M., McCarthy, K., Cullen, P. and Harrod, C., 2007. Investigation of the relationship between fish stocks, ecological quality ratings (Q-values), environmental factors and degree of eutrophication. Environmental Protection Agency, Ireland.

[4] Kelly-Quinn, M., Harrington, T.J., Rippey, B., Bradley, C., Nϕ Chathßin, B., Dodkins, I. and Trigg, D., 2005. Characterisation of reference conditions and testing of typology of rivers. Report to Environment Protection Agency, Dublin, Ireland.

in interpreting SSIS in these areas as the normal rules for assigning Q-values may not apply. Very small streams (tributaries/ditches) may not be capable of supporting the full range or densities of taxa that could be expected in larger rivers, due to increased competition for more limited space and food supplies.

- Seasonal variation in macroinvertebrate communities is well documented. Many taxa will naturally emerge as adults during the spring/summer months. The timing of this emergence varies by species and from year to year as it is tied to water temperatures. The EPA usually sample during summer (June – September) and Q-value is designed to take the absence of certain taxa during the summer into account. Therefore, comparison with the indicator groupings used in Table 3 should be done with caution when sampling in autumn/winter/spring as you might expect more of the sensitive taxa to be present and this does not necessarily mean that it would receive a better Q-value.

Some examples (but these will vary). Where possible check EPA Q-value data to see where particular taxa should be expected in each river):

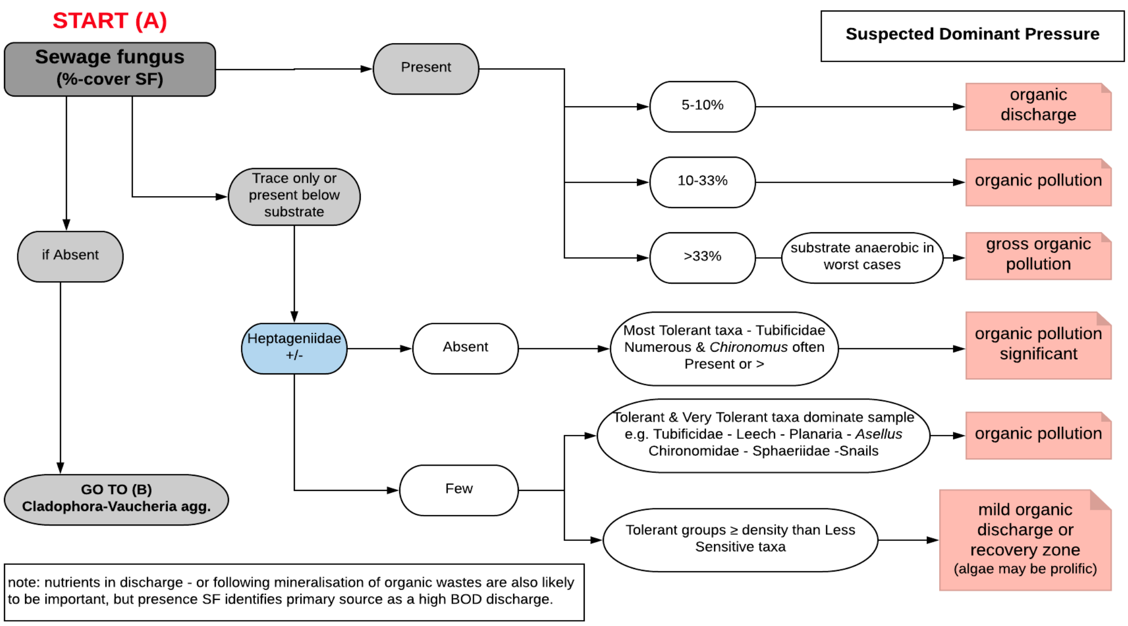
- *Rhithrogena* – Very widespread taxa. Found in most relatively unpolluted streams. They are generally absent from stream faunal communities between July and October each year.
- *Brachyptera* – Generally absent between April and September
- *Chloroperla* – may be absent for about a month in July/August
- *Leuctra* – Multiple species. Depending on species present they may be present year round. The most common species are:
    - *Leuctra fusca* are generally present in streams from February – August.
    - *Leuctra hippopus* are generally present from August – March
    - *Leuctra inermis* are generally present from August – June
- *Ecdyonurus* can generally be expected year round
- *Isoperla* – may be absent for about a month in July/August
- *Amphinemura* - may be absent for about a month in July/August
- *Protonemura* – may be absent from May to July
- *Perla/Dinocras* – Usually takes three years to complete life cycle so they should be present all year round. However, they have a relatively narrow distribution throughout the country.

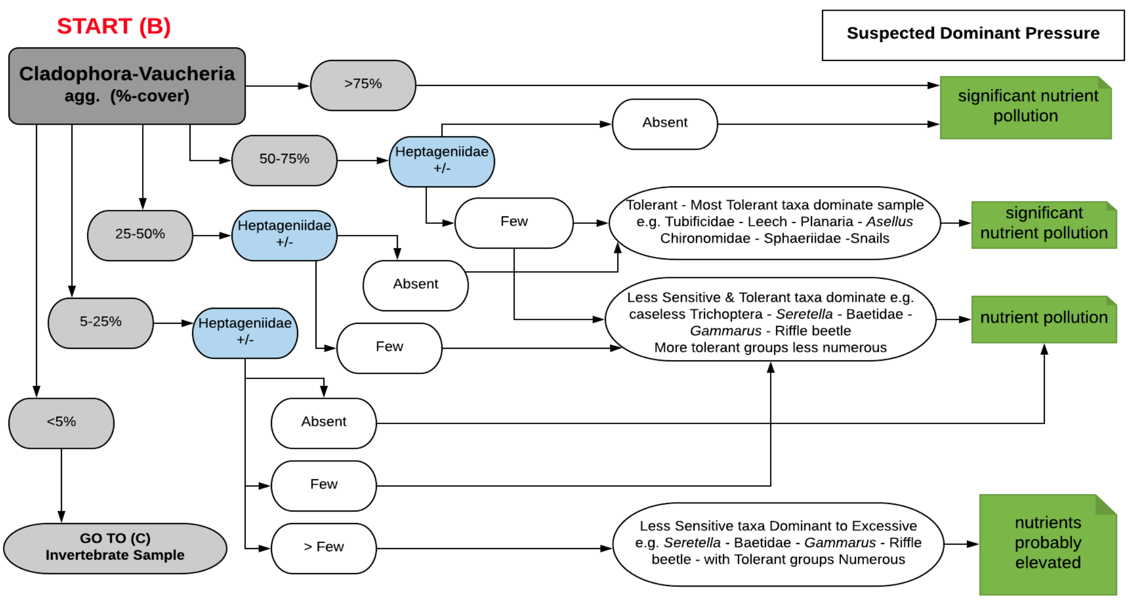
Communities generally reflective of particular pollutants:

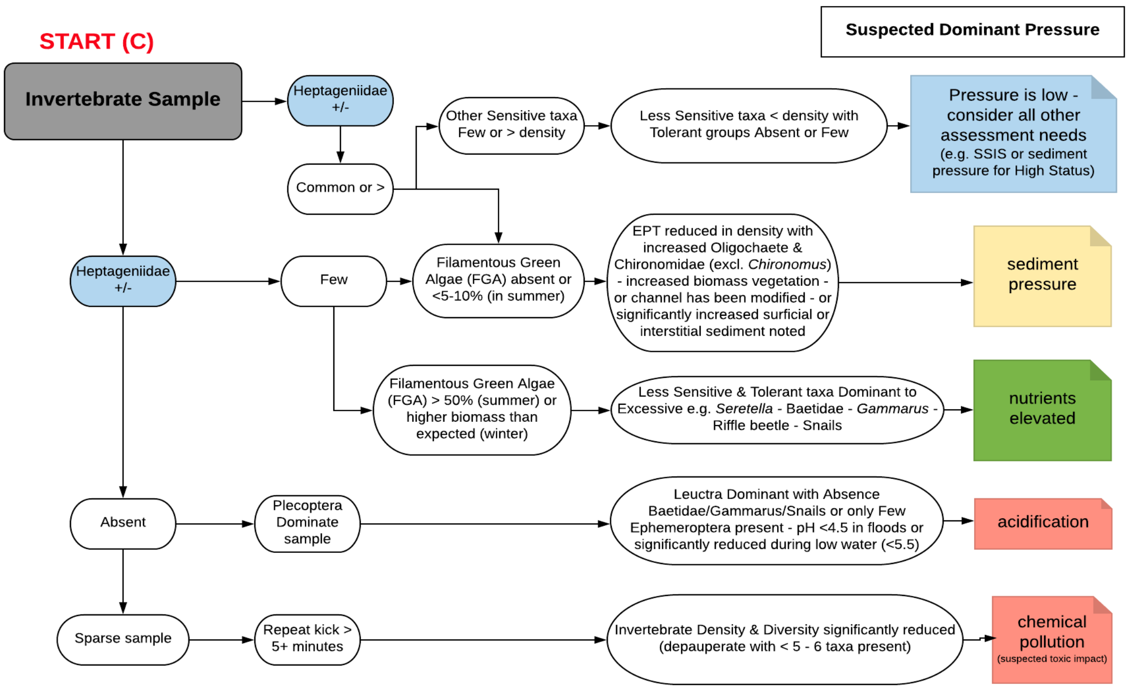
- Stoneflies dominant – acidification (possibly episodic in afforested acid sensitive areas and some streams are naturally acidic)
- Excessive Baetidae, Gammarus, Simuliidae or Potamogyrgus – Organic or nutrient pollution
- High numbers of Chironomidae and Oligocheata – sediment issues. Sediment will usually be visible on the bed or interstitial spaces in this case.
- Absence of Baetidae, Simuliidae and Hydropsychidae but no deposited sediment noted at site – possible sediment issues, particularly suspended sediment. Especially in cases where elevated numbers of Chironomids or Oligocheata are present.
- Very low numbers of invertebrates in sample – possible toxic pollution.

Appendix A

Flow Chart for Rapid Assessment to support the identification of some significant pressures.







START (C)
Suspected Dominant Pressure
Invertebrate Sample
Heptageniidae +/-
Common or >
Other Sensitive taxa Few or > density
Less Sensitive taxa < density with Tolerant groups Absent or Few
Pressure is low - consider all other assessment needs (e.g. SSIS or sediment pressure for High Status)
Heptageniidae +/-
Few
Filamentous Green Algae (FGA) absent or <5-10% (in summer)
EPT reduced in density with increased Oligochaete & Chironomidae (excl. *Chironomus*) - increased biomass vegetation - or channel has been modified - or significantly increased surficial or interstitial sediment noted
sediment pressure
Filamentous Green Algae (FGA) > 50% (summer) or higher biomass than expected (winter)
Less Sensitive & Tolerant taxa Dominant to Excessive e.g. *Seretella* - Baetidae - *Gammarus* - Riffle beetle - Snails
nutrients elevated
Absent
Plecoptera Dominate sample
Leuctra Dominant with Absence Baetidae/Gammarus/Snails or only Few Ephemeroptera present - pH <4.5 in floods or significantly reduced during low water (<5.5)
acidification
Sparse sample
Repeat kick > 5+ minutes
Invertebrate Density & Diversity significantly reduced (depauperate with < 5 - 6 taxa present)
chemical pollution
(suspected toxic impact)

Briefing Note	Ecology Working Group Briefing Note No. 4
Topic	Sampling in Freshwater Pearl Mussel Rivers
Prepared by	Bernie White
Date	10th June 2019
For Circulation to	LAWPRO Catchment Assessment Team

Introduction

The freshwater pearl mussel (*Margaritifera margaritifera*) is a bivalve mollusc found in clean, fast-flowing rivers, and occasionally in lakes. It is a highly threatened animal, categorised as critically endangered in Ireland and across Europe. 90% of all freshwater pearl mussels died out across Europe during the twentieth century. Owing to its threatened status and dramatic decline, the freshwater pearl mussel is listed on Annex II and Annex V of the Habitats Directive.

Adult freshwater pearl mussels can reach lengths of 12-15cm, and live buried, or partially buried in the river bed. Freshwater pearl mussels are filter feeders, inhaling and expelling up to 50L of water per day through siphons, while retaining food particles. This filtering activity means that pearl mussels can help to maintain and improve water quality, where they are present in high numbers.

Image 1: Photo from Aine O'Connor, NPWS website

Image 2: Photo from Kerry LIFE website

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Image 3: Freshwater Pearl Mussels from the Bundorragha catchment (2009). Note this photograph was taken following a survey under licence from NPWS. It is not permitted to touch or remove mussels from a river, unless permission is granted to do so. **Photo: Bernie White.**	**Image 4: Freshwater Pearl Mussels from the Owenriff Priority Area for Action, 16th May 2019. Surveyed under licence by Dr Evelyn Moorkens and Dr Ian Killeen. Note juvenile mussels in left of picture.** **Photo: Bernie White.**

Spatial Data

NPWS has created and maintains a *Margaritifera* GeoDatabase and this is periodically circulated to Irish public authorities. LAWPRO are now included in this circulation (Bernie White as contact point). It currently contains the following shapefiles (or feature classes):

1. Margaritifera_sensitive_areas_year_version# and associated labels (these polygons show the **catchments** of the known extant populations)

2. Margaritifera_Catchments_year_version# (a subset of 1. showing the catchments of the SAC populations)

3. FPM_Habitat_Classification_year_version# (a polyline mapping the extent of freshwater pearl mussel habitat in the SAC catchments)

4. Margaritifera_records_year_version# (a point file illustrating positive records of the species. As with all such records, these represent points in space and time and cannot be interpreted as the current or historical distribution of the species).

The GeoDatabase is not provided in its entirety to the public, and LAWPRO has specifically been provided with this database for the purposes of our current programme. **Please note however that records (point locations or habitat polyline) from this dataset should not be displayed in hard or soft copy reports (e.g. deskstudies), web-mapping (e.g. WFD App) or any other format (e.g. at Community Information Meetings). These are sensitive data, as defined by the NPWS data policy.**

The GeoDatabase is saved in the following location:

GISData - Documents\GIS_NationaLayers\FPM\Margaritifera_GIS_data_NPWS_Sep2018

An example of mapping generated from this database is displayed in **Figure 1**. Please also note that FPM sub-basin plan records from 2010 are also included within this database (Bernie White as contact for further details on sub-basin plans).

National Regulation

The European Communities Environmental Objectives (Freshwater Pearl Mussel) Regulations (S.I. 296 of 2009) were made to set environmental quality objectives for the listed freshwater pearl mussel SAC populations. The EQOs for habitat of the FPM are outlined below as copied from the Regulations Fourth Schedule.

Ecological Quality Objectives for Freshwater Pearl Mussel Habitat

Element	Objective	Notes
Macroinvertebrates	EQR ⩾0.90	High status
Filamentous algae (Macroalgae)	Absent or Trace (<5%)	Any filamentous algae should be wispy and ephemeral and never form mats
Phytobenthos (Diatoms)	EQR ⩾0.93	High status
Macrophytes — rooted higher plants	Absent or Trace (<5%)	Rooted macrophytes should be absent or rare within the mussel habitat
Siltation	No artificially elevated levels of siltation	No plumes of silt when substratum is disturbed

The Regulations also required the preparation of Sub-basin Management Plans, to provide the more detailed programmes of measures for the species under Water Framework Directive River Basin Management Plans. Although the draft plans were not finalised, many of the required measures have been implemented, particularly those for licensed discharges. The sub-basin plans can be accessed here: http://www.wfdireland.ie/docs/5_FreshwaterPearlMusselPlans/. Supporting documents to these plans are also available at this link, including for **macroinvertebrates, phytobenthos (diatoms and macroalgae), fish and hydromorphology**.

NPWS have also developed a national conservation strategy for the freshwater pearl mussel in 2011 that has the objective of ensuring the long-term survival of the species in Ireland, while maintaining its broad geographic range. It sets out a prioritised approach to the implementation of measures necessary to conserve the species and prioritise eight SAC populations that encompass approximately 80% of the Irish population. This document is saved here: **LAWSAT - Documents\36.0 Reference Documents\Freshwater Pearl Mussels**, and illustrates the justification for the prioritisation of the "Top 8" FPM catchments for interventions such as the Pearl Mussel Project (http://www.pearlmusselproject.ie/)., which incorporates the Bundorragha, Owenriff, Dawros, Glaskeelan, Caragh, Kerry Blackwater, Currane and Ownagappul.

The main reason for decline in the FPM is the low level of survival of juvenile mussels, which are extremely sensitive to slight changes in environmental conditions. This is leading to an ageing population, not capable of replenishing itself. Juvenile survival is dependent on a clean, well oxygenated river bed, with little silt, sediment, or algal growth.

Any activities that result in changes in river flow, increased levels of silt, and increased levels of nutrients are contributing to the decline of freshwater pearl mussels. In addition to drainage, and changes to river channel morphology, increased intensification of land use in river catchment areas can contribute to inadequate conditions for freshwater pearl mussel survival.

Survey Equipment

An essential piece of equipment when surveying in stretches of river you know contains, or possibly contains FPM, is a bathyscope (**Image 5**). A bathyscope is an underwater viewing device. It is used to view the underwater world within a river channel by wading (**Image 6**). It eliminates the water surface glare and allows viewing as far as water clarity and light permits and is suitable for water less than 75 cm deep. An alternative and very effective way of viewing the FPM and its habitat, in suitable rivers is snorkelling. Quantitative mussel surveys cannot be reliably carried out using a bathyscope and waders. Snorkelling is required, involving specified numbers of transects/km of river bed when mussels are numerous. LAWPRO will not be undertaking quantitative assessment of FPMs, therefore snorkelling will not be required.

Image 5 Bathyscope

Image 6 Bathyscope Use

Methodology for approach to survey in FPM Sensitive Areas

Pre survey checks

It is mandatory that before sampling is undertaken in an FPM Sensitive Area, that the GeoDatabase is checked for the location of identified freshwater pearl mussel habitat, not just the point records layer. The following layer is critical - Stretches of *Margaritifera* habitat mapped as polylines. An example of this polyline mapping for the Owenriff is displayed in **Figure 1** below. NPWS have concentrated on using the habitat polyline rather than points to fill gaps in knowledge on FPM populations, and the polyline layer is also used as the basis for setting conservation objectives in SACs. This datalayer is only available for SAC populations.

It is recommended that you contact your local NPWS Ranger in advance of your survey, and advise on your planned local catchment assessment (LCA) work. Your local NPWS Ranger will have additional knowledge on populations and historical surveys which will be useful for your LCA reporting.

Weather

In order to determine suitable survey days a variety of meteorological websites can be analysed (i.e. www.met.ie; www.yr.no). Ideally surveys in FPM rivers should be undertaken on sunny days which aids and increases underwater visibility.

Gauge whether conditions are suitable for survey[1]:

a) for safety reasons survey cannot be reliably carried out when rivers are in flood.

b) survey cannot be reliably carried out under conditions of poor visibility, for instance:

- when a river is recovering from heavy rains or is highly coloured
- when it is raining
- in overcast (i.e. more than 60% cloud cover) conditions, or at dawn or dusk.

Underwater viewing is critical in these rivers – do not attempt to survey if you cannot see the river bed using the bathyscope.

Survey & Use of Bathyscope

In water up to 75 cm deep, surveys can be carried out using a bathyscope by wading to check for the presence or absence of FPM. If your river is deeper, it is not safe to use this methodology and it is unlikely that LAWPRO would be surveying in water deeper than this for health and safety reasons. Before any kick sampling is undertaken, a thorough check of the stretch you wish to survey should be undertaken. To effectively check a stretch of 300m in length, a check can take 1 to 1.5 hours. It takes time to get your eyes adjusted to looking through the bathyscope and to distinguish between cobbles and FPM. Your level of effort may also be related to the likelihood of encountering the species:

1. High probability: Within FPM SAC (Catchment in S.I. No 296 of 2009), and habitat mapping indicates stretches of identifiable habitat and prior records. Do not kick sample within identified

[1] Anon (2004). Margaritifera margaritifera Stage 1 and Stage 2 Survey Guidelines produced by the NPWS, Irish Wildlife Manual No. 12.

habitat stretches. Record the following instream observations: macroalgal and macrophyte cover and density. This can be undertaken by wading carefully using the bathyscope.

2. Moderate probability: Catchments with other extant populations (as per Sensitive Areas layer). Perform presence / absence check before kick sampling.
3. Low probability: Catchments with previous records, but current status unknown (as per Sensitive Areas layers). Perform presence / absence check before kick sampling.

What to do if you find Freshwater Pearl Mussels in a location not mapped by the NPWS

If you encounter FPM at a site / in habitat which has not been recorded within the GeoDatabase, a data return should be made to the NPWS using the following excel form:

Margaritifera_records_template_v4, saved in the following location:

GISData - Documents\GIS_NationaLayers\FPM

For any advice required, please contact Bernie White.

Note: It is not permitted to touch or remove mussels from a river, unless permission is granted to do so under licence from NPWS.

References

Anon. (2004) Margaritifera margaritifera Stage 1 and Stage 2 survey guidelines. Irish Wildlife Manuals , No. 12. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland. [LAWSAT - Documents\36.0 Reference Documents\Freshwater Pearl Mussels]

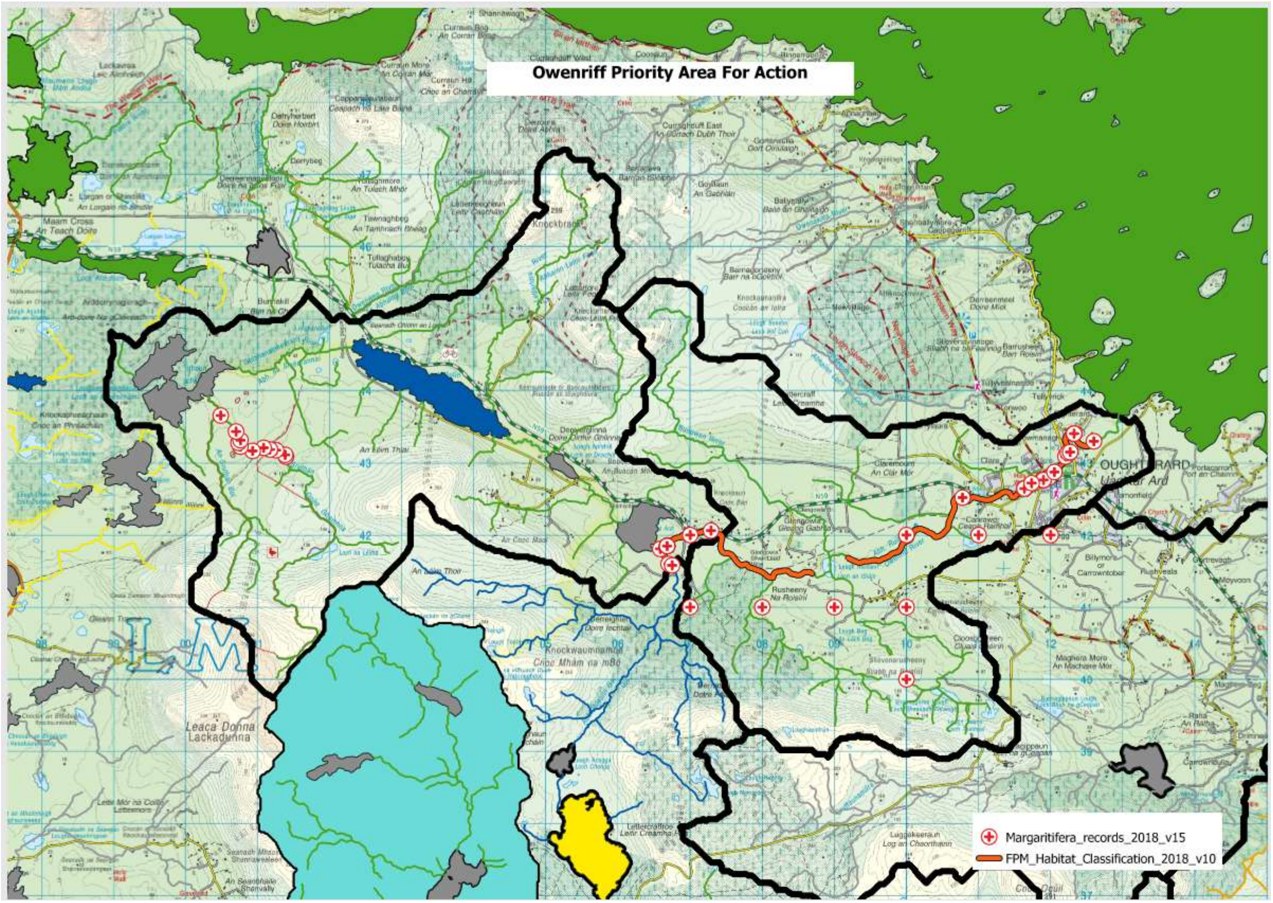

Figure 1 Example of NPWS Freshwater Pearl Mussel database mapping for the Owenriff catchment, Co. Galway

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Briefing Note No.	BN0001 Ecology & Chemistry Working Groups Guidance Note, Version F01
Topic	Identification and interpretation of acute toxic events using SSIS survey information
Date	01/10/2021
Prepared by	Paul O'Callaghan, Stephen Davis, Cormac McConigley, Bernie White
Reviewed by	Bernie White, Maeve Ryan
For circulation to	LAWPRO Catchment Assessment Team

Introduction

Aquatic ecotoxicology is an extremely complex subject with a great diversity of impacts and responses. These depend on multiple (often interacting) factors including for example, the toxic substance(s) in question, their concentration, background conditions (natural physico-chemical conditions and anthropogenic influences) and the organism(s)/species being studied. Responses can be further complicated by combinations of toxins which can interact. Impacts may also be sublethal but reduce an individual organism's or population's fitness making them more susceptible to further stressors (including non-toxic stressors).

For example, chronic low levels of a toxin/toxins may not significantly impact biological communities but may result in a reduction in fitness and any additional pressure(s) (e.g. reduced oxygen, elevated sediment etc.) can result in a significant impact to the ecological status. In other words, two pressures neither of which may result in a significant impact on their own may do so in combination. A typical example is a toxin which would cause minor gill damage limiting oxygen assimilation but not enough to kill the organism. However, if another pressure (e.g. nutrient enrichment) reduced stream oxygen concentrations this may result in mortality.

Potential sources of chemical toxins are numerous and can include sheep dip, industrial and wastewater discharges, discharges from landfills, mine leachate, leaks of coolants and lubricants from machinery as well as domestic misconnections and illegal disposal of hazardous substances in domestic wastewater among others.

All of this is important to keep in mind during catchment assessment work and the presence of even low levels of potentially toxic substances should be noted and considered as part of mitigation efforts.

Acute Toxicity

The core concern for this guidance is acute toxic impact. This occurs when a toxin or combination of toxins result in a rapid and usually drastic negative impact on ecology. This type of impact can be particularly obvious in the invertebrate community and the rapid assessment flowchart (Appendix A) captures what kind of invertebrate assemblage to expect in this type of scenario. It suggests:

If the catchment scientist encounters an unusually sparse sample they should repeat the kick extending this for up to 5 minutes or more. If the invertebrate abundance and diversity is still depauperate (i.e. few taxa present generally in very low numbers) then it is likely to be a toxic effect from chemical pollution.

It is important that the invertebrate assemblage shows BOTH low diversity (i.e. numbers of taxa) AND low abundance (very low numbers of individual taxa). This assumes that good quality habitat has been sampled using sufficient (extra) effort and there are no other obvious indicators of other acute stressors (e.g. massive sediment deposition). One minor caveat here is that due to the absence of grazing macroinvertebrates an increase in algal growth may be observed which may look like minor nutrient enrichment. However, the impact of nutrient enrichment alone would generally lead to a reduction in diversity but not in the overall abundance of macroinvertebrates.

Probably the most common toxic impact LAWPRO will encounter will be due to sheep dip (and other animal treatment chemicals). This describes a variety of products all of which are designed to kill common arthropod pests of sheep. These include extremely potent chemicals (including pyrethroids and organophosphates) which usually act as neurotoxins in insects and certain other arthropods. These chemicals can also be found in other sources including many household, industrial and construction products such as garden insect killers and wood preservatives. Preparations of these chemical are often sold in highly concentrated forms that may be diluted for use. They can result in a severe impact even at very low concentrations and so even very small volumes lost to the environment are significant. If we take the pyrethroid cypermethrin as an example: The inland surface water EQS for cypermethrin in Ireland is 0.00008µg/l. By this standard 1g of cypermethrin would pollute 12,500,000,000 litres (12,500,000 m^3) of water (approx. 5000 50m Olympic swimming pools). A dipping product may be 10% w/w so would contain about 100g/l and typical used sheep dip contains approx. 0.25g/l. Other processes in the environment such as attachment to sediment may reduce concentrations in the water column. Also, the velocity of the receiving river will influence residence time and therefore exposure time that invertebrates experience. These factors working in combination make estimating the specific length of a river that would be impacted difficult. However, you would expect at least several kms to be impacted with most severe impacts closer to the source.

Many farmers are now using pour on preparations including chemicals such as dicyclanil which act as insect growth inhibitors. Less information is available on these but products including them display warnings that they represent serious risk to aquatic life.

Case Study 1 Milltown PAA

The first example below shows two typical SSIS fieldsheets taken downstream of a toxic impact. The first (Fig. 1) shows total of 9 taxa present, however all but Chironomidae were present in very low numbers. It was noted by the catchment scientist that it was difficult to find any invertebrates except for these. The Chironomidae present were very small individuals and had likely rapidly recolonised following the toxic event. The catchment scientists worked upstream from this point sampling periodically as they went and just u/s of a farmyard observed a dramatic improvement in the invertebrate community.

The second SSIS fieldsheet (Fig. 2) shows the community just d/s of the first survey location. Just 7 taxa were present with only Baetidae and Chironomidae in any numbers. This is a good example of partial recovery between toxic events with opportunistic taxa recolonising rapidly. The Baetidae and Chironomidae probably drifted down from u/s.

The ASSAP assessment found that a sheep dipping tank in close proximity to the stream which was not emptied after use was overflowing with rainwater. This was resolved by installation of a submersible pump to move the used dip to a slatted tank to subsequently be landspread. It should be noted however, that this is not an option that is always available particularly on sheep only farms as a slatted tank is unlikely to be available. This is discussed further in Case Study 3.

7-5

SMALL STREAM IMPACT SCORE (SSIS)

SURVEY DETAIL

Location ID (or GR):	
Time:	11:30
Habitat sampled:	Riff
Wet width (m):	3M
Avg. sample depth (m):	25cM

RELATIVE ABUNDANCE CATEGORIES (RA*)

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

SAMPLE TIME (min)

pond-net: 2 stone wash: 1 weed-sweep:

other criteria or habitat feature

1: EPHEMEROPTERA	RA*
Ecdyonurus o ☐	
Heptagenia o ☐	
Rhithrogena o ☐	
Ephemera danica o ☐	
Ephemerellidae o	
Paraleptophlebia o	
Caenis o	
Other	
Baetidae o ✓ RA 1 ←not SSRS	☒
Total no. SSRS Ephemeroptera	
sum RA	
Index score A	0

2: PLECOPTERA	RA*
Perla o ☐	
Dinocras o ☐	
Isoperla o	
Chloroperla o	
Protonemura o	
Amphinemura o	
Leuctra o	
Other	
Other	
Total no. Plecoptera taxa	
sum RA	
Index score B	0

3: TRICHOPTERA	RA*
Limnephilidae o	
Sericostomatidae o	
Glossosomatidae o	
Lepidostomatidae o	
Hydropsychidae o ✓	1
Polycentropodidae o	
Rhyacophila o	
Philopotamidae o	
Other	
Total no. Trichoptera taxa	1
sum RA	1
Index score C	2

4: G.OI.D	RA*
Radix balthica (G) o	
Potamopygrus (G) o ✓	2
Planorbis (G) o	
Ancylus (G) o	
Physa (G) o	
Lumbriculus (OL) o	
Eiseniella (OL) o	
Tubificidae (OL) o ✓	1
Simuliidae (D) o ✓	1
Ceratopogonidae (D) o	

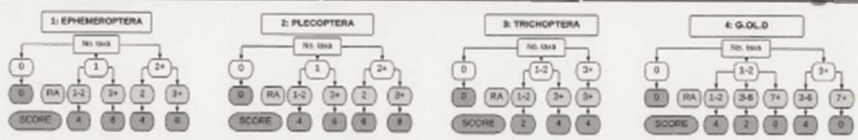
G.OI.D	RA*
Dicranota (D) o	
Tipulidae (D) o	
Chironomidae (D) o ✓	4
Chironomus (D) o	
Other	
Other	
Other	
Total no. G.OI.D taxa	4
sum RA	8
Index score D	0

OTHER TAXA (not SSRS)	RA*
Gammarus o	
Crangonyx o	
Riffle beetle o	
Leech o ✓	1
Flatworm o ✓	1
Odonata o	
Oligochaete	1
Other	
Other	
Other	

ASELLUS INDEX SCORE	
Asellus if absent tick box (score = 4) ✓	4
Asellus if few (1-20) tick box (score = 2)	
Asellus if common (> 20) tick box (score = 0)	
E: *Asellus* index score (4 or 2 or 0)	

Total Index Score (A+B+C+D+E)	6
Average Index Score (Total IS / 5)	1.2
SSR Score = (Average IS) x 2	2.4
SAMPLE TAXON NUMBER	8

> 7.25 Probably not significantly impacted	
> 6.5-7.25 Indeterminate. Evidence of impact	
< 6.5 Probably impacted	
INVERT. DENSITY (E / A / M / L / (S))	



Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

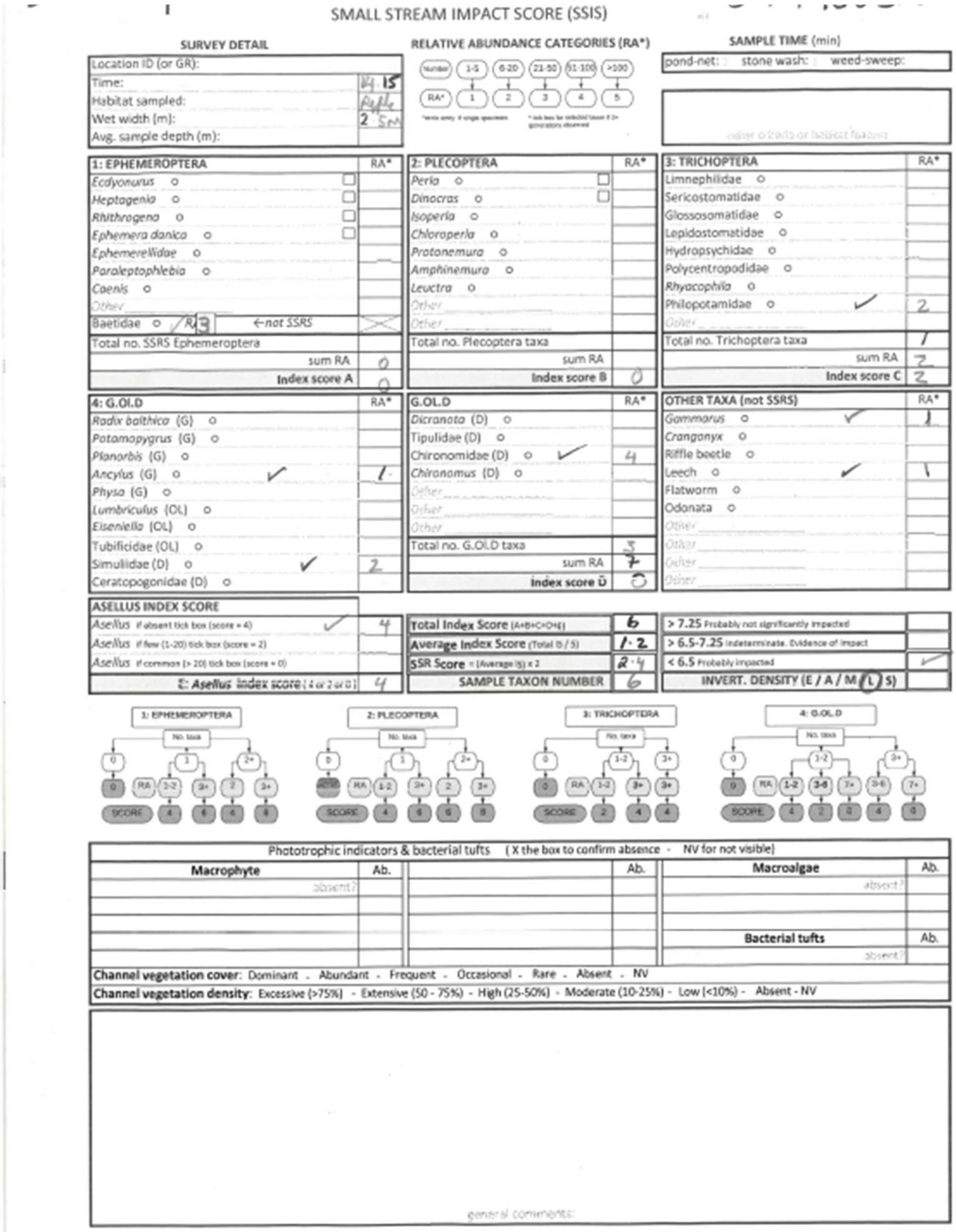
Macrophyte	Ab.		Ab.	Macroalgae	Ab.
absent?				absent?	
				Bacterial tufts	Ab.
				absent?	

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

- Extremely sparse: Hard to find anything other than Chironomidae

Fig. 1 Milltown approx. 700m d/s toxic impact


SMALL STREAM IMPACT SCORE (SSIS)

SURVEY DETAIL: Location ID (or GR): | Time: 14.15 | Habitat sampled: | Wet width (m): 2.5m | Avg. sample depth (m):

RELATIVE ABUNDANCE CATEGORIES (RA*): Number 1-5, 6-20, 21-50, 51-100, >100 → RA* 1, 2, 3, 4, 5

SAMPLE TIME (min): pond-net: | stone wash: | weed-sweep:

1: EPHEMEROPTERA	RA*	2: PLECOPTERA	RA*	3: TRICHOPTERA	RA*
Ecdyonurus		Perla		Limnephilidae	
Heptagenia		Dinocras		Sericostomatidae	
Rhithrogena		Isoperla		Glossosomatidae	
Ephemera danica		Chloroperla		Lepidostomatidae	
Ephemerellidae		Protonemura		Hydropsychidae	
Paraleptophlebia		Amphinemura		Polycentropodidae	
Caenis		Leuctra		Rhyacophila	
Other		Other		Philopotamidae ✓	2
Baetidae ← not SSRS		Other		Other	
Total no. SSRS Ephemeroptera		Total no. Plecoptera taxa		Total no. Trichoptera taxa	1
sum RA	0	sum RA		sum RA	2
Index score A	0	Index score B	0	Index score C	2

4: G.OL.D	RA*	G.OL.D	RA*	OTHER TAXA (not SSRS)	RA*
Radix balthica (G)		Dicranota (D)		Gammarus ✓	1
Potamopyrgus (G)		Tipulidae (D)		Crangonyx	
Planorbis (G)		Chironomidae (D) ✓	4	Riffle beetle	
Ancylus (G) ✓	1	Chironomus (D)		Leech ✓	1
Physa (G)		Other		Flatworm	
Lumbriculus (OL)		Other		Odonata	
Eiseniella (OL)		Other		Other	
Tubificidae (OL)		Total no. G.OL.D taxa	3	Other	
Simuliidae (D) ✓	2	sum RA	7	Other	
Ceratopogonidae (D)		Index score D	0	Other	

ASELLUS INDEX SCORE					
Asellus if absent tick box (score = 4) ✓	4	Total Index Score (A+B+C+D+E)	6	> 7.25 Probably not significantly impacted	
Asellus if few (1-20) tick box (score = 2)		Average Index Score (Total ÷ 5)	1.2	> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus if common (> 20) tick box (score = 0)		SSR Score = (Average (5)) x 2	2.4	< 6.5 Probably impacted	✓
E: Asellus index score (4 or 2 or 0)	4	SAMPLE TAXON NUMBER	6	INVERT. DENSITY (E / A / M / L / S)	L

Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
absent?				absent?	
				Bacterial tufts	Ab.
				absent?	

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV
Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

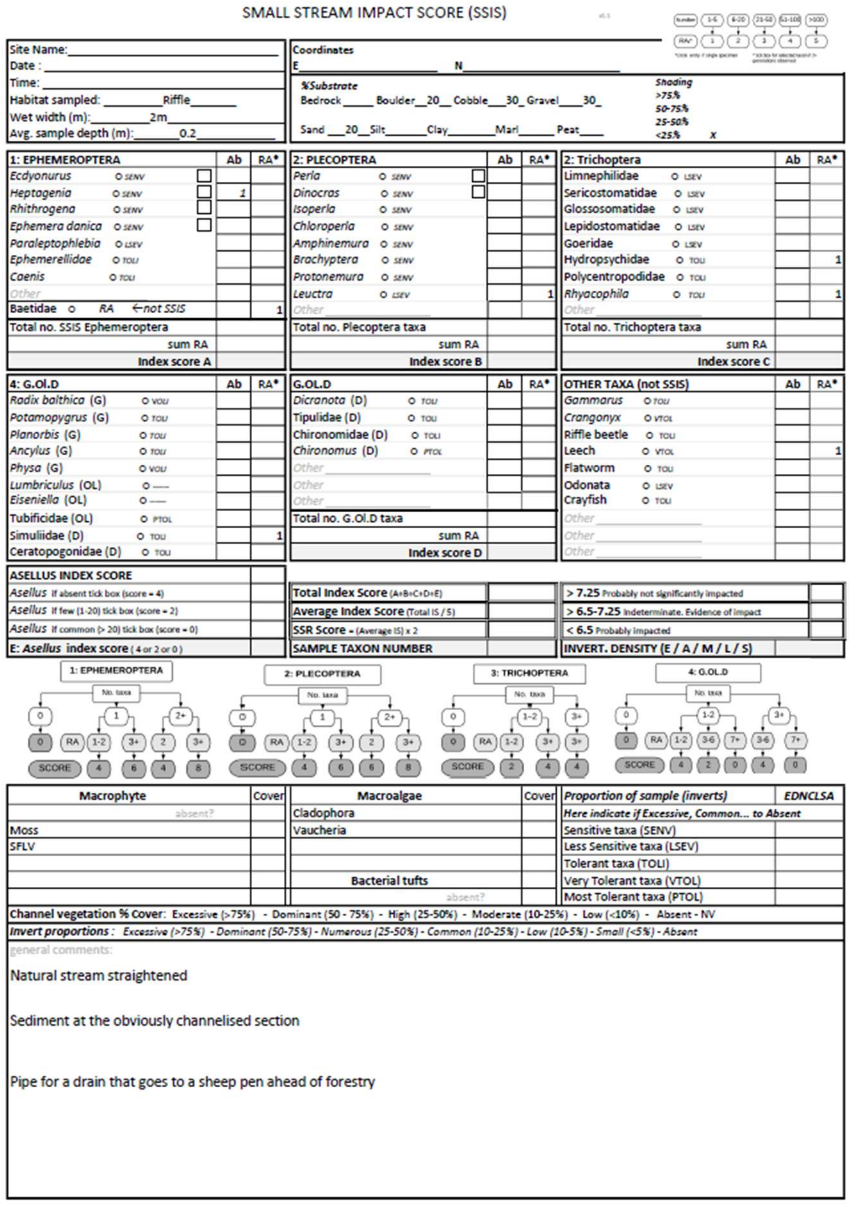
general comments:

Fig. 2 Milltown just d/s toxic impact

Case Study 2 Recess PAA

This is similar to example 1, however in this case the EPA biologist had noted that the invertebrate community at the EPA monitoring point (a high status objective site) had deteriorated to Q3/0 in 2018 (from a previous Q3-4 in 2015 and Q4-5 in 2012), with a toxic impact suspected due to depauperate nature of the sample. The catchment scientists designed a sampling strategy to investigate this which included SSIS surveys from the monitoring point and upstream at a number of locations, together with a catchment walk from the monitoring point up to the top of the catchment. While a number of non-significant pressures were noted (e.g. poor set back along forestry streams, some animal access points being used by sheep which was causing localised sedimentation), they documented a sheep holding pen at the top of the catchment, which was sited over a culverted small stream. Sheep wool was discarded in the pen and around the pen. The SSIS scores were impacted up to the top of the catchment, and therefor an upstream sampled was not possible. It was concluded that the most likely scenario was that activities at the site of the sheep holding pen, or around it, was the source of the pressure. ASSAP engaged with the landowners in this area to raise awareness of the issues associated with use of sheep dip.

The invertebrate community (Fig. 3) just downstream of the sheep holding pen was typical of an acute toxic impact. Very depauperate with only 6 taxa present all in very low numbers, following an extended kick.



SMALL STREAM IMPACT SCORE (SSIS)

Site Name:
Date :
Time:
Habitat sampled: Riffle
Wet width (m): 2m
Avg. sample depth (m): 0.2

Coordinates
E N

%Substrate
Bedrock ___ Boulder 20 Cobble 30 Gravel 30
Sand 20 Silt ___ Clay ___ Marl ___ Peat ___

Shading
>75%
50-75%
25-50%
<25% x

1: EPHEMEROPTERA	Ab	RA*	2: PLECOPTERA	Ab	RA*	2: Trichoptera	Ab	RA*
Ecdyonurus SENV			Perla SENV			Limnephilidae LSEV		
Heptagenia SENV	1		Dinocras SENV			Sericostomatidae LSEV		
Rhithrogena SENV			Isoperla SENV			Glossosomatidae LSEV		
Ephemera danica SENV			Chloroperla SENV			Lepidostomatidae LSEV		
Paraleptophlebia LSEV			Amphinemura SENV			Goeridae LSEV		
Ephemerellidae TOLI			Brachyptera SENV			Hydropsychidae TOLI		1
Caenis TOLI			Protonemura SENV			Polycentropodidae TOLI		
Other			Leuctra LSEV		1	Rhyacophila TOLI		1
Baetidae RA ←not SSIS		1	Other			Other		
Total no. SSIS Ephemeroptera			Total no. Plecoptera taxa			Total no. Trichoptera taxa		
sum RA			sum RA			sum RA		
Index score A			Index score B			Index score C		

4: G.Ol.D	Ab	RA*	G.Ol.D	Ab	RA*	OTHER TAXA (not SSIS)	Ab	RA*
Radix balthica (G) VTOL			Dicranota (D) TOLI			Gammarus TOLI		
Potamopygrus (G) TOLI			Tipulidae (D) TOLI			Crangonyx VTOL		
Planorbis (G) TOLI			Chironomidae (D) TOLI			Riffle beetle TOLI		
Ancylus (G) TOLI			Chironomus (D) PTOL			Leech VTOL		1
Physa (G) VTOL			Other			Flatworm TOLI		
Lumbriculus (OL) —			Other			Odonata LSEV		
Eiseniella (OL) —			Other			Crayfish TOLI		
Tubificidae (OL) PTOL			Total no. G.Ol.D taxa			Other		
Simuliidae (D) TOLI		1	sum RA			Other		
Ceratopogonidae (D) TOLI			Index score D			Other		

ASELLUS INDEX SCORE					
Asellus If absent tick box (score = 4)		Total Index Score (A+B+C+D+E)		> 7.25 Probably not significantly impacted	
Asellus If few (1-20) tick box (score = 2)		Average Index Score (Total IS / 5)		> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus If common (> 20) tick box (score = 0)		SSR Score = (Average IS) x 2		< 6.5 Probably impacted	
E: Asellus index score (4 or 2 or 0)		SAMPLE TAXON NUMBER		INVERT. DENSITY (E / A / M / L / S)	

Macrophyte	Cover	Macroalgae	Cover	Proportion of sample (inverts)	EDNCLSA
absent?		Cladophora		Here indicate if Excessive, Common... to Absent	
Moss		Vaucheria		Sensitive taxa (SENV)	
SFLV				Less Sensitive taxa (LSEV)	
				Tolerant taxa (TOLI)	
		Bacterial tufts		Very Tolerant taxa (VTOL)	
		absent?		Most Tolerant taxa (PTOL)	

Channel vegetation % Cover: Excessive (>75%) - Dominant (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

Invert proportions : Excessive (>75%) - Dominant (50-75%) - Numerous (25-50%) - Common (10-25%) - Low (10-5%) - Small (<5%) - Absent

general comments:

Natural stream straightened

Sediment at the obviously channelised section

Pipe for a drain that goes to a sheep pen ahead of forestry

Fig. 3 Recess just d/s of sheep pen

Case Study 3 – Dawros PAA

On the Traheen_010 (Dawros PAA) a distinct drop in both invertebrate diversity and abundance was observed between and upstream (Fig.4) and downstream (Fig.5, Fig.6) SSIS samples and a toxic impact was suspected. This was confirmed by an extended kick sample of 5 minutes. The rapid assessment flowchart further reinforced this conclusion (Appendix A). Nearby a sheep holding pen was observed which contained foot bath trays (still full and overflowing) as well as drums of formaldehyde, summer dip concentrate and oral medicines. The pen was in close proximity to a steep bank on a tributary of the river.

This incident raised several interesting issues which were communicated to LAWPRO following the resulting ASSAP farm assessement. Removal of animal treatment products to a slatted tank for subsequent land spreading is often recommended as a safe disposal method. However, this was a sheep only farm and no slatted tank or land spreading equipment was available. Furthermore, the footbath is relatively shallow and long so that removal of the liquid to drums for storage is difficult without spillages. The use of a submersible pump would also pose certain difficulties as the pen was not located on a farmyard with a ready source of power and again the foot baths are quite shallow. Even if the liquid was safely removed to drums there are difficulties with disposal of hazardous waste (formalin is a carcinogen) with local authority facilities generally only accepting limited quantities if at all. There is clearly a gap in policy and services as well as education – a matter which has been raised at NTIG and is currently being investigated.

Local Authority Waters Programme

vibrant communities | catchment assessment | healthy waters

18/6/19

SMALL STREAM IMPACT SCORE (SSIS)

v1.1

SURVEY DETAIL

Location ID (or GR): 470644, 755780	
Time:	3.20
Habitat sampled:	run
Wet width (m):	3m
Avg. sample depth (m):	.3m

RELATIVE ABUNDANCE CATEGORIES (RA*)

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

*circle entry if single specimen * tick box for selected taxon if 2+ generations observed

SAMPLE TIME (min)

pond-net: 2 stone wash: 1 weed-sweep:

Stop 2.2.3

Other criteria or habitat features: 50m D.S. of yard

1: EPHEMEROPTERA	RA*
Ecdyonurus o	
Heptagenia o	
Rhithrogena o	
Ephemera danica o	
Ephemerellidae ●	2
Paraleptophlebia o	
Caenis o	
Other	
Baetidae ● RA 3 ←not SSRS	
Total no. SSRS Ephemeroptera	1
sum RA	2
Index score A	4

2: PLECOPTERA	RA*
Perla o ☐	
Dinocras o ☐	
Isoperla o	
Chloroperla o	
Protonemura o	
Amphinemura o	
Leuctra ●	2
Other	
Other	
Total no. Plecoptera taxa	1
sum RA	2
Index score B	4

3: TRICHOPTERA	RA*
Limnephilidae o	
Sericostomatidae o	
Glossosomatidae o	
Lepidostomatidae ● Ind	
Hydropsychidae o	
Polycentropodidae o	
Rhyacophila ●	2
Philopotamidae o	
Other	
Total no. Trichoptera taxa	1
sum RA	2
Index score C	2

4: G.OI.D	RA*
Radix balthica (G) o	
Potamopygrus (G) o	
Planorbis (G) o	
Ancylus (G) o	
Physa (G) o	
Lumbriculus (OL) o	
Eiseniella (OL) o	
Tubificidae (OL) o	
Simuliidae (D) ●	2
Ceratopogonidae (D) o	

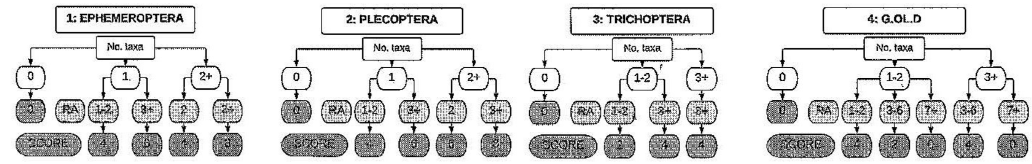
G.OI.D	RA*
Dicranota (D) ●	1
Tipulidae (D) ● Ind	
Chironomidae (D) o	
Chironomus (D) ●	1
Other	
Other	
Other	
Total no. G.OI.D taxa	3
sum RA	4
Index score D	2

OTHER TAXA (not SSRS)	RA*
Gammarus o	
Crangonyx o	
Riffle beetle o	
Leech ●	1
Flatworm o	
Odonata o	
Other	
Other	
Other	
Other	

ASELLUS INDEX SCORE	
Asellus if absent tick box (score = 4)	4
Asellus if few (1-20) tick box (score = 2)	
Asellus if common (> 20) tick box (score = 0)	
E: *Asellus* index score (4 or 2 or 0)	4

Total Index Score (A+B+C+D+E)	16
Average Index Score (Total IS / 5)	3.2
SSR Score = (Average IS) x 2	6.4
SAMPLE TAXON NUMBER	11

> 7.25 Probably not significantly impacted	
> 6.5-7.25 Indeterminate. Evidence of impact	
< 6.5 Probably impacted	✓
INVERT. DENSITY (E / A / M / L / S)	L



Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
absent?				absent?	
				Bacterial tufts	Ab.
				absent?	

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

No Fence on Left or right Bank

Cattle + sheep grazing - presence of cow dung

general comments:

Fig. 4 Traheen_10 (site 2.2.3) u/s footbath station

Local Authority Waters Programme

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17/06/19 SMALL STREAM IMPACT SCORE (SSIS) Traheen 2.2.2

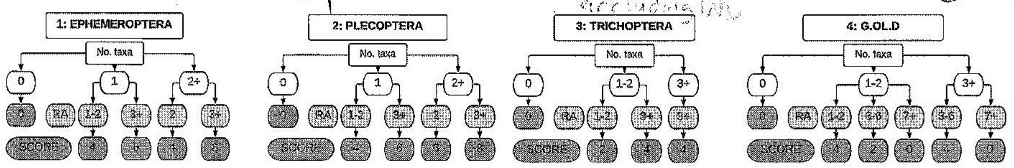
SURVEY DETAIL		RELATIVE ABUNDANCE CATEGORIES (RA*)	SAMPLE TIME (min)
Location ID (or GR):		Number: 1-5, 6-20, 21-50, 51-100, >100	pond-net: 2 stone wash: 1 weed-sweep:
Time: 15:30		RA*: 1, 2, 3, 4, 5	2.2.2
Habitat sampled:		*circle entry if single specimen	469552, 757169
Wet width (m):		*tick box for selected taxon if 2+ generations observed	other criteria or habitat feature
Avg. sample depth (m):			

1: EPHEMEROPTERA	RA*	2: PLECOPTERA	RA*	3: TRICHOPTERA	RA*
Ecdyonurus		*Perla*		Limnephilidae	
Heptagenia		*Dinocras*		Sericostomatidae ✓ IND	
Rhithrogena		*Isoperla*		Glossosomatidae	
Ephemera danica		*Chloroperla*		Lepidostomatidae	
Ephemerellidae		*Protonemura*		Hydropsychidae	
Paraleptophlebia		*Amphinemura*		Polycentropodidae	
Caenis		*Leuctra* ✓	1	*Rhyacophila* ✓ IND	
Other		*Other*		Philopotamidae	
Baetidae ✓ RA 4 ←not SSRS		*Other*		*Other* Goeridae IND	
Total no. SSRS Ephemeroptera	0	Total no. Plecoptera taxa	1	Total no. Trichoptera taxa	0
sum RA		sum RA	1	sum RA	
Index score A		Index score B	4	Index score C	

4: G.OI.D	RA*	G.OI.D	RA*	OTHER TAXA (not SSRS)	RA*
Radix balthica (G)		*Dicranota* (D)		*Gammarus* ✓	
Potamopyrgus (G)		Tipulidae (D)		*Crangonyx*	
Planorbis (G)		Chironomidae (D)		Riffle beetle ✓ larvae	1
Ancylus (G)		*Chironomus* (D) ✓	1	Leech	
Physa (G)		*Other*		Flatworm	
Lumbriculus (OL)		*Other*		Odonata	
Eiseniella (OL)		*Other*		*Other*	
Tubificidae (OL) ✓ IND		Total no. G.OI.D taxa	1	*Other*	
Simuliidae (D) ✓ casts on stones		sum RA	1	*Other*	
Ceratopogonidae (D)		Index score D	1	*Other*	

ASELLUS INDEX SCORE					
Asellus if absent tick box (score = 4)	✓	Total Index Score (A+B+C+D+E)	12	> 7.25 Probably not significantly impacted	
Asellus if few (1-20) tick box (score = 2)		Average Index Score (Total IS / 5)	2.4	> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus if common (> 20) tick box (score = 0)		SSR Score = (Average IS) x 2	4.8	< 6.5 Probably impacted	✓
E: *Asellus* index score (4 or 2 or 0)	4	SAMPLE TAXON NUMBER	8	INVERT. DENSITY (E / A / M / L / S)	

excluding IND



Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
absent?				absent?	
				Bacterial tufts	Ab.
				absent?	

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

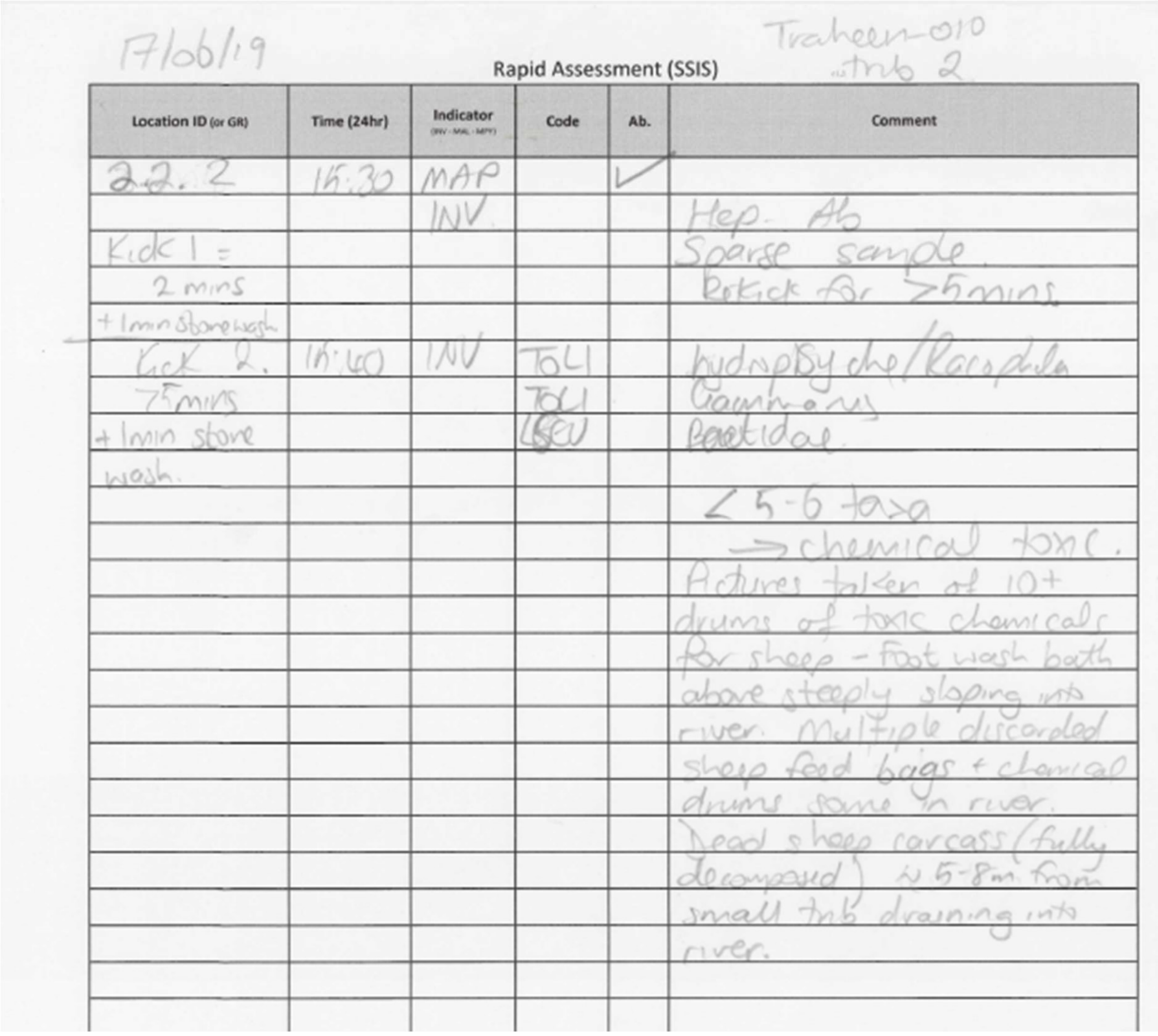
Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

little trib: 79.5% DO 8.19 mg/L
Temp: 14.4 °C
pH: 7.04

SSIS on main trib → poor invert density
conducted Rapid Assessment → same result

general comments:

Fig. 5 Traheen_10 (site 2.2.2) d/s footbath station



17/06/19

Rapid Assessment (SSIS)

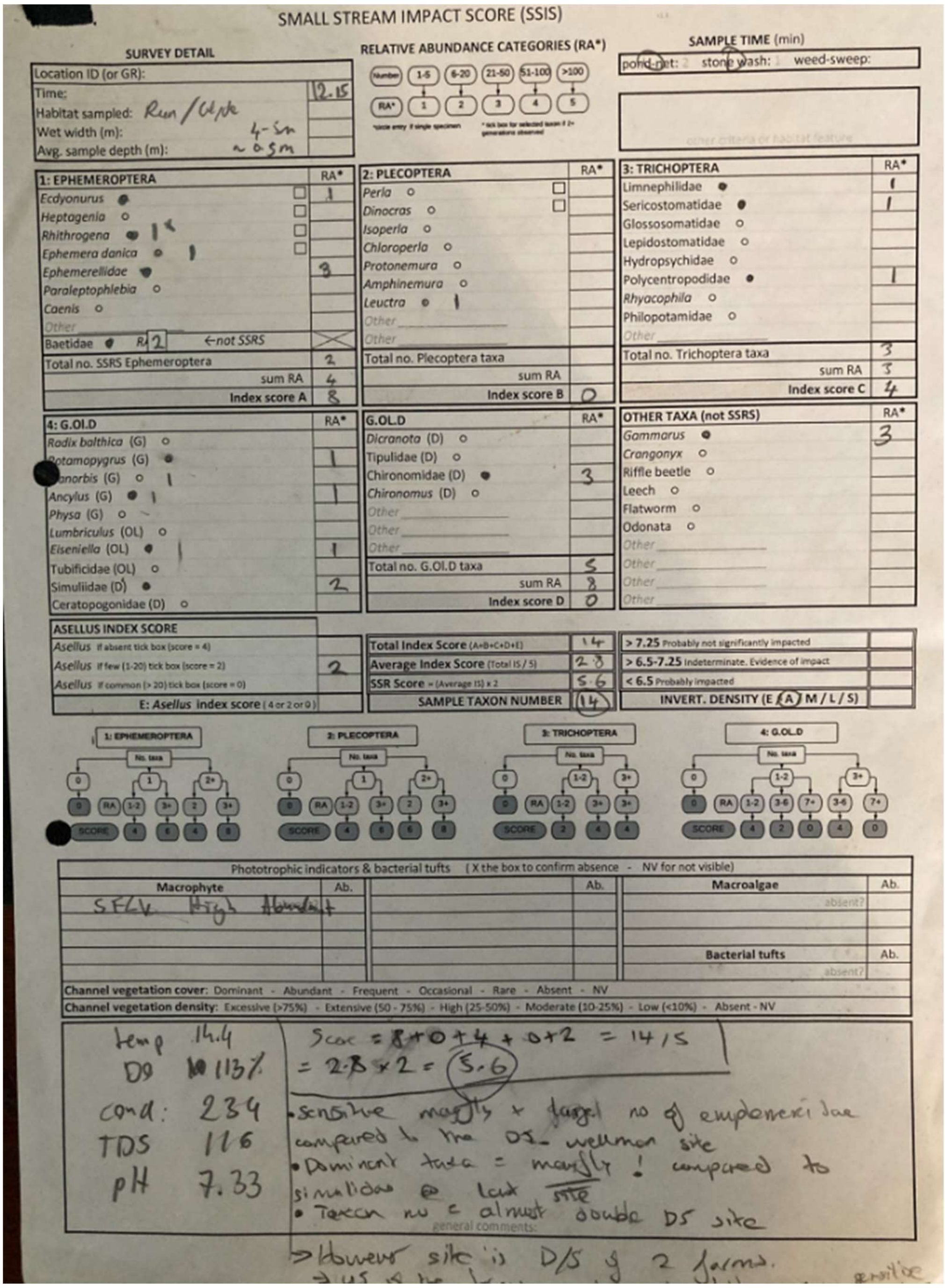
Traheen-010 trib 2

Location ID (or GR)	Time (24hr)	Indicator (INV - MAL - MPY)	Code	Ab.	Comment
2.2.2	15:30	MAP		✓	
		INV			Hep. Ab
Kick 1 =					Sparse sample.
2 mins					Rekick for >5mins
+1min stone wash					
Kick 2.	15:40	INV	TOL1		hydropsyche/Racophila
75mins			TOL1		Gammarus
+1min stone			LSEU		Baetidae
wash.					
					< 5-6 taxa
					→ chemical toxic.
					Pictures taken of 10+
					drums of toxic chemicals
					for sheep - foot wash bath
					above steeply sloping into
					river. Multiple discarded
					sheep feed bags + chemical
					drums some in river.
					Dead sheep carcass (fully
					decomposed) ~5-8m from
					small trib draining into
					river.

Fig. 6 Traheen_010 site 2.2.2 rapid assessment with extended kick sample

Case Study 4 – Moynalty PAA

In this example biological status d/s of a licensed facility dropped between 2009 and 2012 with the nearest Q value dropping from Q3/4 to Q3. The licensed facility (a plastics factory) invested in improved wastewater treatment in 2012 which appeared to result in an improvement in phosphate and ammonium concentrations d/s however the biological status did not improve. Samples were taken by LAWPRO catchment scientists u/s and d/s of the facility. The u/s sample reflected nutrient or organic pollution with a fairly diverse community (14 taxa) dominated by less sensitive and tolerant taxa (Fig. 7). The d/s sample had reduced diversity with 9 taxa (2 of which were single specimens) as well as reduced abundance with nearly all taxa showing lower numbers than u/s (Fig. 8). EPA chemical sampling in 2018 showed elevated concentrations of several substances in the effluent including Antimony, Barium, Copper and Zinc. This is a good example of a toxic impact possibly causing a combination of lethal and sublethal effects. There are already nutrient and possible sediment pressures upstream; the addition of the toxic substances is enough to remove any sensitive taxa and reduce the fitness of the remaining more tolerant taxa resulting in lower abundance and diversity.



SMALL STREAM IMPACT SCORE (SSIS)

SURVEY DETAIL

Location ID (or GR):	
Time:	12.15
Habitat sampled: Run / Glide	
Wet width (m): 4-5m	
Avg. sample depth (m): ~0.5m	

RELATIVE ABUNDANCE CATEGORIES (RA*)

Number: 1-5, 6-20, 21-50, 51-100, >100
RA*: 1, 2, 3, 4, 5

SAMPLE TIME (min)

pond-net: 2 stone wash: 1 weed-sweep:

1: EPHEMEROPTERA	RA*
Ecdyonurus	1
Heptagenia	
Rhithrogena	
Ephemera danica	
Ephemerellidae	3
Paraleptophlebia	
Caenis	
Other	
Baetidae RA 2 ←not SSRS	
Total no. SSRS Ephemeroptera	2
sum RA	4
Index score A	8

2: PLECOPTERA	RA*
Perla	
Dinocras	
Isoperla	
Chloroperla	
Protonemura	
Amphinemura	
Leuctra	
Other	
Other	
Total no. Plecoptera taxa	
sum RA	
Index score B	0

3: TRICHOPTERA	RA*
Limnephilidae	1
Sericostomatidae	1
Glossosomatidae	
Lepidostomatidae	
Hydropsychidae	
Polycentropodidae	1
Rhyacophila	
Philopotamidae	
Other	
Total no. Trichoptera taxa	3
sum RA	3
Index score C	4

4: G.OI.D	RA*
Radix balthica (G)	
Potamopygrus (G)	1
Planorbis (G)	
Ancylus (G)	1
Physa (G)	
Lumbriculus (OL)	
Eiseniella (OL)	1
Tubificidae (OL)	
Simuliidae (D)	2
Ceratopogonidae (D)	

G.OI.D	RA*
Dicranota (D)	
Tipulidae (D)	
Chironomidae (D)	3
Chironomus (D)	
Other	
Other	
Other	
Total no. G.OI.D taxa	5
sum RA	8
Index score D	0

OTHER TAXA (not SSRS)	RA*
Gammarus	3
Crangonyx	
Riffle beetle	
Leech	
Flatworm	
Odonata	
Other	

ASELLUS INDEX SCORE	
Asellus if absent tick box (score = 4)	
Asellus if few (1-20) tick box (score = 2)	2
Asellus if common (> 20) tick box (score = 0)	
E: Asellus index score (4 or 2 or 0)	

Total Index Score (A+B+C+D+E)	14
Average Index Score (Total IS / 5)	2.8
SSR Score = (Average IS) x 2	5.6
SAMPLE TAXON NUMBER	14

> 7.25 Probably not significantly impacted	
> 6.5-7.25 Indeterminate. Evidence of impact	
< 6.5 Probably impacted	
INVERT. DENSITY (E / A / M / L / S)	A

Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
SFCV High Abundant				absent?	
				Bacterial tufts	Ab.
				absent?	

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV
Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

temp 14.4
DO 113%
cond: 234
TDS 116
pH 7.33

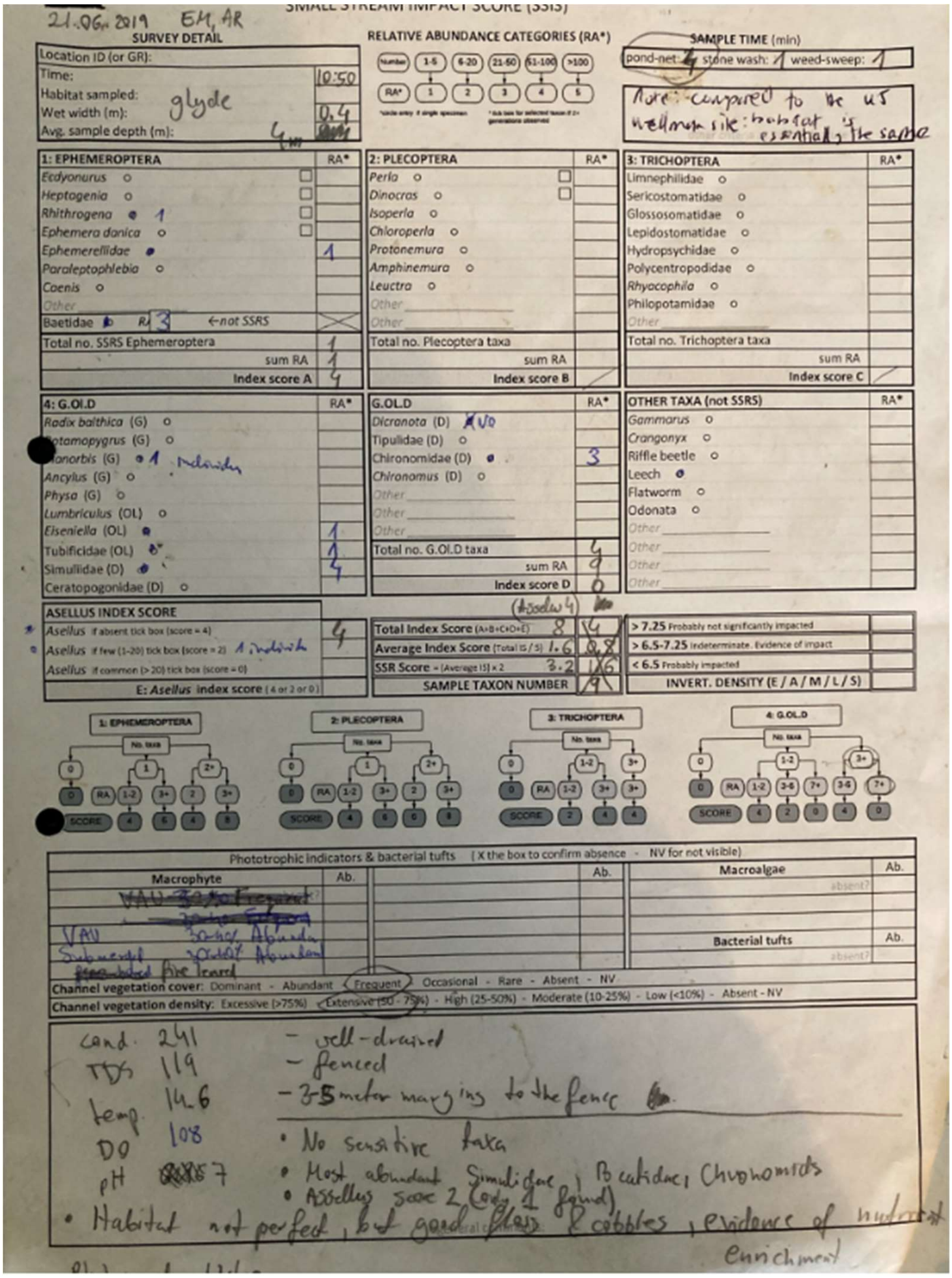
Score = 8+0+4+0+2 = 14/5
= 2.8 x 2 = 5.6

• Sensitive mayfly & larger no of ephemerellidae compared to the DS wellman site
• Dominant taxa = mayfly! compared to simulidae @ lux site
• Taxon no = almost double DS site

general comments:

> However site is D/S of 2 farms.

Fig. 7 Moynalty u/s licensed facility



SMALL STREAM IMPACT SCORE (SSIS)

21.06.2019 EM, AR

SURVEY DETAIL

Location ID (or GR):	
Time:	10:50
Habitat sampled:	glyde
Wet width (m):	0.4
Avg. sample depth (m):	4

RELATIVE ABUNDANCE CATEGORIES (RA*)

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

SAMPLE TIME (min): pond-net: 2 stone wash: 1 weed-sweep: 1

Note: compared to the u/s Wellman site: habitat is essentially the same

1: EPHEMEROPTERA	RA*
Ecdyonurus	
Heptagenia	
Rhithrogena 1	
Ephemera danica	
Ephemerellidae	1
Paraleptophlebia	
Caenis	
Other	
Baetidae RA 3 ←not SSRS	
Total no. SSRS Ephemeroptera	1
sum RA	1
Index score A	4

2: PLECOPTERA	RA*
Perla	
Dinocras	
Isoperla	
Chloroperla	
Protonemura	
Amphinemura	
Leuctra	
Other	
Other	
Total no. Plecoptera taxa	
sum RA	
Index score B	

3: TRICHOPTERA	RA*
Limnephilidae	
Sericostomatidae	
Glossosomatidae	
Lepidostomatidae	
Hydropsychidae	
Polycentropodidae	
Rhyacophila	
Philopotamidae	
Other	
Total no. Trichoptera taxa	
sum RA	
Index score C	

4: G.OI.D	RA*
Radix balthica (G)	
Potamopygrus (G)	
Planorbis (G) 1 individual	
Ancylus (G)	
Physa (G)	
Lumbriculus (OL)	
Eiseniella (OL)	1
Tubificidae (OL)	1
Simuliidae (D)	4
Ceratopogonidae (D)	

G.OI.D	RA*
Dicranota (D) NO	
Tipulidae (D)	
Chironomidae (D)	3
Chironomus (D)	
Other	
Other	
Other	
Total no. G.OI.D taxa	4
sum RA	9
Index score D	0

OTHER TAXA (not SSRS)	RA*
Gammarus	
Crangonyx	
Riffle beetle	
Leech	
Flatworm	
Odonata	
Other	
Other	
Other	
Other	

ASELLUS INDEX SCORE	
Asellus if absent tick box (score = 4)	
Asellus if few (1-20) tick box (score = 2) 1 individual	4
Asellus if common (> 20) tick box (score = 0)	
E: Asellus index score (4 or 2 or 0)	

	(Asellus 4)	
Total Index Score (A+B+C+D+E)	8	4
Average Index Score (Total IS / 5)	1.6	0.8
SSR Score = (Average IS) × 2	3.2	1.6
SAMPLE TAXON NUMBER		9

> 7.25 Probably not significantly impacted	
> 6.5-7.25 Indeterminate. Evidence of impact	
< 6.5 Probably impacted	
INVERT. DENSITY (E / A / M / L / S)	

Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
~~VAU 30% Frequent~~				absent?	
~~30% Frequent~~				Bacterial tufts	Ab.
VAU 30% Abundant				absent?	
Submerged 30% Abundant					
~~Fine leaved~~ Fine leaved					

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

Channel vegetation density: Excessive (>75%) - Extensive (50-75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

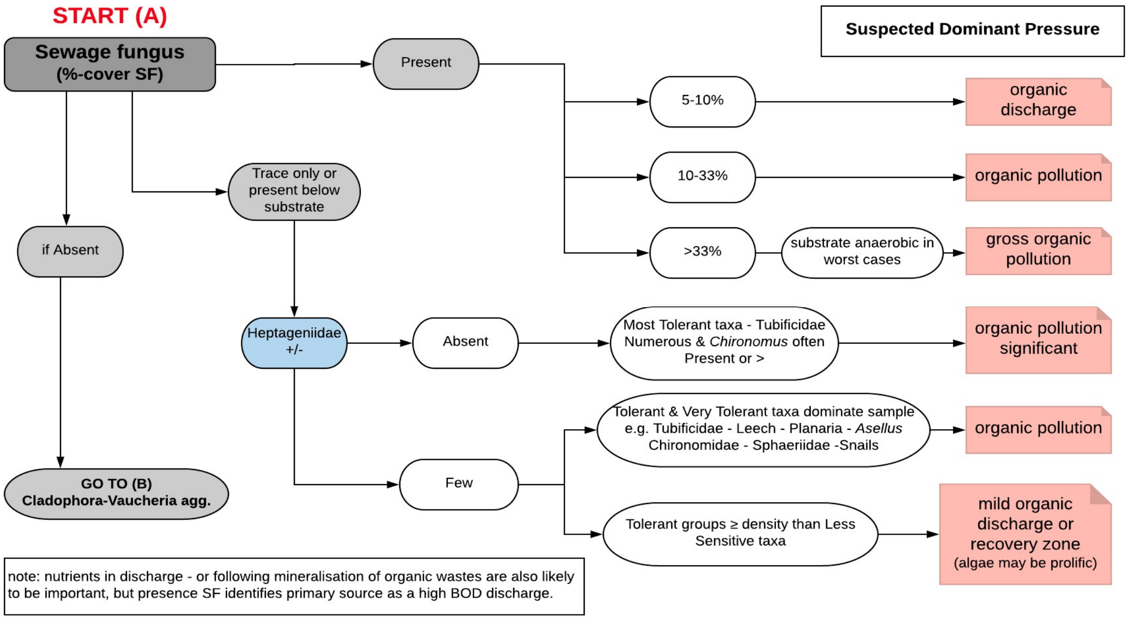
Cond. 241 — well-drained
TDS 119 — fenced
temp 14.6 — 3-5 meter margins to the fence
DO 108 • No sensitive taxa
pH 7 • Most abundant Simulidae, Baetidae, Chironomids
• Asellus score 2 (only 1 found)
• Habitat not perfect, but good flow & cobbles, evidence of nutrient enrichment

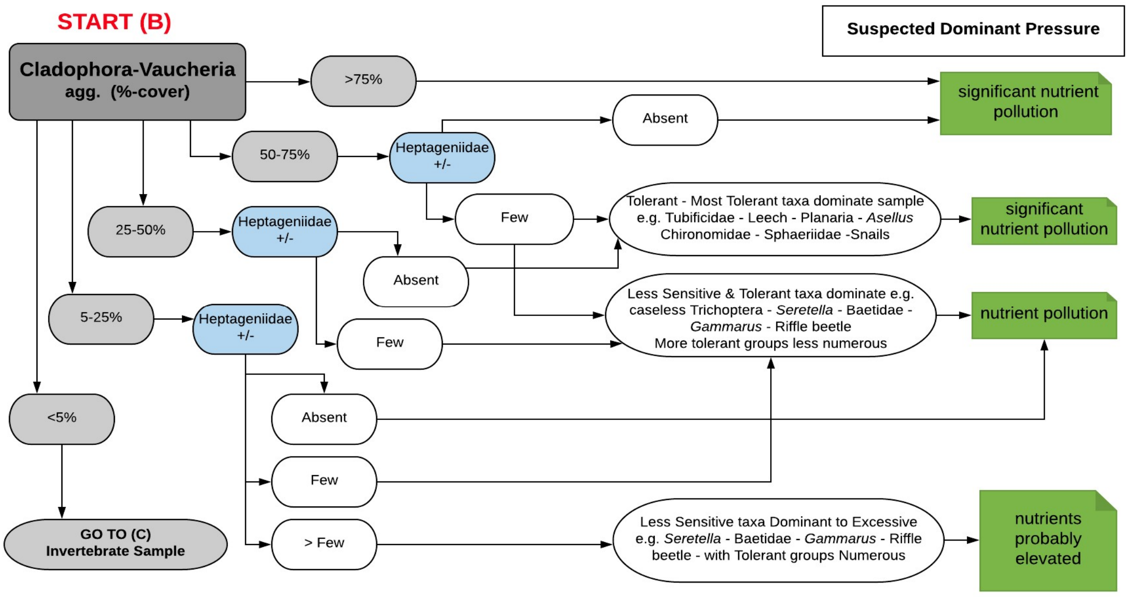
Fig. 8 Moynalty d/s licensed facility

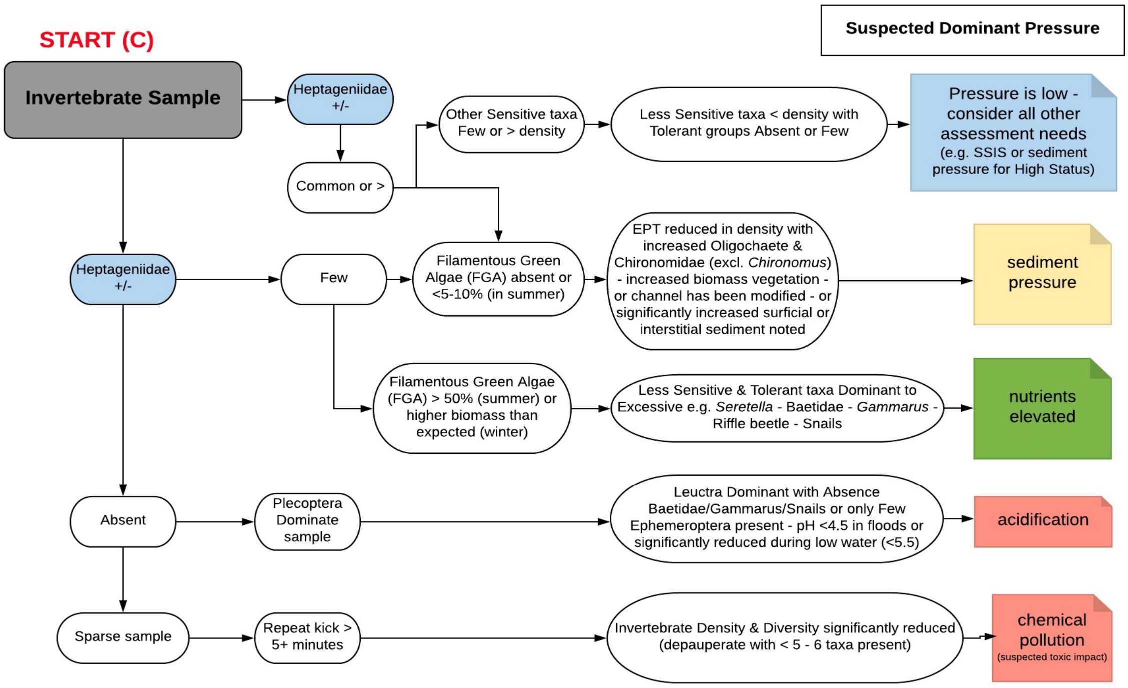
Appendix A

Local Authority waters Programme
vibrant communities | catchment assessment | healthy waters

Flow Chart for Rapid Assessment to support the identification of some significant pressures.







START (C)
Suspected Dominant Pressure
Invertebrate Sample
Heptageniidae +/-
Common or >
Other Sensitive taxa Few or > density
Less Sensitive taxa < density with Tolerant groups Absent or Few
Pressure is low - consider all other assessment needs (e.g. SSIS or sediment pressure for High Status)
Heptageniidae +/-
Few
Filamentous Green Algae (FGA) absent or <5-10% (in summer)
EPT reduced in density with increased Oligochaete & Chironomidae (excl. *Chironomus*) - increased biomass vegetation - or channel has been modified - or significantly increased surficial or interstitial sediment noted
sediment pressure
Filamentous Green Algae (FGA) > 50% (summer) or higher biomass than expected (winter)
Less Sensitive & Tolerant taxa Dominant to Excessive e.g. *Seretella* - Baetidae - *Gammarus* - Riffle beetle - Snails
nutrients elevated
Absent
Plecoptera Dominate sample
Leuctra Dominant with Absence Baetidae/Gammarus/Snails or only Few Ephemeroptera present - pH <4.5 in floods or significantly reduced during low water (<5.5)
acidification
Sparse sample
Repeat kick > 5+ minutes
Invertebrate Density & Diversity significantly reduced (depauperate with < 5 - 6 taxa present)
chemical pollution
(suspected toxic impact)

Field Guide – Biological Indicators

Small Stream Impact Score (SSIS)

Appendix D - V.1.3

2021

Table Of Contents

SMALL STREAM IMPACT SCORE (SSIS)

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

Site Name: ____________________
Date : ____________________
Time: ____________________
Habitat sampled: ____________________
Wet width (m): ____________________
Avg. sample depth (m): ____________________

Coordinates
E ____________________ N ____________________

%Substrate
Bedrock _____ Boulder _____ Cobble _____ Gravel _____
Sand _____ Silt _____ Clay _____ Marl _____ Peat _____

Shading
>75%
50-75%
25-50%
<25%

1: EPHEMEROPTERA		Ab	RA*
Ecdyonurus	o *A* ☐		
Heptagenia	o *A* ☐		
Rhithrogena	o *A* ☐		
Ephemera danica	o *A* ☐		
Paraleptophlebia	o *B*		
Ephemerellidae	o *C*		
Caenis	o *C*		
Other			
Baetidae o *C (not SISS) Ab___ RA___*			
Total no. SSIS Ephemeroptera			
sum RA			
Index score A			

2: PLECOPTERA		Ab	RA*
Perla	o *A* ☐		
Dinocras	o *A* ☐		
Isoperla	o *A*		
Chloroperla	o *A*		
Amphinemura	o *A*		
Brachyptera	o *A*		
Protonemura	o *A*		
Leuctra	o *B*		
Other			
Total no. Plecoptera taxa			
sum RA			
Index score B			

3: Trichoptera		Ab	RA*
Limnephilidae	o B		
Sericostomatidae	o B		
Glossosomatidae	o B		
Lepidostomatidae	o B		
Goeridae	o B		
Hydropsychidae	o C		
Polycentropodidae	o C		
Rhyacophila	o *C*		
Other			
Total no. Trichoptera taxa			
sum RA			
Index score C			

4: G.OI.D		Ab	RA*
Radix balthica (G)	o D		
Potamopygrus (G)	o *C*		
Planorbis (G)	o *C*		
Ancylus (G)	o *C*		
Physa (G)	o D		
Lumbriculus (OL)	o -----		
Eiseniella (OL)	o -----		
Tubificidae (OL)	o E		
Simuliidae (D)	o C		
Ceratopogonidae (D)	o C		

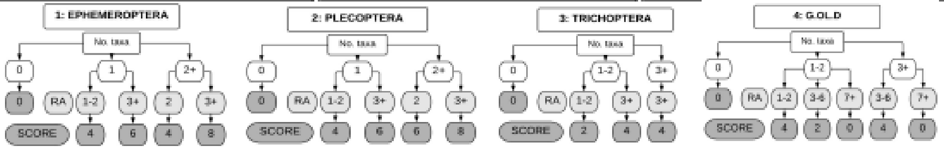
G.OI.D		Ab	RA*
Dicranota (D)	o *C*		
Tipulidae (D)	o C		
Chironomidae (D)	o C		
Chironomus (D)	o *E*		
Other			
Other			
Other			
Total no. G.OI.D taxa			
sum RA			
Index score D			

OTHER TAXA (not SSIS)		Ab	RA*
Gammarus	o *C*		
Crangonyx	o *D*		
Riffle beetle	o C		
Leech	o D		
Flatworm	o C		
Odonata	o B		
Crayfish	o C		
Other			
Other			
Other			

ASELLUS INDEX SCORE	
Asellus o *D* if absent tick box (score = 4)	
Asellus o *D* if few (1-20) tick box (score = 2)	
Asellus o *D* if common (> 20) tick box (score = 0)	
E: *Asellus* index score (4 or 2 or 0)	

Total Index Score (A+B+C+D+E)		
Average Index Score (Total IS / 5)		
SSI Score = (Average IS) x 2		
SAMPLE TAXON NUMBER		

> 7.25 Probably not significantly impacted		
> 6.5-7.25 Indeterminate. Evidence of impact		
< 6.5 Probably impacted		
INVERT. DENSITY (E / A / M / L / S)		



Macrophyte	Cover	Macroalgae	Cover	*Proportion of sample (inverts)*	*EDNCFP*
absent?		Cladophora		*Here indicate if Excessive, Common...*	
		Vaucheria		Class A	
				Class B	
				Class C	
		Bacterial tufts		Class D	
		absent?		Class E	

Channel vegetation % Cover : Excessive (>75%) - Dominant (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

Invert proportions : *Excessive (>75%) - Dominant (51-75%) - Numerous (21-50%) - Common (6-20%) - Few (1-5%) - Present (1-2 individuals)*

general comments:

Rapid assessment. Noted important Taxa in the comment box
Circle answers and use the results to follow the RA flow chart

Site name__________ **Date**________ **Time** ______ **Coordinates**____________					
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

Site name__________ **Date**________ **Time** ______ **Coordinates**____________					
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

Site name__________ **Date**________ **Time** ______ **Coordinates**____________					
Sewage fungus	Absent	Trace	5-10%	10-33%	>33%
Cladophora-Vaucheria or FGA	<5%	5-25%	25-50%	50-75%	>75%
Heptageniidae	Absent	Few	>Few	Common	>75%
Plecoptera	Absent	Few	Common	Dominant	
Most Tolerant Taxa	Dominant		Not Dominant		
Less Tolerant	Dominant		Not Dominant		
Most Tolerant Density > Less Sensitive Taxa Density				Yes	No
Over all density very low?				Yes	No
Number of taxa > 6				Yes	No
Probes DO Ph Con Temp	Flow Chart Result and any notes.				

Biological Indicator Lookup Tables for Small Stream Impact Score (SSIS)

Habitat sampled for kick (the predominate or add multiple categories)	
riffle	R
glide	G
pool	P
margins	M

All relevant Habitat criteria must be noted on Master Sheet (e.g.)
substrate quality
extent siltation & compaction
extent of shading if significant
extent calcification if present

Invertebrate Sample Density (intermediate categories can be used on fieldsheet)	
Excessive	E
Abundant	A
Moderate	M
Low	L
Very sparse	S

Invertebrate Density for RA (intermediate categories can be used on fieldsheet)	
Excessive	E
Abundant	A
Moderate	M
Low	L
Very few	S
Absent	AB

MAL Cover observation (indicative %-cover for guidance only)	
Dominant (>75%)	D
Abundant (>50%- ≤75%)	A
Frequent (>25%- ≤50%)	F
Occasional (>5%- ≤25%)	O
Rare (≤5%)	R
Absent	Ab
Not visible	NV
Not surveyed	NS

MYP Cover observation (indicative %-cover for guidance only)	
Dominant (>75%)	D
Abundant (>50%- ≤75%)	A
Frequent (>25%- ≤50%)	F
Occasional (>5%- ≤25%)	O
Rare (≤5%)	R
Absent	Ab
Not visible	NV
Not surveyed	NS

Invertebrate Indicator (INV)	
Sensitive taxa	SENV
Less Sensitive taxa	LSEV
Tolerant taxa	TOLI
Very Tolerant taxa	VTOL
Most Tolerant taxa	PTOL
Heptageniidae	**HPT**
Ecdyonurus	**ECD**
Ephemoptera-Plecoptera-Trichoptera	**EPT**
Baetidae	**BAT**
Snails	**SNL**
Chironomidae	**CHR**
Simuliidae	**SIU**
Gammarus	**GAM**
Asellus	**ASL**
Tubificidae	**TUB**
Invertebrate community depapurate	**INVD**

Macroalgal Indicators (MAL)	
Cyanobacterial mat	CYMT
Cladophora agg.	CLAD
Vaucheria	VAU
Filamentous green algae	FGA
Stigeoclonium	STIC
Ulva	ULVA
Drapnaraldia	DRAP
Batrachospermum	BRTC
Lemanea	LEMA
Thickened biofilm	TBIO
Filamentous diatoms	FDIA
Mucilaginous diatoms	GDIA
Didyomosphenia	DIDY
Calcified algae	CALH
Nostoc	NOSC
Cyanobacterial colonies	CYMC
Chaetophora	CHA
Other macroalgae	OMAC
FGA - low alkalinity community	FGLA
Bulbochaete	BULB
Stigonema	STIG

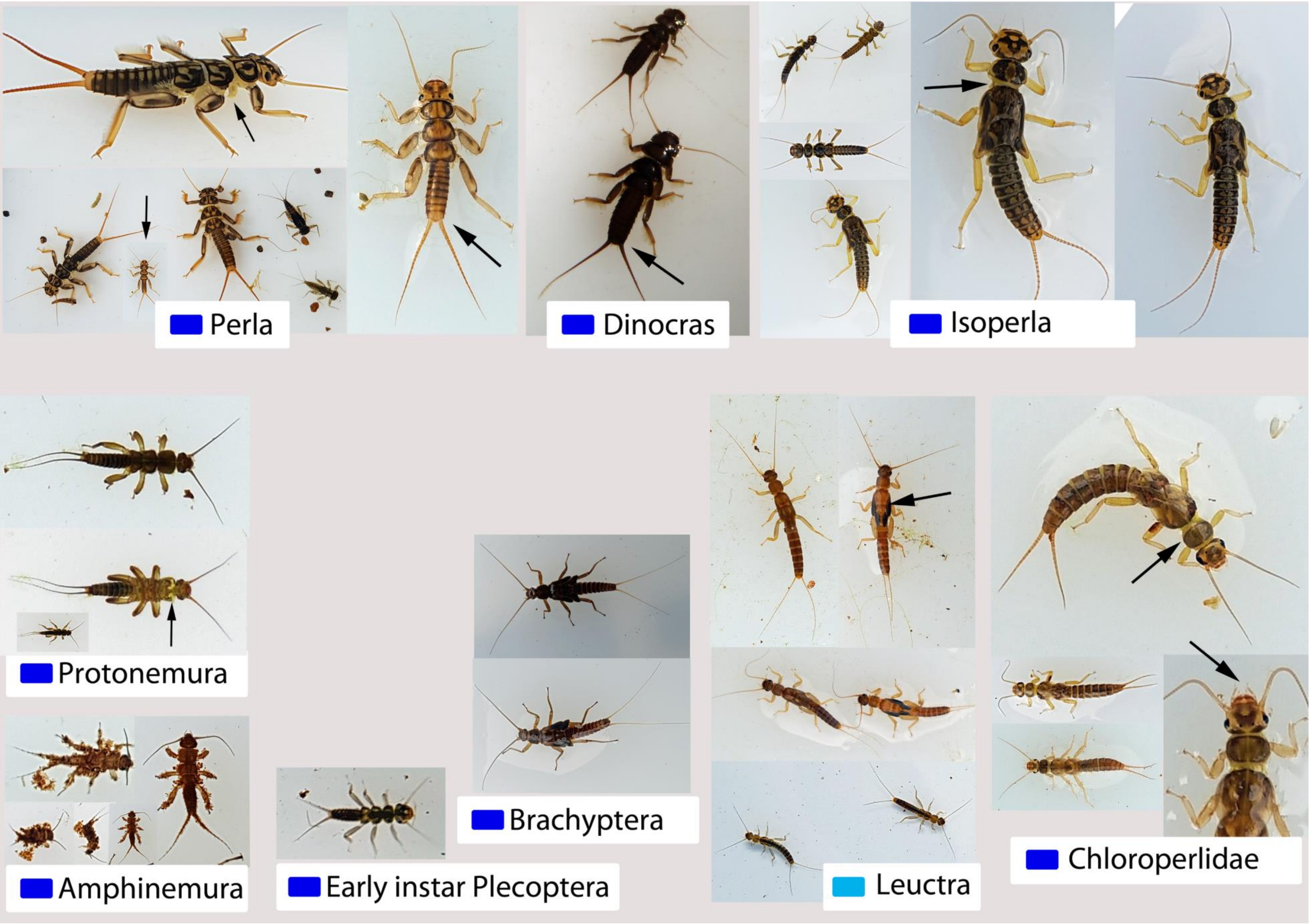
Macrophyte Indicator (MPY)	
Channel vegetation biomass	PTBI
Emergent vegetation	EVG
Bryophyte	BRYO
Moss	MOS
Liverwort (acid-very acid taxa only)	LIVT
Emergent broad-leaved	EBLV
Emergent reeds/sedges/rushes	ERSR
Floating-leaved (rooted)	FLOT
Free floating	FREE
Amphibious	AMPH
Submerged broad-leaved	SBLV
Submerged linear-leaved	SLLV
Submerged fine-leaved	SFLV
Opportunistic algae	OPPA
Leptodictyon riparium	LPYR
Sparganium erectum	SPER
Schoenoplectus	SCIP
Fontinalis antipyretica	FATY
Fontinalis squamosa	FSQA
Ranunculus	RAN

Invertebrate Indicators (INV)

Some commonly occuring and widespread indicator for SSIS

(list is not intended to be exhaustive)

Page	Indicator		Common name	Group I (Order etc.)	Group II (Family etc.)	Taxon (Index taxa & others that maye be encountered in species lists)
5	Sensitive taxa	SENV	Mayflies	Ephemeroptera	Heptageniidae	Ecdyonurus, Heptagenia (incl. Electrogena & Kageronia), Rhithrogena
6	Sensitive taxa	SENV	Mayflies	Ephemeroptera	Ephemeridae	*Ephemera danica*
6	Sensitive taxa	SENV	Mayflies	Ephemeroptera	Siphlonuridae & other Mayfly	Siphlonurus (localised) & some rarer or less commonly encountered taxa.
4	Sensitive taxa	SENV	Stoneflies	Plecoptera	Perlidae	Perla, Dinocras
4	Sensitive taxa	SENV	Stoneflies	Plecoptera	Perlodidae	Isoperla (also Diura but rarer)
4	Sensitive taxa	SENV	Stoneflies	Plecoptera	Chloroperlidae	Chloroperla, Siphonoperla
4	Sensitive taxa	SENV	Stoneflies	Plecoptera	Nemouridae	Protonemura, Amphinemura (Nemoura & Nemurella)
4	Sensitive taxa	SENV	Stoneflies	Plecoptera	Taeniopterygidae	*Brachyptera risi*
-	Sensitive taxa	SENV	Stoneflies	Plecoptera	Capniidae	Capnia (laboratory confirmation typically required to separate from Leuctra)
10	Sensitive taxa	SENV	Pearl Mussel	Unionidae	Margaritiferidae	*Margaritifera margaritifera*
	Indicator		Common name	Group I (Order etc.)	Group II (Family etc.)	Taxon (Index taxa & others that maye be encountered in species lists)
6	Less Sensitive taxa	LSEV	Mayflies	Ephemeroptera	Leptophlebiidae	Paraleptophlebia & Leptophlebia
6	Less Sensitive taxa	LSEV	Mayflies	Ephemeroptera	Baetidae	All Baetidae excluding *B. rhodani* (e.g. *Alainites muticus*)
4	Less Sensitive taxa	LSEV	Stoneflies	Plecoptera	Leuctridae	Leuctra
9	Less Sensitive taxa	LSEV	Dragonflies & Damselflies	Odonata	Anisoptera & Zygoptera	Anisoptera, Zygoptera
7	Less Sensitive taxa	LSEV	Cased Caddisflies	Trichoptera	All Cased Trichoptera	Glossosomatidae, Goeridae, Hydroptilidae, Lepidostomatidae, Limnephilidae, Sericostomatidae etc.
	Indicator		Common name	Group I (Order etc.)	Group II (Family etc.)	Taxon (Index taxa & others that maye be encountered in species lists)
6	Tolerant taxa	TOLI	Mayflies	Ephemeroptera	Baetidae	*Baetis rhodani*
6	Tolerant taxa	TOLI	Mayflies	Ephemeroptera	Ephemerellidae	Ephemerella (incl. Serratella)
6	Tolerant taxa	TOLI	Mayflies	Ephemeroptera	Caenidae	Caenis
8	Tolerant taxa	TOLI	Caseless Caddisflies	Trichoptera	All Caseless Trichoptera	Hydropsyche, Rhyacophila, Polycentropus, Philopotamus
9	Tolerant taxa	TOLI	Water Beetles	Coleoptera	Elmidae & others	Riffle beetle & other beetles e.g. *Orechtochilus villosus*
11	Tolerant taxa	TOLI	Midges, Blackflies, Craneflies	Diptera	Dipteran	All except Chironomus - e.g. Simuliidae, Chironomidae, Dicranota, Tipula
9	Tolerant taxa	TOLI	Shrimp	Amphipoda	Gammaridae	Gammarus, (but excluding Crangonyx)
9	Tolerant taxa	TOLI	Freshwater crayfish	Decapoda	Astacidae	*Austropotamobius pallipes*
11	Tolerant taxa	TOLI	Flatworms	Tricladida	Planariidae - Dugesiidae etc.	Planaria, Dugesia, Dendrocoelum
10	Tolerant taxa	TOLI	Snails & Limpets	Gastropoda	Gastropods	Potamopygrus, Ancylus, Planorbis (excluding Radix & Physa)
	Indicator		Common name	Group I (Order etc.)	Group II (Family etc.)	Taxon (Index taxa & others that maye be encountered in species lists)
9	Very Tolerant taxa	VTOL	Waterlouse	Isopoda	Asellidae	Asellus
9	Very Tolerant taxa	VTOL	Shrimp	Amphipoda	Crangonyctidae	Crangonyx
9	Very Tolerant taxa	VTOL	Alderfly	Megaloptera	Sialidae	Sialis
10	Very Tolerant taxa	VTOL	Pond & bladder snails	Gastropoda	Lymnaeidae, Physidae	*Radix balthica* , Physa
10	Very Tolerant taxa	VTOL	Cockles - "orb & *pea mussels"*	Veneroida	Sphaeriidae	Sphaerium, Pisidium
11	Very Tolerant taxa	VTOL	Leeches	Hirudinea	All Leech	Glossophonia, Erpobdella (excl. Piscicola - which is a tolerant taxa)
	Indicator		Common name	Group I (Order etc.)	Group II (Family etc.)	Taxon (Index taxa & others that maye be encountered in species lists)
11	Most Tolerant taxa	PTOL	Sludge worms	Oligochaeta	Tubificidae	Tubifex
11	Most Tolerant taxa	PTOL	Chironomus	Diptera	Chironomus	Chironomus



Stoneflies

Diversity higher in Autumn-Spring period. Record incidence of multiple generations for Perla & Dinocras.

Perla & Dinocras - Large stoneflies with distinct **gills** protruding at thorax. Dinocras is darker brown including **final abdominal segment** which is distinctly lighter coloured in Perla.

Isoperla - Medium sized robust nymphs are olive-green with a light pattern of dorsal markings (can be obscured by dark hairs). Paler yellow ventrally. **No gills.**

Chloroperlidae - Distinctly **oval** pronotum and wing cases in mature nymphs somewhat rounded relative to Leuctra which is superficially similar in appearance.

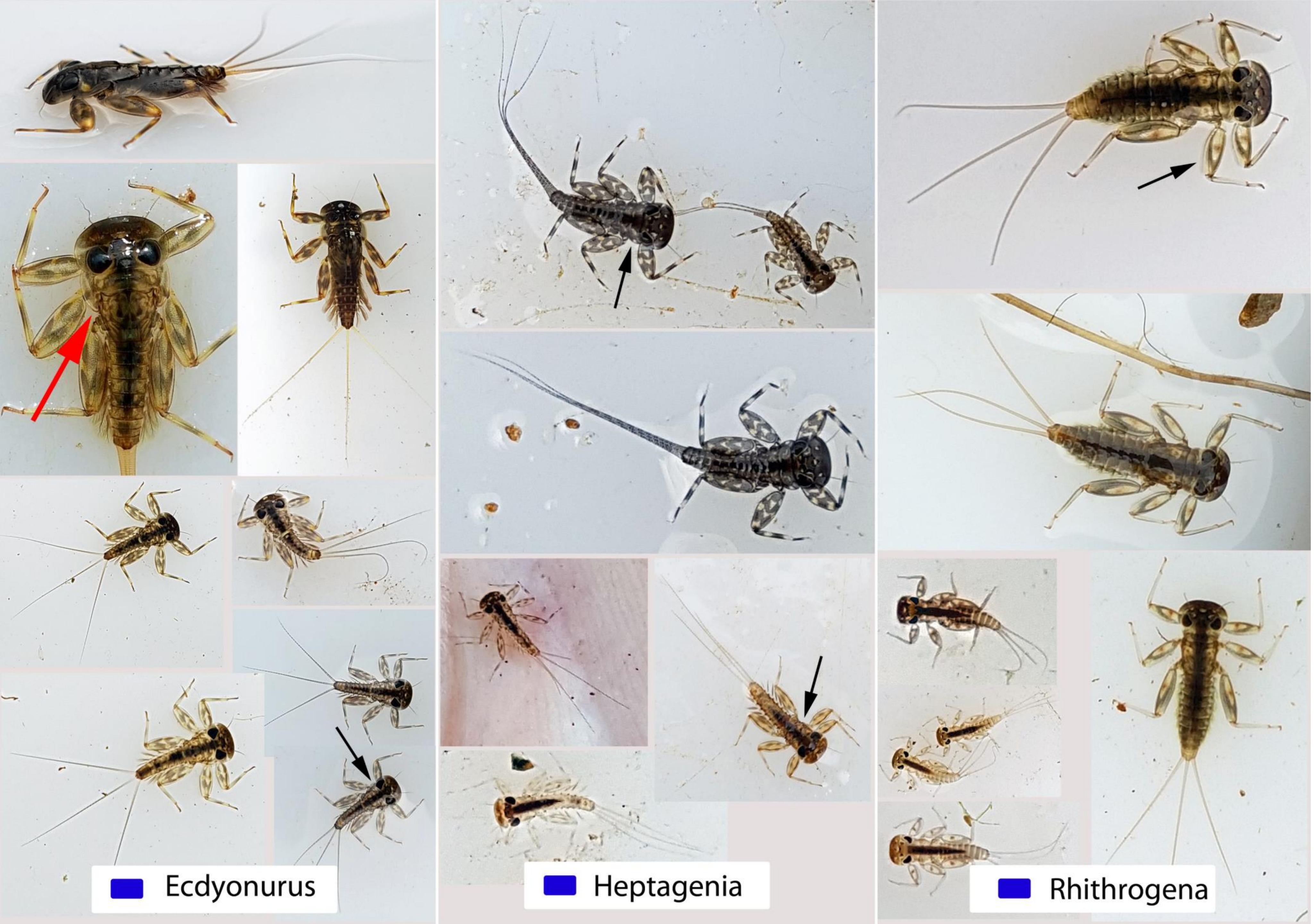
Leuctra - Small **slender nymphs** with short hindlegs. Wing buds in later instars in line with abdomen giving streamlined appearance. Very common. (Capnia is difficult to separate!)

Brachyptera - Very dark coloured with **long antennae** and thrashes “deliberately” from side to side when hanging in water. Distinctive **plate** on last ventral segment.

Protonemura - Small dark stout nymphs – 3 sausage shaped **gills** on each side of prosternum (handlense for small nymphs).

Amphinemura – Crawling **very small** dark and typically heavily **covered in silt** with feathery white gills on underside prosternum (handlense!!!).

Other Stoneflies – other localised or early instar stoneflies can be recorded as Plecoptera other.



Heptageniidae

- Important group of pollution sensitive “stone-clingers” distinguishable in the field.
- Important to note multiple **instars** or “generations” (distinctly larger versus smaller nymphs co-occurring in the sample).
- Very earliest instars of Ecdyonurus and Heptagenia can be difficult to separate – a handlense and favourable lighting often required to do this in the field.

Ecdyonurus

- Backward **projection** on pronotum gives “wider” appearance – diagnostic for Ecdyonurus.

Heptagenia

- **Lacks** backward **projection** giving narrower profile.
- (includes Electrogena & Kageronia)

Rhithrogena

- Distinctive **spot** visible on femur of each leg.

Other Mayfly

Ephemera Danica

Creamy-brown elongate nymphs with gills over back of abdomen. A burrowing nymph of softer sediments, swimming with undulations of body. Record multiple generations if observed.

Ephemerellidae

Stout brown clinging nymphs with a barred pattern on legs and often also on tail. Small waving dorsal gills over abdomen.

Caenidae

Very small squat nymphs having two obvious plates on top of abdomen. Crawling and covered in silt particles somewhat.

Baetis rhodani

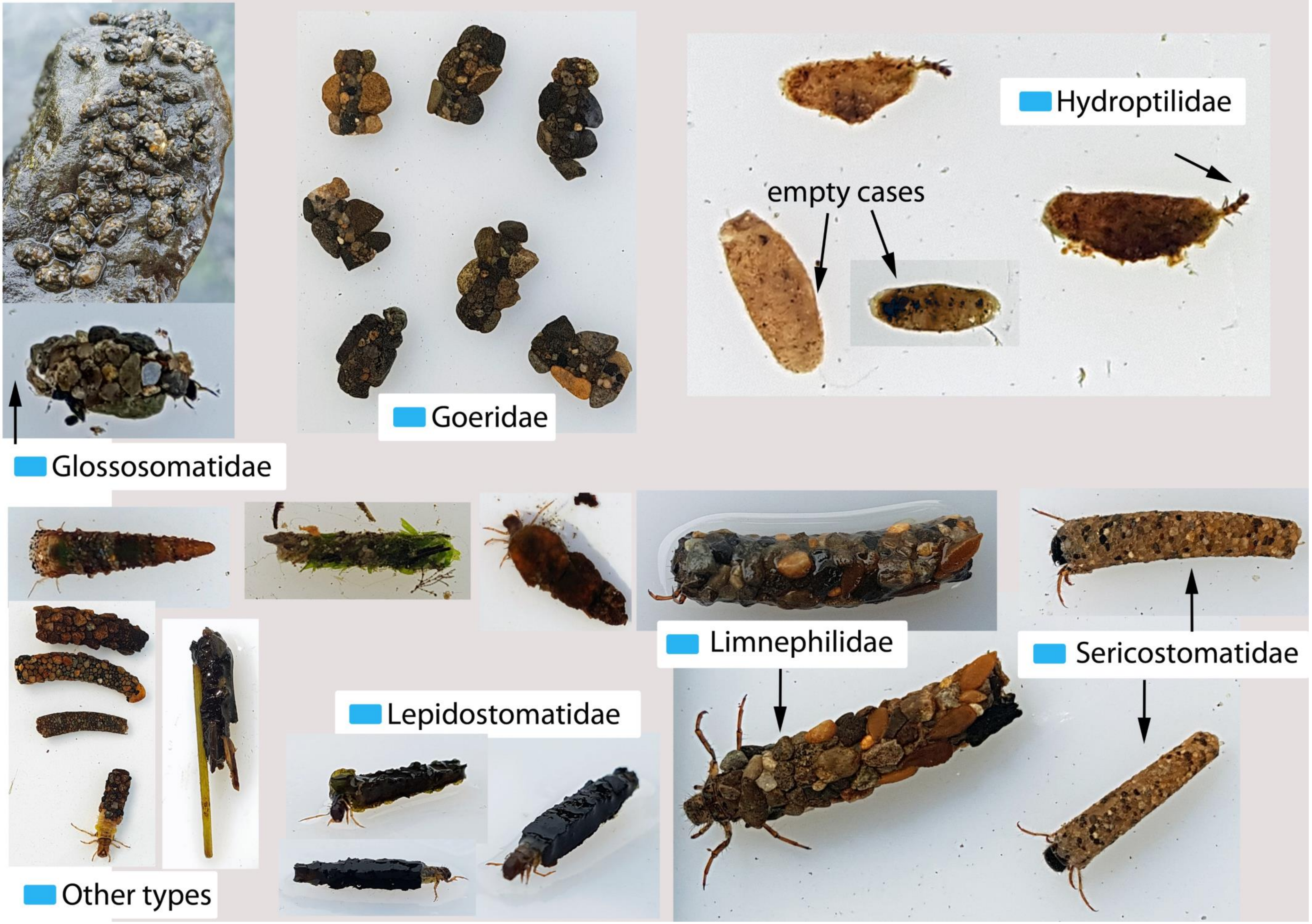
Swimming mayfly, often in short bursts. Cylindrical tapered body with shorter middle tail. Black median band at centre of tail absent. The commonest mayfly and often forming large densities in corner of tray. *Alainites muticus* (syn. *Baetis muticus*) has a narrower darker body with quite closely set antennae. Other species are less widespread and referred to as Baetidae in species lists.

Leptophlebiidae

Superficially similar body shape to Baetidae but smaller and darker with finely branching (forked) gills from abdomen.

Siphlonurus (and others)

Some localised and less well distributed mayfly occasionally may be encountered.



Cased Caddisflies

- Cases may be fixed to substrate or mobile.
- A relative comparison of difference in total numbers of taxa between reaches can be important (e.g. in potamon rivers).
- **Empty cases are not counted**.

Glossosomatidae

- Cases made of small stones (10 x 5 mm). Flat bottom with convex dorsal surface.
- Often crowded together on stable substrate.

Goeridae

- Similar size and habitat to above but easily identified by larger stones along lateral edges (for ballast) with case composed of finer sand.

Hydroptilidae

- Very small compressed cases made of fine sand - like a small seed.

Sericostomatidae

- Curved cases made of coarse sand with a very smooth finish.

Limnephilidae

- Diverse range of materials used to construct cases – from coarse stones to vegetation.

Lepidostomatidae

- Cases square in cross section and constructed of vegetation.

Caseless Caddisflies

- Four common and easy to identify indicator taxa described here.

Hydropsyche

- Dark brown plates on dorsum (1^{st}-2^{nd}-3^{rd} segments).
- Tufted gills from **underside** of abdomen.
- **Brush** like bristles on anal prolegs "swished" from side to side when hanging in water.

Rhyacophila

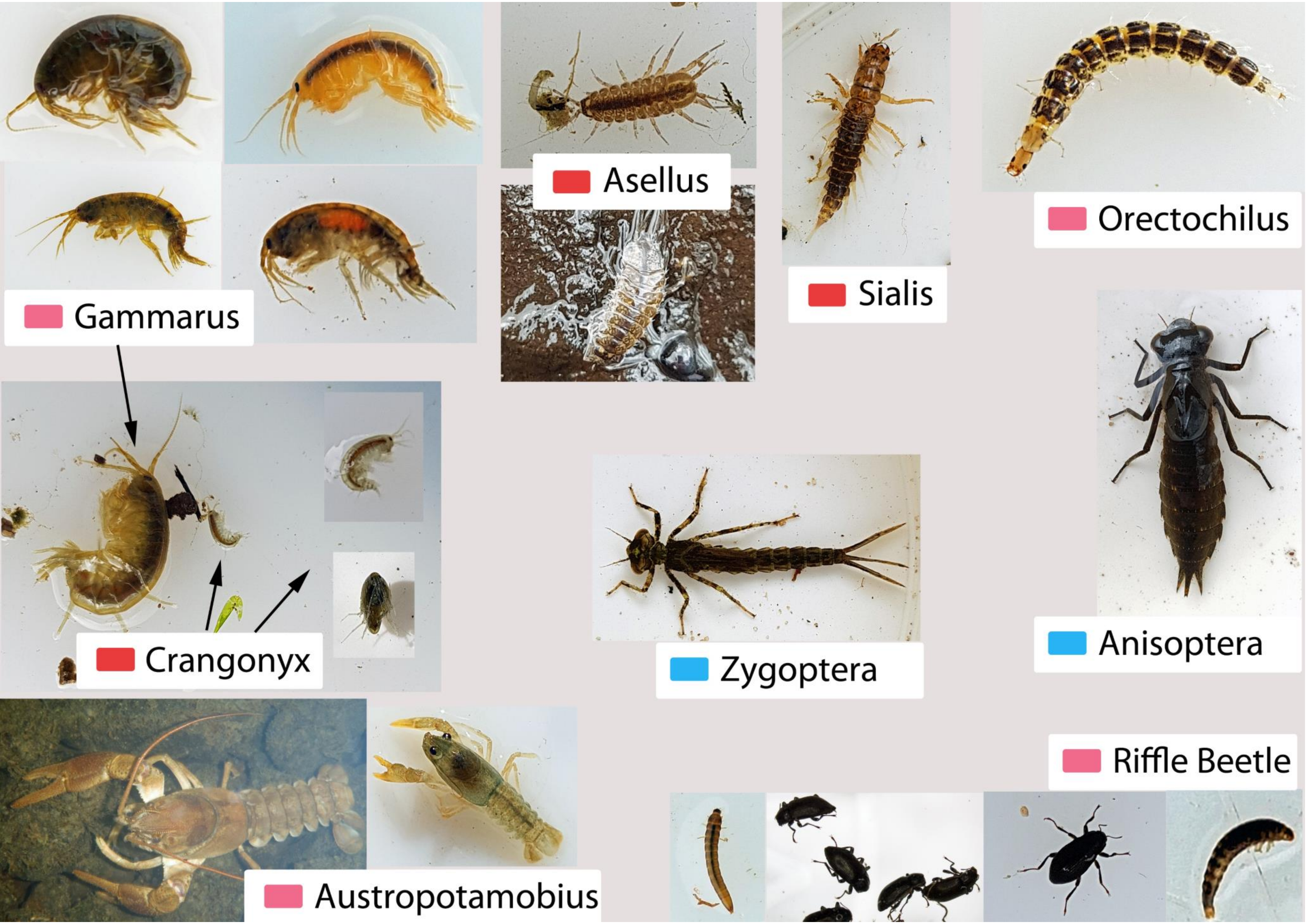
- Greenish with filamentous **gills** projecting **laterally** from sides of abdomen.
- Note pupal case

Polycentropus

- No gills on abdomen.
- Long basal segment on anal proleg.
- Often "**pinkish**" colouration.

Philopotamus

- No gills on abdomen.
- Typically **orange** – brown head and pronotum, with **paler** body.



Other groups

Gammarus

- Freshwater shrimp. Yellow-brown with adults swimming on their side.

Crangonyx

- Smaller than Gammarus. Light blue-grey colouration. Walk upright.

Asellus

- Resembles a woodlouse. 7 pairs of walking legs. Dorso-ventrally flattened and grey-brown in colour.

Sialis

- Alderfly larva – body tapers to long tail with 7 pairs of lateral gills. Powerful mandibles with teeth.

Orectochilus villosus

- Beetle larva – small narrow orange head with distinct mandibles.

Anisoptera

- Dragonfly larva – stout nymphs with short spine like terminal appendages. Slow crawler.

Zygoptera

- Slender nymphs with three leaf-like appendages. Swims gracefully with undulations of abdomen.

Riffle Beetle

- Several species of small black crawling beetles. Larvae also distinctive. Many other beetle taxa and can be recorded as Beetle other.

Austropotamobius pallipes

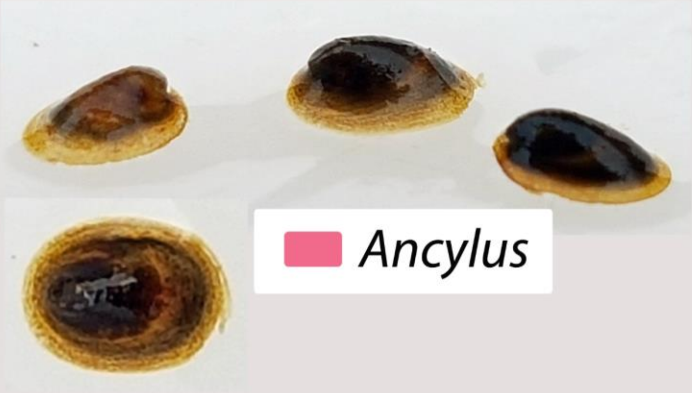
- Freshwater crayfish – remember to disinfect and dry gear thoroughly between waterbodies.

Margaritifera

Dreissena

Sphaeriidae

Potamopygrus



Ancylus

Planorbis

Radix balthica

Snail – Limpet – Mussel

Snails with apertures opening to the right are “dextral” and those opening to the left are “sinstral” (when turned upside down with spire facing away from you).

Margaritifera – Large dark bivalves with robust heavy shells eroded at the hinge. Protected species of high conservation importance: visual estimates only and return carefully if accidentally disturbed.

Sphaeriidae – Small delicate whitish-yellow bivalves.

Potamopygrus – small dark coloured snails – no operculum (cf. Bithynia).

Ancylus – Small oval thin walled river limpet.

Planorbis – Flattened and coiled shell.

Radix balthica – (syn. *Lymnaea peregra*) Dextral without operculum. Short pointed spire. Shell not translucent. Several other closely related species differ in shape of shell.

Physa – (no picture - see SSRS) Thin shiny ovoid shaped shells (sinstral).

Others – new records of Zebra mussel and Asian clam (Corbicula) to be reported.

Leeches – Worms – Midge

Flatworms (Triclads) - Free-living contractile flattened worms – dark black to creamy white in colour.
Leeches - Body with suckers at both ends, without obvious head structure.
Tubificidae - Delicate translucent red coloured worms, forming coils.
Eiseniella - Aquatic segmented work with distinctive clitellum. Cylindrical forward of the clitellum but square in cross section to the rear.
Lumbriculus - Segmented reddish brown worm with an iridescent green sheen. Never coils and swims with powerful wriggling motion. Fragments easily.
Chironomidae - Small "worm-like" with visible head, prolegs and legs. Variously coloured, including red.
Chironomus - As above, always red but has additional 4 tubular ventral gills on last segment. MUST NOT BE RECORDED UNLESS PRESENCE OF GILLS IS CONFIRMED.
Ceratopogonidae - Small very slender transparent. Weak swimmer - lashing from side to side.
Simullidae – Club shaped body with a swollen posterior end – readily attaches to tray. Often very high densities downstream of lakes or on Ranunculus.
Tipulidae – Maggot like (creamy coloured) with 6 lobes around spiracular disc.
Dicranota – Maggot like with 5 pairs well developed prolegs and 2 long appendages on abdominal tip.

Page	Macroalgal Indicators	Code	Description
13	Sewage fungus	SWF	Slimy or only slightly textured white-brown coloured - below organic discharge
14	Cyanobacterial mat	CYMT	**Musty organic mats** that are often shiny blue-black on the surface, slimy and thickened- many produce dangerous toxins and have known to kill animals after material ingested
18	Cladophora agg.	CLAD	An important indicator - check for **branching** (some forms are poorly branching but less common). Rhizoclonium included here
18	Vaucheria	VAU	Mole **pelt algae** forming distinctive dark green "velvety" prostrate mats
17	Filamentous green algae	FGA	a "catch-all" name for a diverse range of **unbranched filamentous algae**
17	Stigeoclonium	STIC	A branching but typically very **slimy bright green** alga - often abundant in Spring, especially in siliceous uplands (or below metal contaminated streams, with a further form thriving below organic discharges)
17	Ulva	ULVA	Also often recorded as Enteromorpha - bright green or yellow-green **irregular** in outline and **soft textured**
17	Draparnaldia	DRAP	Mucilaginous amorphous and **minutely branched** - only slightly beaded and light green coloured
15	Batrachospermum	BAT	Frogspawn alga - **gelatinous slimy beaded** branched red algae that collapses in hand - from near purple to olive green in colour.
15	Lemanea	LEMA	Coarse textured, **firm tapering** and slightly branching filaments that are olive green in colour
16	Enhanced biofilm	EBIO	When a **brown slimy film** over substrate is extensive, or the biofilm is becomming excessively thickened in otherwise high status oligotrophic rivers
16	Filamentous diatoms	FDIA	Typically brown or lighter coloured filaments that **fragment** and break up readily when disturbed (i.e. nearly impossible to pick up)
16	Mucilaginous diatoms	GDIA	Mucilaginous **diatom blobs** having a loose or undefined amorphous structure
16	Didyomosphenia	DIDY	Has a texture like **cotton wool** - clean white or dirty brown (indicates older colony covered in epiphytes)
20	Calcified algae	CALH	**Hard and calcareous - blue-grey colour** and found on the top surface of calcified substrates (*Phormidium incrustatum* agg.)
19	Nostoc	NOSC	Amorphous but **firm textured olive coloured** colonies - nitrgoen fixing.
19	Cyanobacterial colonies	CYMC	Small round dark brown-black or drab green **hardened colonies** - rare. (3mm diameter to macroscopically much more significant).
19	Chaetophora	CHA	Small light green balls or colonies that have a **jelly like** consistency and can be easily squashed between fingers
19	Other macroalgae	OMAC	a "catch-all" name for any amophus **unidentifiable macroalgal forms** that cannot be identifed and are sufficiently abundant to indicate something about the system (cf. not a trivial encounter!)
20	FGA - (low alkalinity community)	FGLA	For a mixed **low alkalinity community** - composed of several species like Moeugotia, Bulbochaete, Stigonema and other macroalgae often present
20	Bulbochaete	BULB	Short **prostrate yellow-green** filamentous algae.
20	Stigonema	STIG	**Black coarse prostrate mat** growing in the splash zone on stable rocks - often overlooked.

Sewage Fungus

"Bacterial tufts" is a WFD name for the variety of heterotrophic slimes (incl. fungus & protozoa) that are more commonly known as sewage fungus (SF).

With elevated concentrations of biodegradable organic matter in a discharge, massive quantities can develop, even with low winter temperatures.

Growths quickly disappear with collapse of colonies following as quickly, with cessation of discharges. The greater biomass of SF may be susceptible to loss owing to increased shear stress during higher water levels. It may often only be detectable under cobble substrate (e) or be reduced to areas of marginal vegetation (f) in these cases.

Further declines in oxygen may result in anoxia of gravel substrate (becomes blackened with a smell of hydrogen sulphide) where oxygen exchange is impeded in this habitat (a). Only the most pollution tolerant invertebrates (Tubifex & Chironomus) will tolerate these conditions (a - inset).

The source of the discharge can often be traced back to individual locations and should be rectified quickly when temperature is high or water levels are low.

Freshwater sponge or Didymosphenia may be misidentified as SF, but these organisms have a coarser texture (SF is typically slimy). The extent, density and other relevant features should be noted (surface-subsurface occurrence, or significant anoxia if present).

Cyanobacterial Mats

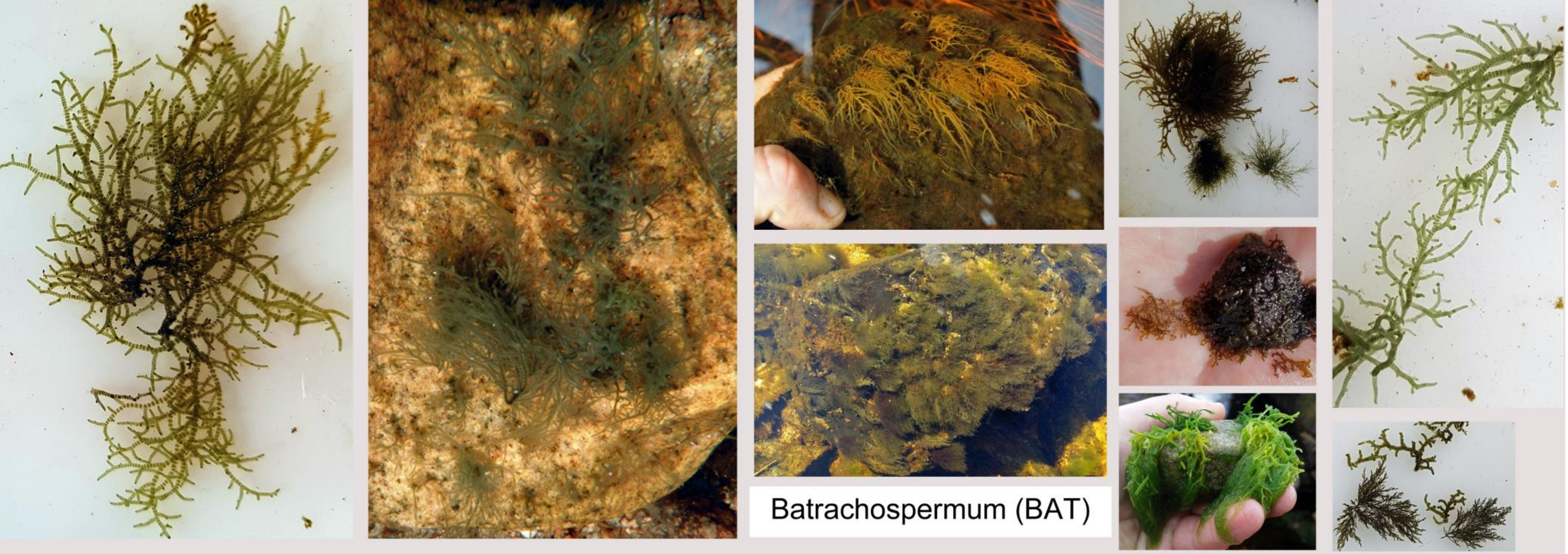
“Musty organic mats” or cyanobacteria are often overlooked on the river bed because of their general dark colouration, although they can be widespread.

A variety of organisms (Phormidium, Lyngbya or Oscillatoria sp.) form these unmistakable thickened mats.

They typically have a dark shiny blue-black surface, sometimes with bubbles of oxygen on the top surface of the leathery mats giving a silvery appearance.

THEY HAVE A VERY MUSTY SMELL.

THEY PRODUCE A RANGE OF TOXINS that are very potent and dangerous in relatively small amounts – killing dogs and livestock that ingest material washed up on shorelines.



Batrachospermum (BAT)

A “Red alga” – varying in colour from olive green (typically) but golden brown, dark brown, bright yellow-green, or almost blue-green to violet-black.

Known as frogspawn alga because of its unmistakable texture – slippery and beaded.

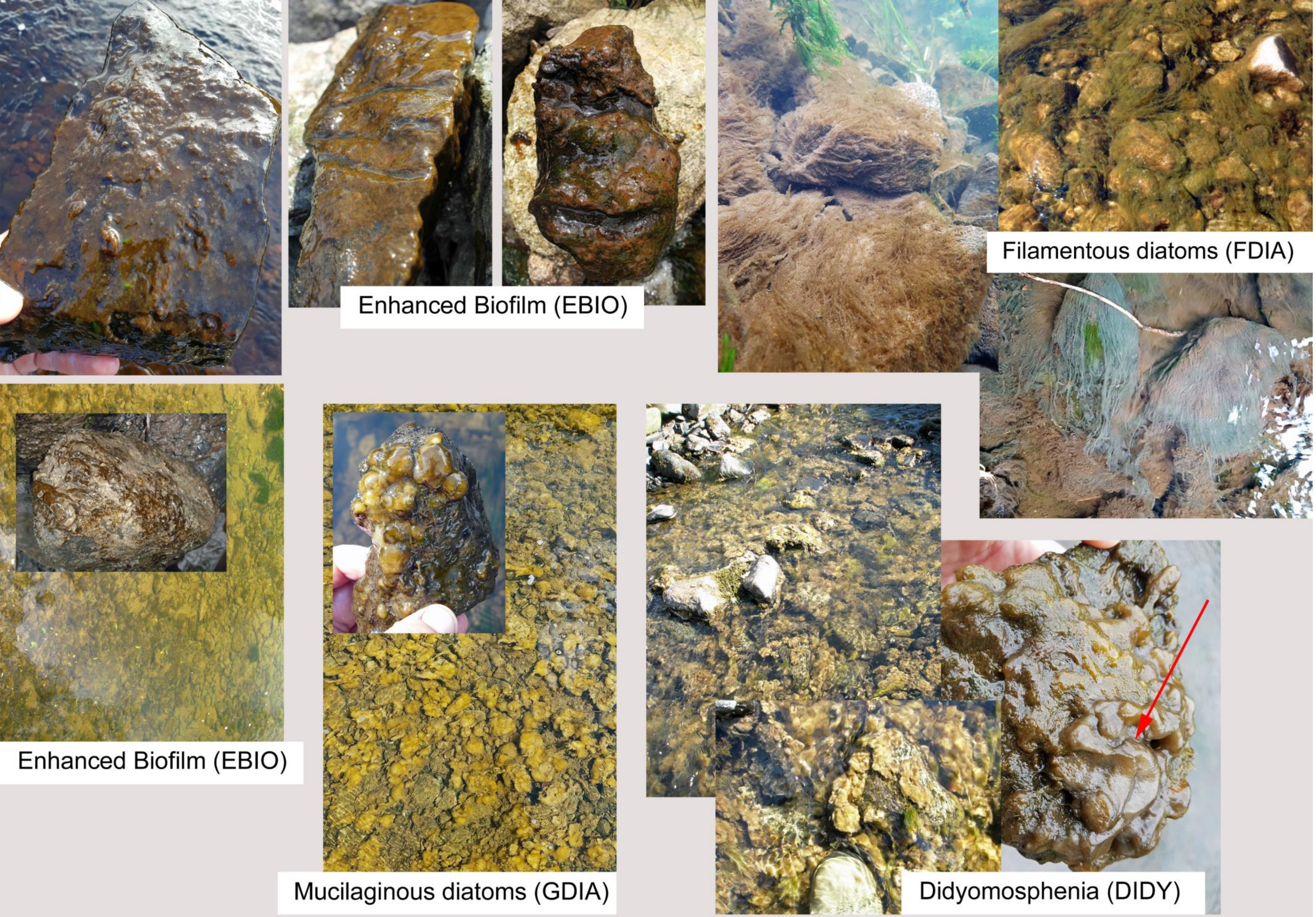
Attached to stable substrate (i.e. rocks and cobble)

Lemanea (LEMA)

A “Red alga” – robust drab olive-green tapering filaments that are slightly branching towards the base.

Firm textured with a somewhat “greasy” feel. Has “knobbly joints”.

Attached to boulders.



Diatom Biofilm

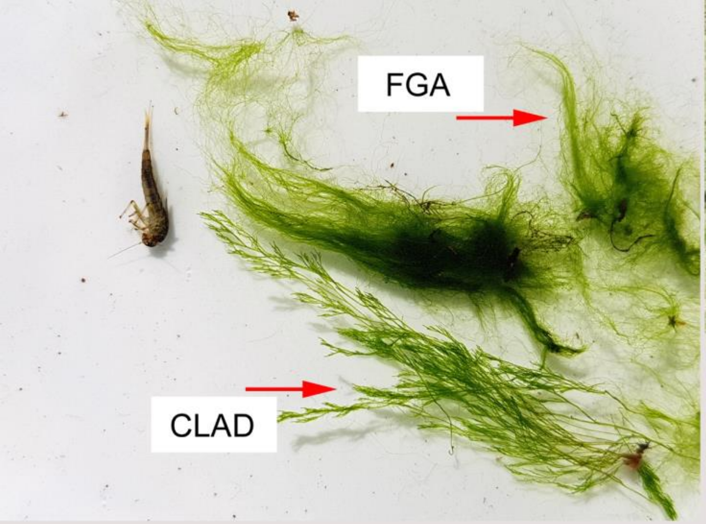
The first two of these indicators may be important in oligotrophic or former high status waterbodies (see text).

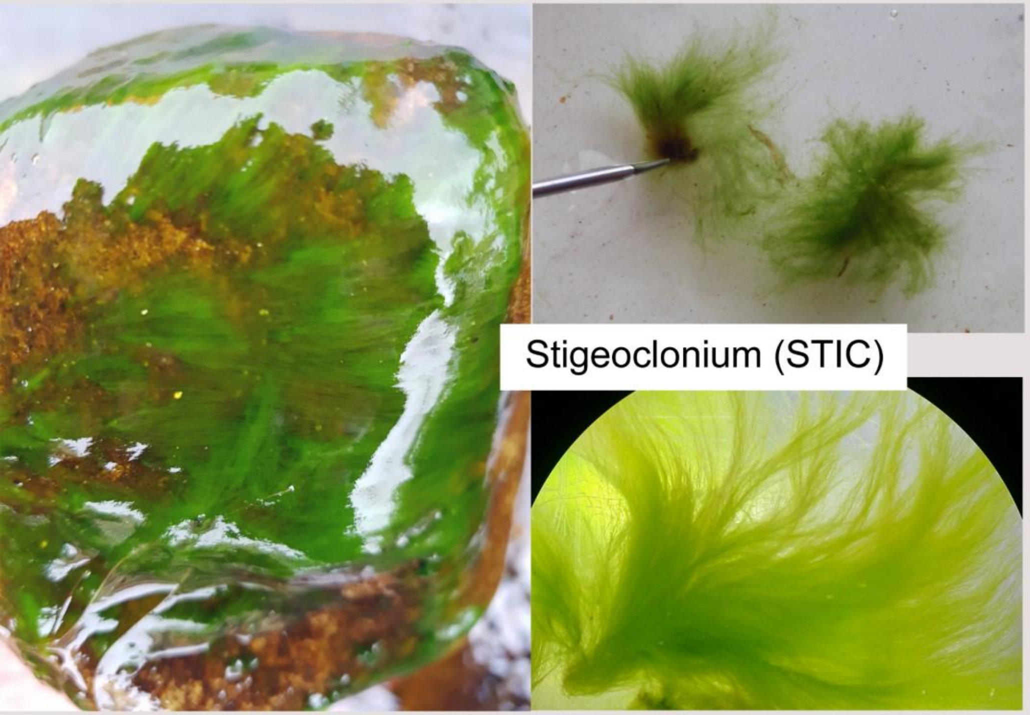
Enhanced biofilm (EBIO) – when the biofilm on substrate becomes thickened - excessively thickened, by diatom (brown slick) or other accelerated growths of the phytobenthos.

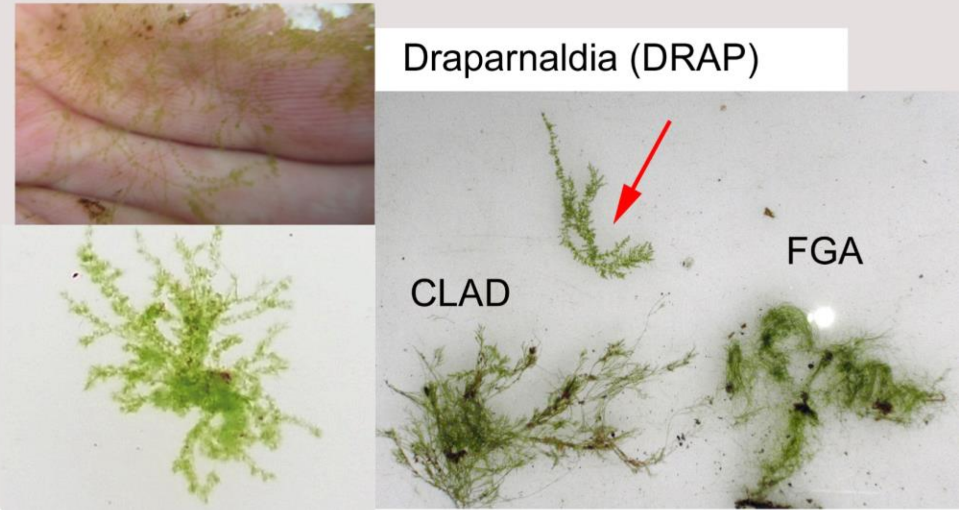
Filamentous diatoms (FDIA) – delicate trailing filaments of diatoms that fragment when touched.

Mucilaginous diatoms (GDIA) - Globular - amorphous colonies of diatoms (often *Gomphonema minutum*) that are gelatinous and often golden yellow coloured (pure white colonies also can be found and have a different trophic optimum). Slimy to touch.

Didyomosphenia (DIDY) - Has a texture like cotton wool - clean white to dirty brown (indicating older colony covered in epiphytes).







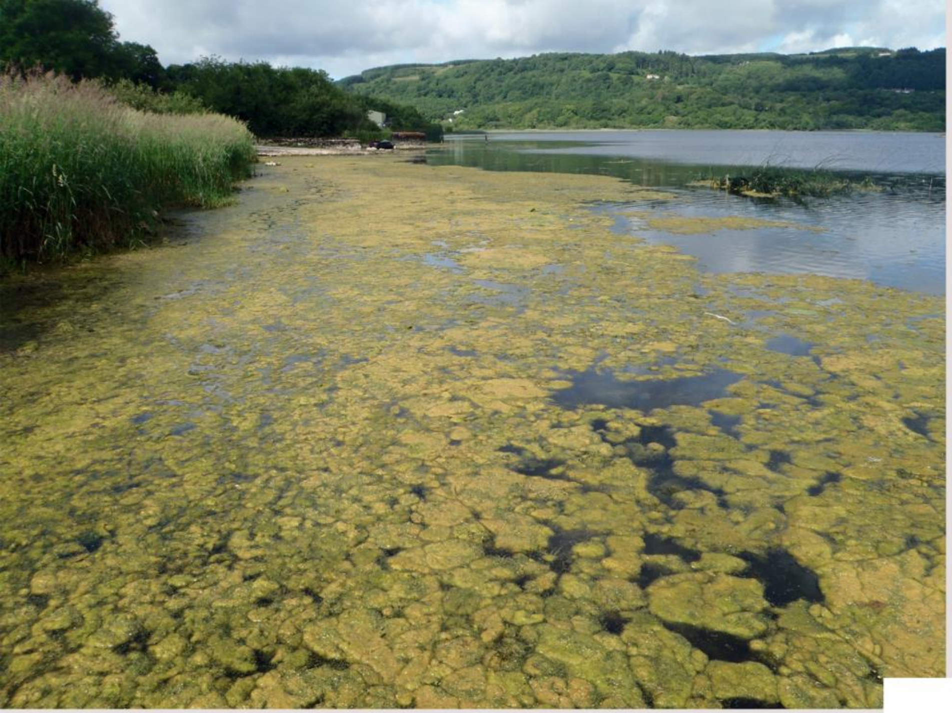
Filamentous Algae (FGA)

Filamentous Green Algae (FGA) - a "catch-all" name for a diverse range of **unbranched** filamentous algae. Compare the robust branching of *Cladophora glomerata* (CLAD) or the fine branching of Stigeoclonium sp. Often long streaming filaments.

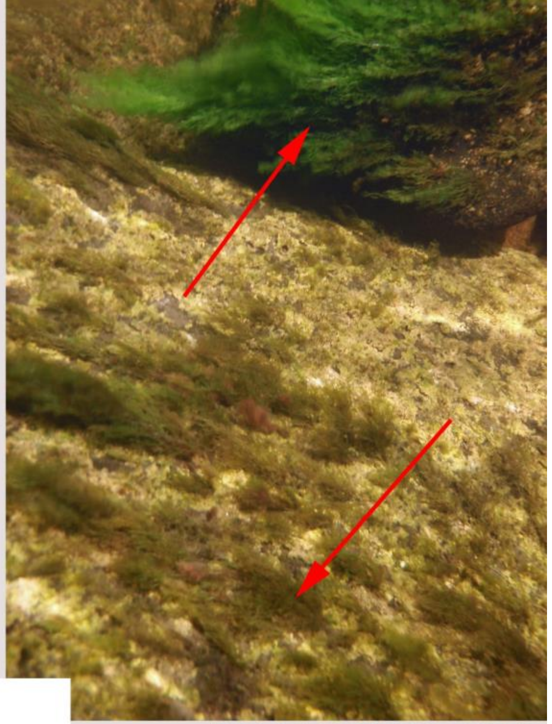
Stigeoclonium (STIC) – A branching and somewhat slimy or flimsy distinctively green coloured alga. Short prostrate growth form.

Ulva (ULVA) - bright or light-green, **irregular in outline** and soft textured (syn. Enteromorpha).

Draparnaldia (DRAP) - Mucilaginous, minutely branched delicate filaments - only slightly beaded and green coloured. Difficult to pick up.



Cladophora glomerata (CLAD)

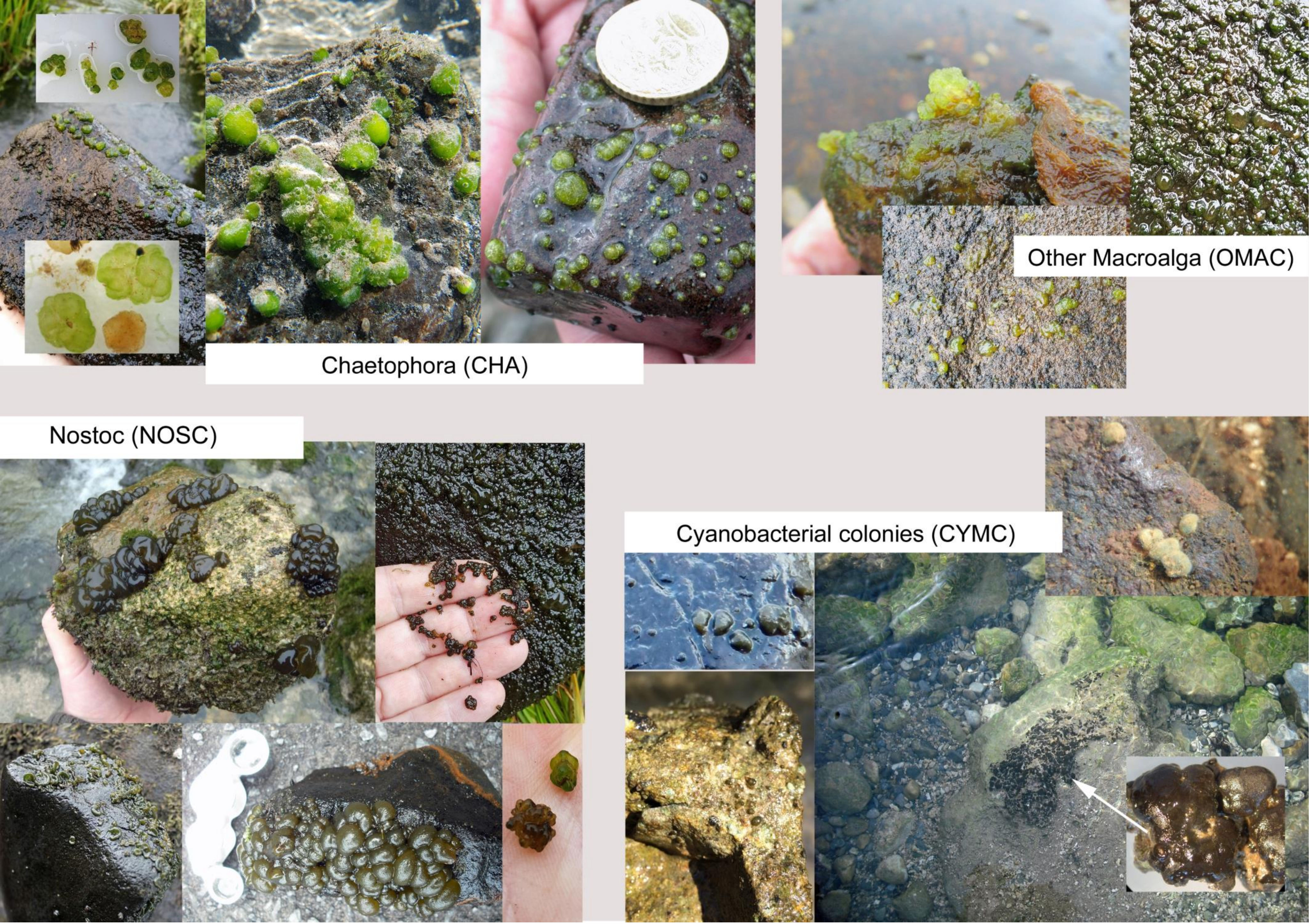


Vaucheria (VAU)

Filamentous Algae (FGA)

Cladophora glomerate (CLAD) – Commonly known as “blanketweed”. Probably the most widespread nuisance alga. Easily identified by the relatively large coarsely branching structure (for a filamentous alga that is!). Many former species reduced to synonymy. Variable in form and poorly branching forms found. Rhizoclonium not considered here, looks very similar and found in equivalent habitat.

Vaucheria (VAU) – Know as mole-pelt alga because of its characteristic growth form.



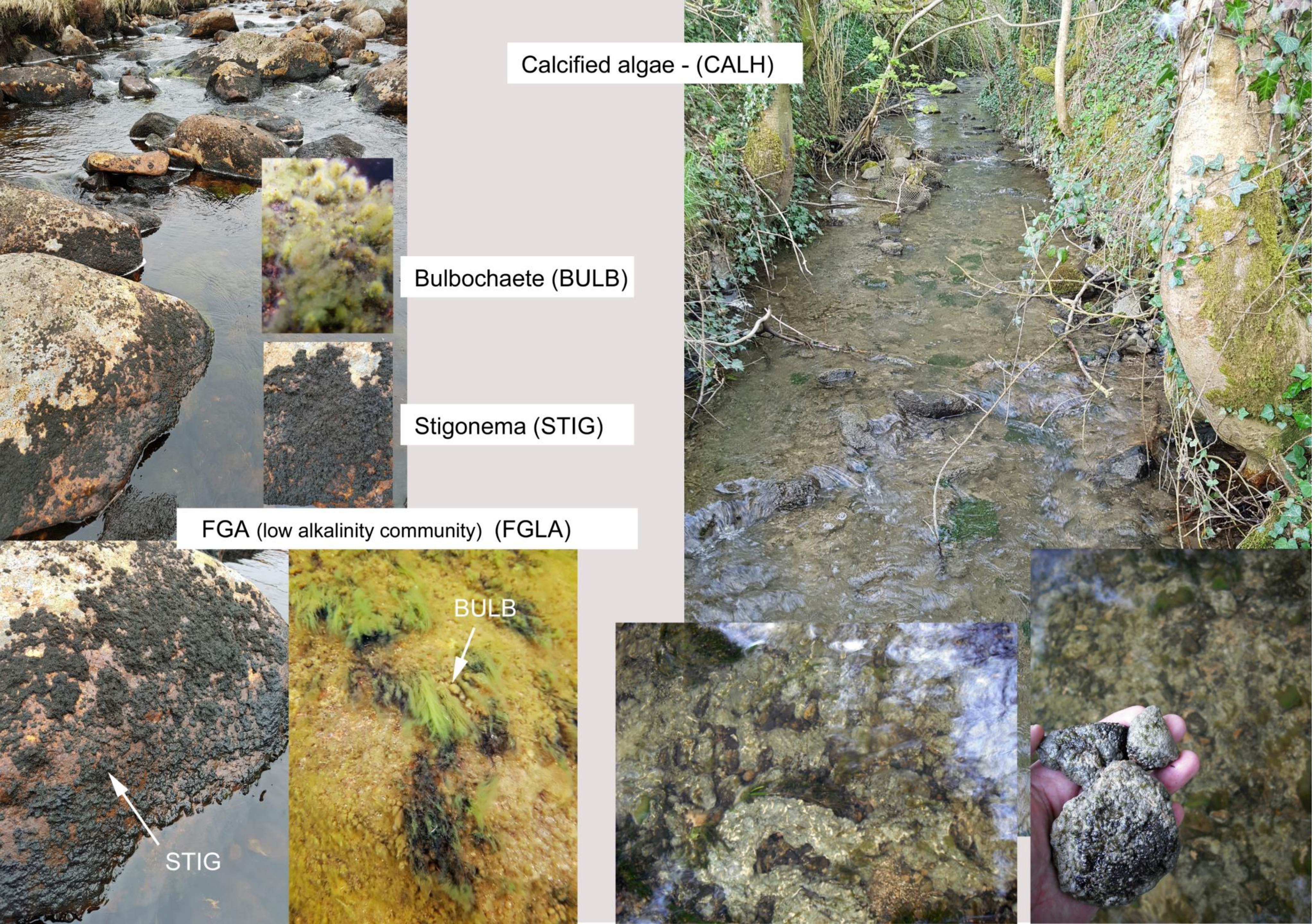
Macroalgae

Chaetophora (CHA) – small spherical or irregularly shaped green colonies that are jelly like in consistency.

Nostoc (NOSC) – Dark olive green colonies with a firm muscilage and will not squash easily between fingers. Several species of this nitrogen fixing cyanobacteria will be encountered.

Cyanobacterial colonies (CYMC) – a diverse group of quite specialised algae that may be encountered in the highest quality low order streams – probably at high status.

Othere Macroalga (OMAC) - a "catch-all" name for any amorphous unidentifiable macroalgal forms.



Other Communities

FGA (low alkalinity community) **(FGLA)**
Some lower alkalinity oligotrophic rivers draining peatland catchments may have higher filamentous algal cover than anticipated. Stigonema **(STIG)** is also often encountered in the splash zone and should be recorded in such situations. Bulbochate **(BULB)**, Moeugotia and other algae are found here. This community rarely consists of a single opportunistic form, but upland catchments can also occasionally have relatively high cover of FGA and more specialist assessment is required in these cases.

Calcified algae (CALH)
A cyanobacteria (*Phormidium incrustatum* agg.) is associated with the precipitation of calcium carbonate in this stream type. This cyanobacteria is a light blue-grey colour and is also influenced by a range of natural typological factors. The condition of available habitat in the stream bed should be noted and any lack of loose substrate for Heptageniidae should be reported – or if the stream bed becomes completely cemented.

Page	Macrophyte Indicator	Code	Description
22	Channel vegetation cover	PTCV	Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV
22	Channel vegetation biomass	PTBI	Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - NV
23	Emergent vegetation	EVG	emergent taxa particularly when extensive in a modified reach *Sparganium erectum* (SPER), *Schoenoplectus* (SCIP) etc.
25	Bryophyte	BRYO	Total cover for all undifferentiated bryophyta (liverworts and mosses)
25	Moss	MOS	All mosses growing submerged including *Fontinalis antipyretica* (FATY), *F. squamosa* (FSQA), *Leptodictyum riparium* (LPYR)
25	Liverwort	LIVT	the low alkalinity indicator taxa *Scapania, Marsupella, Jungermannia, Nardia sp.* (note Chiloscyphus (CILO) not included)
23	Emergent broad-leaved	EBLV	broad leaved plants rooted in the channel sediment e.g. Apium, Berula etc.
23	Emergent reeds/sedges/rushes	ERSR	Narrow-leaved reeds, sedges and rushes
24	Floating-leaved (rooted)	FLOT	rooted in the water having clearly floating leaves e.g. Nuphar (Water lilly), *Potamogeton natans* etc.
24	Free floating	FREE	*Lemna trisulca, L. minor* and other free-floating taxa
23	Amphibious	AMPH	rooted in marginal (bank-side) habitats and trailing into the water
24	Submerged broad-leaved	SBLV	rooted in the water with broad leaves submerged e.g. Potamogetons
24	Submerged linear-leaved	SLLV	rooted in the channel with distinctly linear leaves e.g. *Sparganium emersum*
24	Submerged fine-leaved	SFLV	rooted in the water with fine leaves e.g. *Myriophyllum* , *Juncus bulbosus var. fluitans* , *Ranunculus sp.* (RANN)
24	Opportunistic algae	OPPA	Cladophora (CLAD), Vaucheria (VAU) and filamentous green algae (FGA)

May 2017 - Absent Cover & Absent Density

May 2018 - Dominant Cover & Excessive Density

Abundant Cover - High Density

Abundant Cover - Low Density

Occasional Cover - Low Density

Macrophyte Cover & Density

- Estimating the extent of cover and density of macrophytes is an important criteria in some circumstances (for HYMO or when dissolved oxygen concentration is low).
- Useful estimates of these metrics can be made for the entire community and potentially also for individual indicator groups – if the data provides some useful insight for management.

Ballygar River (Left)

- Dramatic change in biomass in this reach. The reach had been cleared of all vegetation in 2017, but extensive regeneration had occurred in this modified channel a year later.

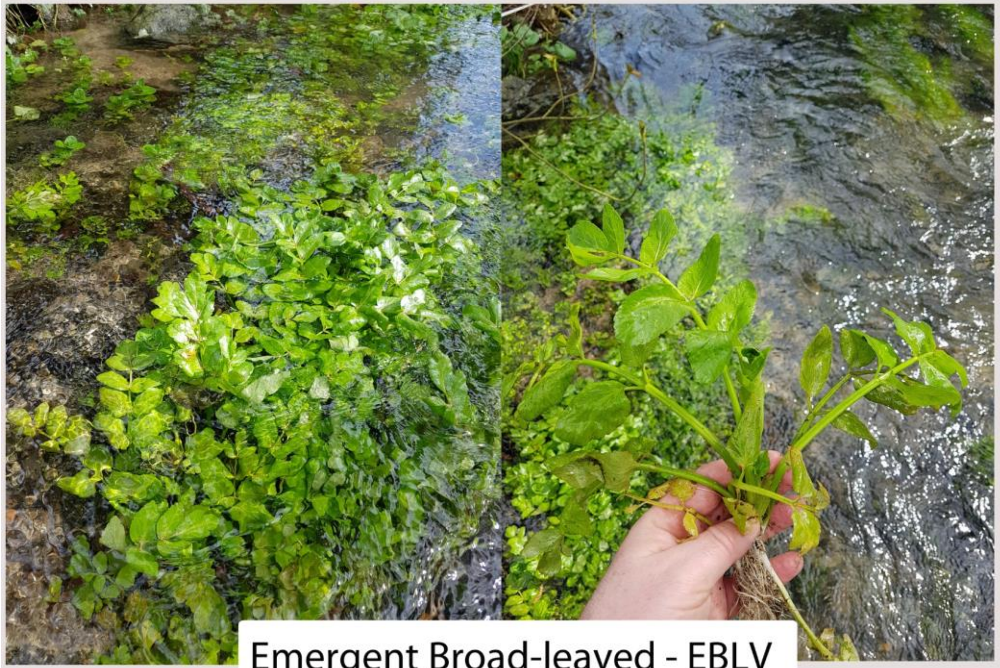
Visual estimation

- High biomass of plants (density) may or may not always follow from high total cover.
- Estimates of cover are easier to record when abundance is low or extensive in a reach. Considering individual sections of the channel may help for situations where intermediate levels of cover are found.
- A tendency exists to overestimate the actual extent of cover – look also at the blank spaces when estimating total cover.

Emergent reeds/sedges/rushes - ERSR

Sparganium erectum - SPER

Schoenoplectus - SCIP



Emergent Broad-leaved - EBLV

Amphibious - AMPH

Floating-leaved (rooted) - FLOT

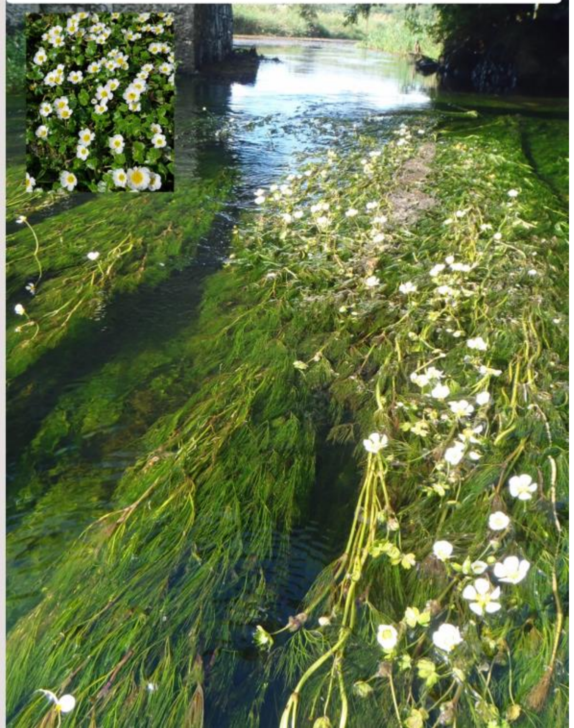
Free floating - FREE

Submerged linear-leaved - SLLV

Submerged broad-leaved - SBLV

Opportunistic alga - OPPA

Submerged fine-leaved - SFLV



Bryophyta

- Aquatic bryophytes are a challenging group. Ignore bankside or species high up in the splash zone. Consider only those growing within the permanent wetted channel. Record as general bryophyta if unsure.
- Liverworts thrive in acidic conditions that are not enriched (*cf*. Chiloscyphus - more neutral water).

***Leptodictyum riparium* –** Very flattened prostrate growth form with leaves tapering to weak wavy hair point. Pollution tolerant.

Fontinalis antipyretica – leaves in obvious ranks of three and very keel shaped – widespread and will tolerate some decline in condition.
Fontinalis squamosa – leaves also in ranks of three but difficult to discern. Leaves much smaller, narrow and rolled. Often much darker black or even reddish on occasion – less frequent and tolerates lower pH than *F. antipyretica*.

Liverwort – Relative to mosses, their structure is typically a lot more delicate and less likely to have large branching growth forms. The leaves are often more translucent and softer (broadly rounded and less pointed than mosses). Some of the acid indicator taxa when viewed from above often look like miniature roses.

Chiloscyphus – leaves obviously growing side-by-side on the stem – opposite.

Biological Indicator Lookup Tables for Small Stream Impact Score (SSIS)

Habitat sampled for kick (predominate or multiple categories)	
riffle	R
glide	G
pool	P
margins	M

All relevant Habitat criteria must be noted on Master Sheet (e.g.)
substrate quality
extent siltation & compaction
extent of shading if significant
extent calcification if present

Invertebrate Sample Density (intermediate categories can be used)	
Excessive	E
Abundant	A
Moderate	M
Low	L
Very sparse	S

Invertebrate Density for RA (intermediate categories can be used)	
Excessive	E
Abundant	A
Moderate	M
Low	L
Very few	S
Absent	AB

MAL Cover observation (indicative %-cover for guidance only)	
Excessive (>75%)	E
Dominant (>50%- ≤75%)	D
High (>25%- ≤50%)	H
Moderate (>10%- ≤25%)	M
Low (≤10%)	L
Absent	AB
Not visible	NV
Not surveyed	NS

MYP Cover observation (indicative %-cover for guidance only)	
Excessive (>75%)	E
Dominant (>50%- ≤75%)	D
High (>25%- ≤50%)	H
Moderate (>10%- ≤25%)	M
Low (≤10%)	L
Absent	AB
Not visible	NV
Not surveyed	NS

Invertebrate Indicator (INV)	
Sensitive taxa	SENV
Less Sensitive taxa	LSEV
Tolerant taxa	TOLI
Very Tolerant taxa	VTOL
Most Tolerant taxa	PTOL
Heptageniidae	**HPT**
Ecdyonurus	**ECD**
Ephemoptera-Plecoptera-Trichoptera	**EPT**
Baetidae	**BAT**
Snails	**SNL**
Chironomidae	**CHR**
Simuliidae	**SIU**
Gammarus	**GAM**
Asellus	**ASL**
Tubificidae	**TUB**
Invertebrate community depapurate	**INVD**

Macroalgal Indicators (MAL)	
Cyanobacterial mat	CYMT
Cladophora agg.	CLAD
Vaucheria	VAU
Filamentous green algae	FGA
Stigeoclonium	STIC
Ulva	ULVA
Drapnaraldia	DRAP
Batrachospermum	BRTC
Lemanea	LEMA
Thickened biofilm	TBIO
Filamentous diatoms	FDIA
Mucilaginous diatoms	GDIA
Didyomosphenia	DIDY
Calcified algae	CALH
Nostoc	NOSC
Cyanobacterial colonies	CYMC
Chaetophora	CHA
Other macroalgae	OMAC
FGA - low alkalinity community	FGLA
Bulbochaete	BULB
Stigonema	STIG

Macrophyte Indicator (MPY)	
Channel vegetation biomass	PTBI
Emergent vegetation	EVG
Bryophyte	BRYO
Moss	MOS
Liverwort (acid-very acid taxa only)	LIVT
Emergent broad-leaved	EBLV
Emergent reeds/sedges/rushes	ERSR
Floating-leaved (rooted)	FLOT
Free floating	FREE
Amphibious	AMPH
Submerged broad-leaved	SBLV
Submerged linear-leaved	SLLV
Submerged fine-leaved	SFLV
Opportunistic algae	OPPA
Leptodictyon riparium	LPYR
Sparganium erectum	SPER
Schoenoplectus	SCIP
Fontinalis antipyretica	FATY
Fontinalis squamosa	FSQA
Ranunculus	RAN

Freshwater Bryophyte Identification Guide (Selection of Indicator species)

Lynda Weekes IT Tralee
School of Pharmaceutical and Life Sciences

Is it a moss or a liverwort?........how can I tell?

Mosses:
***Leaves found all around stem**, not in two ranks (there are a few exceptions though)*
Leaves generally the same size, although sometimes smaller on branches than on stems

Liverworts:
*Main leaves in **two ranks on stem** – so **generally flattened looking***
If roundy –looking, leaves still in two ranks but just bent around stem on either side.
*May have **tiny extra leaves** along underside of stem*

Colour coding:

- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

THE MOSSES

	Fontinalis antipyretica	*Fontinalis squamosa*
Description	True aquatic, conspicuous trailing moss. **Tip sides look angled.** Leaves folded in with **distinct keel** (v shaped). Hand-lens **– no nerve**	True aquatic, conspicuous trailing moss**. Finer** than *F. antipyretica* and **darker in colour** – more brown. **Tip sides look rounded. Leaves rounded at back.** Hand-lens – **no nerve**
Distribution	True aquatic, fully submerged unless exposed due to drought. Common in **alkaline** flowing waters Rocks boulders and larger cobbles	True aquatic, fully submerged unless exposed due to drought. Common in **acidic** flowing waters. Rocks boulders and larger cobbles

T-section of leaf

T-section of leaf

	Hygrohypnum spp.
Description	Semi-aquatic, moss with **leaves curved to one side.** Hold to one side and it looks like it has millipede legs Hand-lens **–feint single or Double nerve**
Distribution	Along river margins or submerged on rocks and boulders

Note:
Two species: hard to tell apart in the field but both indicate high/good water quality
H. ochraceum – Acid
H. luridum - Alkaline

Colour coding:

- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

	Platyhypnidium riparioides
Description	Aquatic moss, can be trailing It usually is a fat looking moss Look at tips they look like the shape of roses from the side Hand-lens – leaves shaped like shovels, Decent single nerve
Distribution	Submerged on rocks and boulders clear clean waters. Only exposed in drought. No preference for acid or alkaline

	Leptodictyum riparium
Description	Semi-aquatic moss, can be trailing or weft-like Flat moss, looks almost two ranked like a liverwort Can be straggly. Leaves tapering to a very fine point Looks softly spiky due to pointy leaves. Few other mosses present with this, often more macroalgae instead
Distribution	Submerged or semi-submerged on rocks and boulders silty nutrient rich waters. Replaces *Fontinalis* when nutrient levels rise.

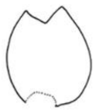
Brachythecium **spp.**
You will come across a lot of this
A variety of different species and a variety of
Colours - golden, light green, dark green, yellowish

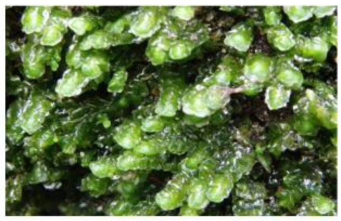
To eliminate it from your enquiries, look for bent over tips, that
End in what looks like pointed beaks - like corncrake's head

Colour coding:

- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

	Marsupella emarginata	*Chiloscyphus polyanthos*	*Scapania undulata*
Description	**Tight rounded cushions** Look carefully at leaves with hand lens - **notched**	**Leaves rounded in two ranks – flat.** Straggly weft Hand-lens – tiny leaves on back of stem	Leaves rounded but **look double layered** (because of folded leaf lobes)
Habitat	**Clear Acidic** waters upland only Upland bog/heathland small streams	Clear **alkaline** waters, upland and lowland streams/rivers Fast flowing waters Stuck on to rocks and boulders	Clear **acidic** waters, upland and lowland streams/rivers Fast flowing waters Stuck on to rocks and boulders





Potential confusion……both *Chiloscyphus??*…………………..*No*

Species A – notice one side of leaf base attached to back, other side to front so looks semi-flat and semi-rounded as half-wrapped around stem

Species B – Notice that leaf base is attached to same side - looks truly flat

Species A is Jungermannia **spp.**

Species B is Chiloscyphus

Freshwater Vascular plant Identification Guide (Selection of Indicator species)

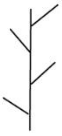
Lynda Weekes IT Tralee
School of Pharmaceutical and Life Sciences

Colour coding:
- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

The Pondweeds (*Potamogeton* spp.)

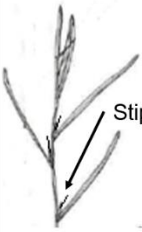
15 species and 13 hybrids (11 hybrids are rare)
Found in still & flowing waters varying nutrient levels

Is it a pondweed?..... To check:



- Should have Alternate leaves

- Has Stipules




Stipule

Some species with floating leaves (waxy feel)

Some species with submerged leaves (translucent)

Some species have both

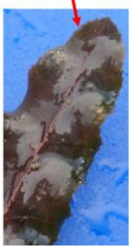
Some species Broad leaves

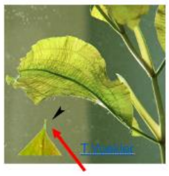
Some species linear leaves

Submerged broad leaved species

Scientific name	***Potamogeton crispus***	***Potamogeton lucens***
Common name	Curled pondweed	Shining pondweed
Description	**Leaves toothed** (seen with naked eye) edge, usually **wavy margins**	Large **fine net-like leaves**, **tip mucronate**; stipule 2 very obvious ribs.
Distribution	Still or slow nutrient-rich waters; frequent	Deep calcareous nutrient-rich slow waters lakes and rivers. Often thick stands along edges of deep rivers

Toothed edge





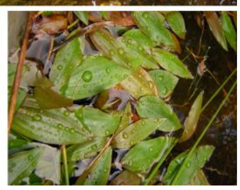
Mucronate tip


Floating broad leaved species

Scientific name	***Potamogeton natans***	***Potamogeton polygonifolius***
Common name	Broad-leaved pondweed	Bog pondweed
Description	Floating leaves 'leathery' with **translucent veins** (hold up to light) and with **discoloured kink** on leaf stem at leaf base.	Floating leaves 'leathery' with **opaque veins** (hold up to light – look darker) but **no kink or differing colour in leaf stem**
Distribution	Still or slow waters; deep or shallow abundant. **Mixed nutrient levels**	**Peaty acidic** shallow waters still and flowing.


Kink and may be yellowish

No kink

Colour coding:
- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

Narrow leaved species and lookalikes

Scientific name	*Potamogeton pectinatus*	*Zannichellia palustris*	*Juncus bulbosus*
Common name	Fennel pondweed	Horned pondweed	Bulbous rush
Description	**Leaves alternate,** linear, can be very lush and long. Leaves **arise from the top of sheaths**	**Leaves opposite,** linear, a depressed channel instead of midrib; **beaked fruits**	**Aquatic form** with tubular leaves, no midrib. **Looks 'grassy' and untidy, branching random**
Habitat/ Distribution	Lakes and ponds, sometimes rivers **abundant in polluted waters**	Fresh or brackish waters, nutrient rich	**Acidic waters, nutrient poor**

Leaf from top of sheath

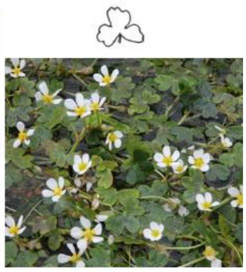
Terrestrial form

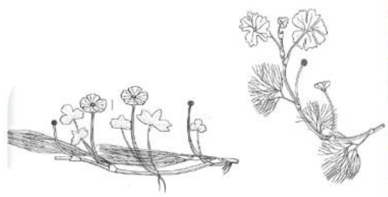
The Water Crowfoot – *Ranunculus* subgenus Batrachium

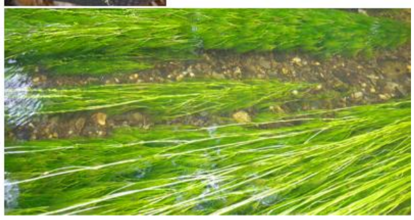
3 species, very hard to tell apart and not necessary for water quality purposes

Description:
Submerged capillary- like Leaves and floating lobed Leaves when flowering White and yellow buttercup-like flowers

Distribution:
Moderately flowing waters, **High to good water quality**.
Reduces and then absent in waters richer in nutrients







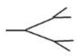
The Water Lillies – *Nymphaea* and *Nuphar*

Scientific name	***Nymphaea alba***	***Nuphar lutea***
Common name	White water-lily	Yellow water-lily
Description	**White flower**; **leaves rounded** with **'crazy paving' venation** on underside, **floating leaves only**	**Yellow flower**; **leaves oval** with **dichotomous venation on underside, both floating** and **submerged leaves(like floppy lettuce)** present
Habitat/ distribution	Mainly lakes and pools; frequent in W	Clay rivers, lakes canals; common

Crazy paving venation

Floating leaf

Dichotomous venation



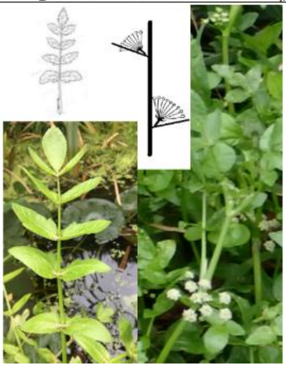
Submerged leaf

Colour coding:

- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

Marginal species - broadleaved

Scientific name	***Berula erecta***	***Apium nodiflorum***	***Rorippa nasturtium aquaticum***
Common name	Lesser water parsnip	Fools water-cress	Water cress
Description	Leaves usually **5-9 or more pairs of leaflets,** with **sharp teeth, white flowers** (grouped like **an umbrella**) **on stem tips.** Poisonous	Leaves usually **4-6 pairs of leaflets, with blunt teeth**; white flowers (grouped like **an umbrella**) **in leaf axils**	Leaves usually 4-6 pairs of leaflets, **no teeth, rounde. S**mall **white 4-petalled** flowers in **clusters** at stem tips
Habitat/ Distribution	**Calcareous** waters, often submerged. medium – high nutrient levels	Alkaline river edges, often submerged medium-high nutrient levels	Base rich rivers, ditches and pools medium-high nutrients


Marginal species – Narrow leaved

Scientific name	***Sparganium erectum***	***Sparganium emersum***	***Schoenoplectus lacustris***
Common name	Branched bur-reed	Unbranched bur-reed	Common clubrush
Description	**Flower heads branched. Leaves >10mm** wide; Emergent leaves ▲ in T-section; submerged leaves – straps. **Leaf-base cells look like brick-work**	**Flower heads unbranched Leaves <10mm** wide; both emergent and submerged leaves, **similar to *S. erectum***	**Tubular upright stems** with **sedge-like inflorescence**, linear **ribbon-like aquatic leaves** with **white flecks on inner surface**
Habitat/ Distribution	River & lake margins, ditches; frequent	River & lake margins, ditches; frequent	River, canals & lake margins; frequent, medium - nutrient rich



Leaf-base cells look like brick-work


TS of emergent stem

Floating pennywort (***Hydrocotyle ranunculoides***)

Description: Spreads rapidly by stolons (horizontal stems). Key ID features is leaf stalk being attached to leaf **between lobes and not in** centre (our native pennywort)
Distribution: Ponds and pools, localised
Native of: N & S America

lobes


Native:
Marsh Pennywort
(*Hydrocotyle vulgaris*)

Leaf smaller
Leaf stalk attached in centre of leaf like an umbrella

Look-alike

Invasive:
Floating Pennywort

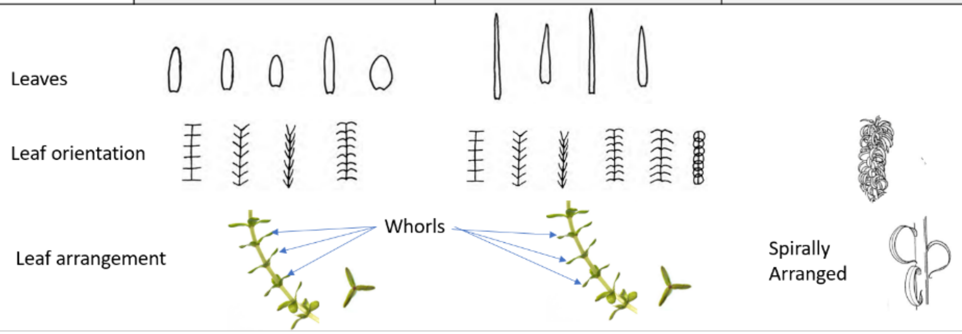
Leaf larger
Leaf stalk attached in between leaf lobes
Leaf **kidney shaped**

Colour coding:

- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

The Waterweeds (*Elodea spp* & *Lagarosiphon*)

Scientific name	**Elodea canadensis**	**Elodea nuttallii**	**Lagarosiphon major**
Common name	Canadian waterweed	Nuttalls waterweed	Curly waterweed
Description	Leaves in **whorls of 3**(5), usually oblong, **broadest at midleaf**. Alien	**Leaves in whorls of 3**(5), usually linear, **broadest at base**; at least **some leaves curled backwards**. Invasive	Leaves **spirally arranged** on stem and **strongly curled backwards**. Invasive
Habitat/Distribution	Lowland rivers, canals, ponds; frequent, high nutrients	Lowland rivers, lakes, canals, ponds; locally frequenthigh nutrients	Lakes and artificial waters; local high nutrients



	Native to: North America	Native to: North America	Native to: Southern Africa





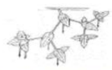


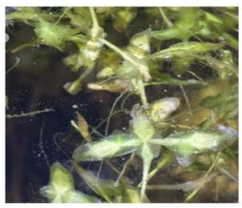


The Duckweeds (*Lemna* spp.)

Scientific name	***Lemna minor***	***Lemna minuta***	***Lemna trisulca***
Common name	Common duckweed	Least duckweed	Ivy-leaved duckweed
Description	Leaves 3-5mm in diametre, round/oval, single root from centre of each leaf	Leaves <3mm diametre, oblong, single nerve; invasive	Leaves ivy-shaped at the end of short stalks; plant suspended in water below the surface.
Habitat/distribution	Still waters, common	Still waters, occasional	Still or slow flowing waters, occasional
	Native in IRL	Native to: N & S America Invasive	Native in IRL





Colour coding:

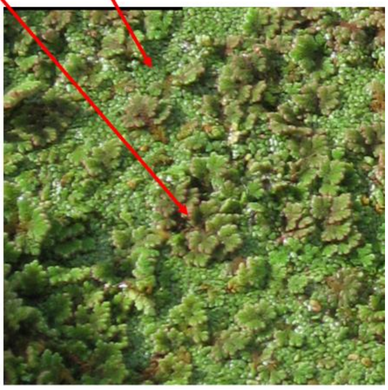
- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

The Waterfern (*Azolla filiculoides*)

Native Duckweed

Native Duckweed

Azolla

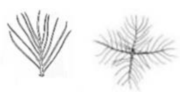


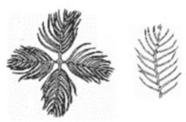
Description:
Fern-like
Often beads of water on top – hydrophobic
Black/brown roots
Bright green but often reddish due to stress

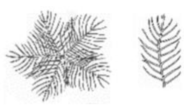
Distribution:
Still water, canals, sheltered river banks,
Ponds and pools
Native to: North and Central America

The Water Milfoils (*Myriophyllum* spp.)

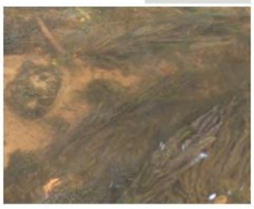
Scientific name	Myriophylum alterniflorum	Myriophyllum spicatum	Myriophyllum verticillatum	Myriophyllum aquaticum
Common name	Alternate milfoil	Spiked milfoil	Whorled milfoil	Parrot's feather
Description	Leaves mostly in **whorls of 4** (**3 if in calcareous water**), **5-8 segments** each side, leaves floppy (wet cat's tail if out of water)	Leaves mostly in **whorls of 4**, **8-15 segments each side**, leaves stiffer Reddish tinge to stems	Leaves mostly **in whorls of 5**, 15 leaf segments each side No reddish tinge	**Leaves emerging, feathery and stiff, blue-green, hydrophobic**. Only female (fragmentation)
Habitat/ Distribution	Usually **acidic waters**, frequent in west. Oligotrophic - mesotrophic	Usually **basic waters**, widespread. **Nutrient rich**	Mainly still waters; occasional **Nutrient rich**	**Still ponds**, potentially in rivers, spreading, **invasive**. **Eutrophic**







Submerged
Pull out of water
hold upside-down
– like wet cats tail



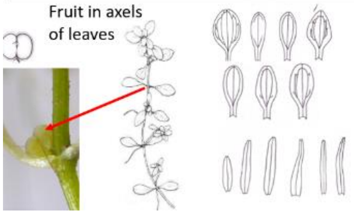
Submerged
Pull out of water
hold upside-down
– leaves quite stiff
and remain
sticking out

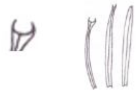
Emergent – sticks
up out of water.
Stiff, bright green
Invasive

The Starworts and New Zealand pygmyweed

Colour coding:
- High Status waters
- Good water quality
- Moderate/poor water quality
- Alien/Invasive

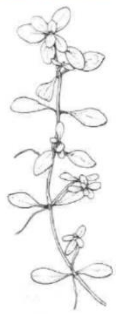
Scientific name	*Callitriche* spp. – General ID	*Callitriche brutia*	*Crassula helmsii*
Common name	Water starworts	Pedunculate water-starwort	**New Zealand Pygmyweed**
Description	Can be small and straggly, but also lush large submerged plants Floating leaves broader, submerged leaves usually narrower. **All species notched tips – may need hand-lens to see**	Can be small and straggly, but also lush large submerged plants Floating leaves broader, submerged leaves **always narrow at least some with spanner-shaped tips.**	Can form thick carpets, leaves narrow and **pointed and succulent**
Habitat/ Distribution	Mixed habitats, still to slow flowing waters, **mostly in more nutrient rich environments**	More acidic flowing waters, good indicator of **low nutrient levels**	Localised, still pools and ponds.





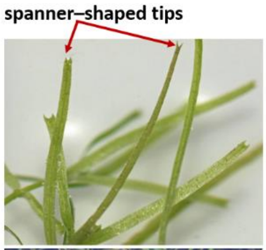
Note: If spanner tips missing – inconclusive ID

Notched tips



Exposed form

Flat narrow leaves with **notched** and **spanner–shaped tips**



Succulent narrow leaves

Bank – terrestrial invasives you may come across

Montbretia

Gunnera

Japanese knotweed

Himalayan Balsam

Giant hogweed

Note:

Have native lookalikes to Gunnera and Giant hogweed, but native species small to tall in size, Invasive species however- HUGE

Information and some photographs on invasives from National Biodiversity Data Centre and Invasive Species Ireland: https://www.biodiversityireland.ie/
Bryophyte and vascular plants mostly taken by Lynda Weekes
Some from WikiCommons – attributes on photos
Diagrams from Haslam, S. Sinker, C., Wolseley, P. 1976 *British water plants*. Field Studies Council AIDGAP Guides. UK.

Briefing Note No.	BN0001
Topic	Interpretation of SSIS in Blue Dot Rivers
Date	11th May 2021
Prepared by	Cormac Mc Conigley, Paul O'Callaghan, Stephen Davis, Bernie White
Reviewed by	Bernie White, Catchment Manager (Western Region)
For circulation to	LAWPRO Catchment Scientists

Catchment scientists have identified that in High Status Objective (Blue Dot) rivers the SSIS tends to return a score of "Probably not Significantly Impacted" much of the time even when the biological community is likely reflective of a departure from unimpacted condition. This does not allow variations in the catchment to be identified or confidence in the assessment results. The scientists are not able to determine whether a particular sample is or is not significantly impacted within a Blue Dot river using of the current design.

This is the expected behaviour of the SSIS which is an evolution of the Small Streams Risk Score (SSRS). The SSRS was developed to identify if a river was at risk of not achieving the Good status objective. However, this has obvious problems if the objective is High, when Good status would be unsatisfactory.

To address this issue, we propose that additional rules are applied to the SSIS when sampling in Blue Dot rivers to determine if a site is probably impacted. It is essential that we remain aware that these rules when applied will only indicate if the site is **probably** impacted or not, like the SSIS alone in good status objective rivers. Therefore, the following guidance is provided to aid assessments at high status objective sites:

- The most important consideration is the time of year when the sample is collected. If you are surveying a Blue Dot river you **must** carry out the survey in the summer (June to September) to have a reasonable idea if it is probably impacted. This is due to the tendency for there to be fewer sensitive taxa in the river during the summer – refer to Guidance Document - 2019 05 23_ECO_WG_BN001_Interpretation of SSIS Scores_F01[1]. You expect to capture more sensitive taxa in the winter. Therefore, due to natural invertebrate life cycles and some pressures being less prevalent in winter, if a sample is collected outside of the summer, it is more likely to return a favourable result (probably not impacted) erroneously.
- The habitat must be suitable. For Blue Dot rivers it is particularly important that you sample in a suitable riffle that would provide habitat for sensitive taxa. If samples are collected in glides or other habitats you are more likely to capture fewer of the most sensitive taxa and erroneously identify a probable impact.
- Bear in mind the substrate type when sampling also. For example, bedrock may provide less favourable habitat than boulders/cobbles for sensitive taxa. Refer to EPA taxa lists for the site where available to get an idea of what to expect.

[1] LAWSAT - Documents\10.0 Working Groups\Ecology WG\Guidance documents

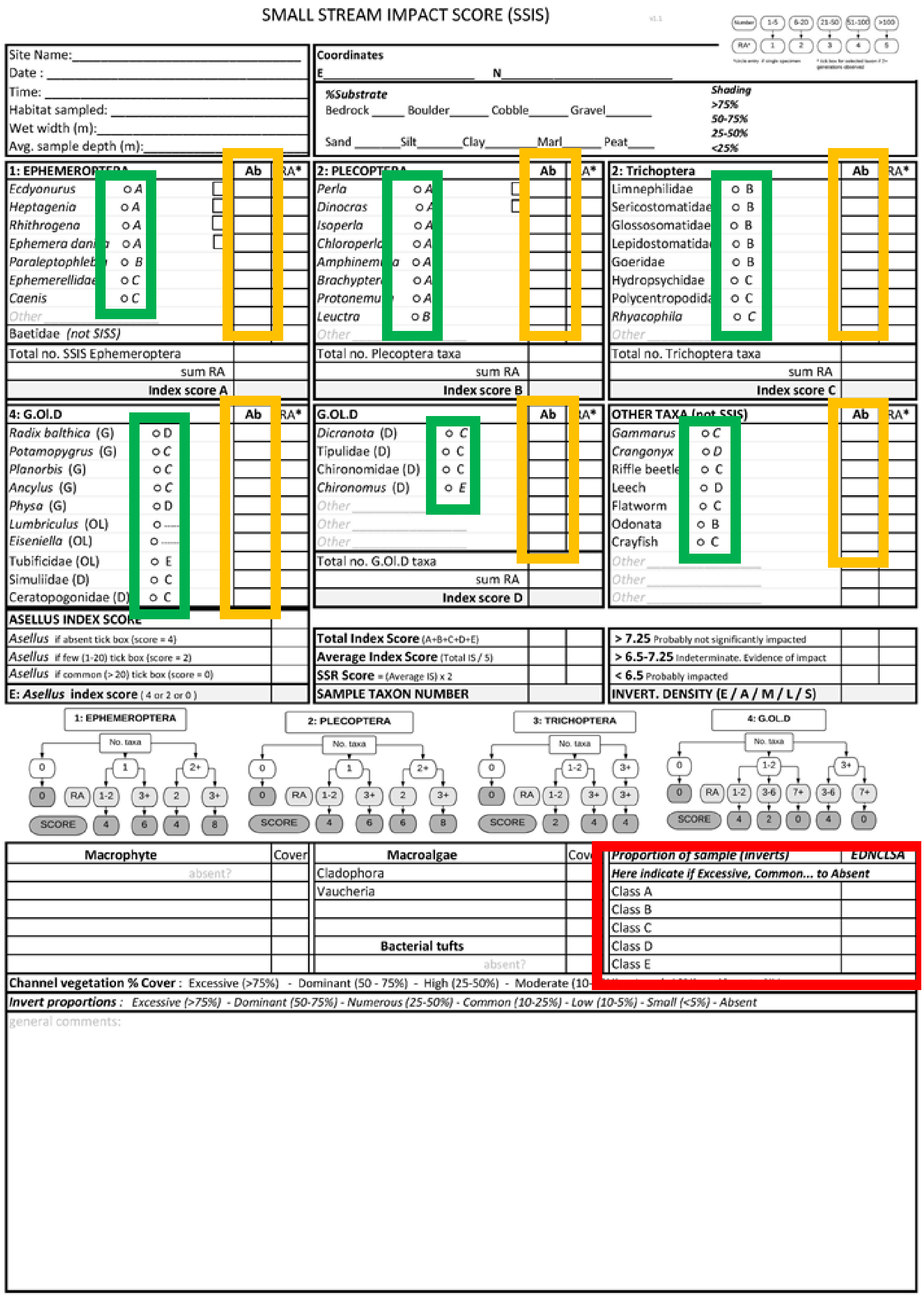
- When looking at the sample determine roughly the percentage of the community that are Group A taxa. These taxa are indicated on the most recent SSIS sheets (2020 07 01 SSIS Updated D05[2]) but broadly includes the flat mayflies and all stoneflies except *Leuctra*. These taxa combined must make up at least 30% of the invertebrate abundance. This is just a guide percentage, you are not expected to count all individuals of each taxa, but to get an accurate estimate from the tray. Use the abundance boxes (Ab – Orange boxes in **Figure 1**) on the new SSIS sheet to indicate the abundance of Group A taxa, again ballpark figures are ok you do not have to spend a lot of time counting each individual if the numbers are high.
- There must be at least 2 Group A taxa and each of these should make up at least 10% of the population.
- Group D and E taxa (the most tolerant groups) should make up less than 10% of the abundance when combined.

You will see at the bottom of the SSIS field sheet you can indicate the percentage of the community made up of each group (Red box in **Figure 1**). The group to which each taxon belongs is indicated in the green boxes on **Figure 1**.

It is important to note that these are guidelines and require some additional interpretation by catchment scientists based on prevailing site conditions, algal cover, and characteristics on the day e.g., DO, conductivity etc.

[2] LAWCO\LAWSAT - Documents\10.0 Working Groups\Ecology WG\SSIS and RA Field sheets

New Fieldsheet



SMALL STREAM IMPACT SCORE (SSIS)

Number: 1-5, 6-20, 21-50, 51-100, >100
RA*: 1, 2, 3, 4, 5

Site Name:	Coordinates
Date :	E N
Time:	%Substrate: Bedrock Boulder Cobble Gravel
Habitat sampled:	Sand Silt Clay Marl Peat
Wet width (m):	Shading: >75% 50-75% 25-50% <25%
Avg. sample depth (m):	

1: EPHEMEROPTERA		Ab	RA*	2: PLECOPTERA		Ab	RA*	2: Trichoptera		Ab	RA*
Ecdyonurus	o A			*Perla*	o A			Limnephilidae	o B		
Heptagenia	o A			*Dinocras*	o A			Sericostomatidae	o B		
Rhithrogena	o A			*Isoperla*	o A			Glossosomatidae	o B		
Ephemera danica	o A			*Chloroperla*	o A			Lepidostomatidae	o B		
Paraleptophlebia	o B			*Amphinemura*	o A			Goeridae	o B		
Ephemerellidae	o C			*Brachyptera*	o A			Hydropsychidae	o C		
Caenis	o C			*Protonemura*	o A			Polycentropodidae	o C		
Other				*Leuctra*	o B			*Rhyacophila*	o C		
Baetidae *(not SISS)*				*Other*				*Other*			
Total no. SSIS Ephemeroptera				Total no. Plecoptera taxa				Total no. Trichoptera taxa			
sum RA				sum RA				sum RA			
Index score A				Index score B				Index score C			

4: G.Ol.D		Ab	RA*	G.OL.D		Ab	RA*	OTHER TAXA (not SSIS)		Ab	RA*
Radix balthica (G)	o D			*Dicranota* (D)	o C			*Gammarus*	o C		
Potamopygrus (G)	o C			Tipulidae (D)	o C			*Crangonyx*	o D		
Planorbis (G)	o C			Chironomidae (D)	o C			Riffle beetle	o C		
Ancylus (G)	o C			*Chironomus* (D)	o E			Leech	o D		
Physa (G)	o D			*Other*				Flatworm	o C		
Lumbriculus (OL)	o			*Other*				Odonata	o B		
Eiseniella (OL)	o			*Other*				Crayfish	o C		
Tubificidae (OL)	o E			Total no. G.Ol.D taxa				*Other*			
Simuliidae (D)	o C			sum RA				*Other*			
Ceratopogonidae (D)	o C			Index score D				*Other*			

ASELLUS INDEX SCORE				
Asellus if absent tick box (score = 4)	Total Index Score (A+B+C+D+E)		> 7.25 Probably not significantly impacted	
Asellus if few (1-20) tick box (score = 2)	Average Index Score (Total IS / 5)		> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus if common (> 20) tick box (score = 0)	SSR Score = (Average IS) x 2		< 6.5 Probably impacted	
E: *Asellus* index score (4 or 2 or 0)	SAMPLE TAXON NUMBER		INVERT. DENSITY (E / A / M / L / S)	

1: EPHEMEROPTERA — No. taxa: 0 / 1 / 2+ — 0, RA, 1-2, 3+, 2, 3+ — SCORE: 0, 4, 6, 4, 8

2: PLECOPTERA — No. taxa: 0 / 1 / 2+ — 0, RA, 1-2, 3+, 2, 3+ — SCORE: 0, 4, 6, 6, 8

3: TRICHOPTERA — No. taxa: 0 / 1-2 / 3+ — 0, RA, 1-2, 3+, 3+ — SCORE: 0, 2, 4, 4

4: G.OL.D — No. taxa: 0 / 1-2 / 3+ — 0, RA, 1-2, 3-6, 7+, 3-6, 7+ — SCORE: 0, 4, 2, 0, 4, 0

Macrophyte	Cover	Macroalgae	Cover	Proportion of sample (inverts)	EDNCLSA
absent?		Cladophora		Here indicate if Excessive, Common... to Absent	
		Vaucheria		Class A	
				Class B	
				Class C	
		Bacterial tufts		Class D	
		absent?		Class E	

Channel vegetation % Cover : Excessive (>75%) - Dominant (50 - 75%) - High (25-50%) - Moderate (10-

Invert proportions : Excessive (>75%) - Dominant (50-75%) - Numerous (25-50%) - Common (10-25%) - Low (10-5%) - Small (<5%) - Absent

general comments:

Figure 1: Updated SSIS Fieldsheet (version D05)

Case studies

Below we present a couple of case studies to illustrate how this guidance would be used. These SSIS were carried out before this guidance was produced and before the SSIS Fieldsheet was updated. Therefore, we are limited to estimating the percentages of the community made up of each Group. Further examples using the updated Fieldsheet will be added when they have been used in the field more extensively.

Lough Nastackan

Lough Nastackan is a PAA that includes the Blue Dot river LOUGH NASTACKAN STREAM_010. The waterbody dropped from high to poor in 2013.

LAWPRO carried out surveys around the monitoring point on 11th September 2019 and scored an SSIS of 8. However, from just this score it is not possible to determine if the waterbody is impacted due to its high status objective.

Applying the rules presented above we would have determined that this site is "Probably not Significantly Impacted for HSO" as there were three Group A taxa present, 2 in good numbers and the total abundance over 30% of the community, while tolerant taxa were not present in high numbers (**Figure 2**).

In this case the EPA surveyed the site again on the 19th of September, just 8 days after LAWPRO. They determined that the site had returned to high status and would have confirmed our assessment using this guidance if it had been in place at the time. For a complete breakdown of the taxa captured by the EPA and LAWPRO see **Table 1**.

Caha_020

The Caha_020 is a Blue Dot river that dropped to good status in 2015. LAWPRO sampled the monitoring point in April 2019 and the SSIS score resulting was 9.6 (Probably not Significantly Impacted). However, if we were to apply the guidance presented above, we would determine that the waterbody is Probably Impacted. There are several Group A taxa present but we can see that they would not make up 30% of the community. There are quite high numbers of GOLD taxa and non-scoring taxa which would lower the percentage of the community made up of Group A taxa (**Figure 3**).

Note also that the sample was collected in April, not in the summer. We would expect this site to score better in April than in the summer. It is likely that if a site is impacted in spring it will be in a poorer condition in the summer. In future following this guidance we would not sample HSO waterbodies in April and would only sample them between June and September.

The EPA monitored the location again on the 13th of June 2019 and confirmed that the site was at Good status. It is also notable that the EPA identified a similar community of Group A taxa to LAWPRO **Table 1**.

11/9/19

SMALL STREAM IMPACT SCORE (SSIS)

SURVEY DETAIL

Location ID (or GR): LOUGH NAST. 2	
Time: 12:45	
Habitat sampled: RIFFLE/GLIDE	
Wet width (m): 3m	
Avg. sample depth (m): ~0.4m	

RELATIVE ABUNDANCE CATEGORIES (RA*)

Number	1-5	6-20	21-50	51-100	>100
RA*	1	2	3	4	5

SAMPLE TIME (min)

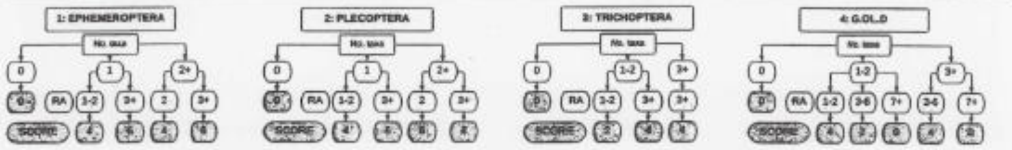
pond-net: stone wash: weed-sweep:

658989
947437

1: EPHEMEROPTERA	RA*	2: PLECOPTERA	RA*	3: TRICHOPTERA	RA*
Ecdyonurus ✓	2	*Perla*		Limnephilidae	
Heptagenia ✓	1	*Dinocras*		Sericostomatidae ✓	1
Rhithrogena ✓	2	*Isoperla*		Glossosomatidae	
Ephemera danica		*Chloroperla*		Lepidostomatidae	
Ephemerellidae		*Protonemura*		Hydropsychidae ✓	1
Paraleptophlebia		*Amphinemura*		Polycentropodidae ✓	1
Caenis		*Leuctra*		*Rhyacophila*	
Other		Other		Philopotamidae	
Baetidae ✓ RA 2 ←not SSRS	X	Other		Other GOERIDAE	1
Total no. SSRS Ephemeroptera	3	Total no. Plecoptera taxa		Total no. Trichoptera taxa	5
sum RA	5	sum RA		sum RA	4
Index score A	8	Index score B	/	Index score C	4

4: G.OL.D	RA*	G.OL.D	RA*	OTHER TAXA (not SSRS)	RA*
Radix balthica (G)		*Dicranota* (D)		*Gammarus* ✓	2
Potamopygrus (G) ✓	1	Tipulidae (D)		*Crangonyx*	
Planorbis (G)		Chironomidae (D) ✓	1	Riffle beetle ✓	1
Ancylus (G) ✓	2	*Chironomus* (D)		Leech	
Physa (G)		Other		Flatworm	
Lumbriculus (OL)		Other		Odonata	
Eiseniella (OL) ✓	1	Other		Other	
Tubificidae (OL)		Total no. G.OL.D taxa	5	Other	
Simuliidae (D) ✓	1	sum RA	6	Other	
Ceratopogonidae (D)		Index score D	4	Other	

ASELLUS INDEX SCORE					
Asellus if absent tick box (score = 4)	✓	Total Index Score (A+B+C+D+E)	20	> 7.25 Probably not significantly impacted	✓
Asellus if few (1-20) tick box (score = 2)		Average Index Score (Total IS / 5)	4	> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus if common (> 20) tick box (score = 0)		SSR Score = (Average IS) x 2	8	< 6.5 Probably impacted	
E: *Asellus* index score (4 or 2 or 0)	4	SAMPLE TAXON NUMBER		INVERT. DENSITY (E / A / M / L / S)	M



Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)

Macrophyte	Ab.		Ab.	Macroalgae	Ab.
absent?				absent?	
				Bacterial tufts	Ab.
				absent?	

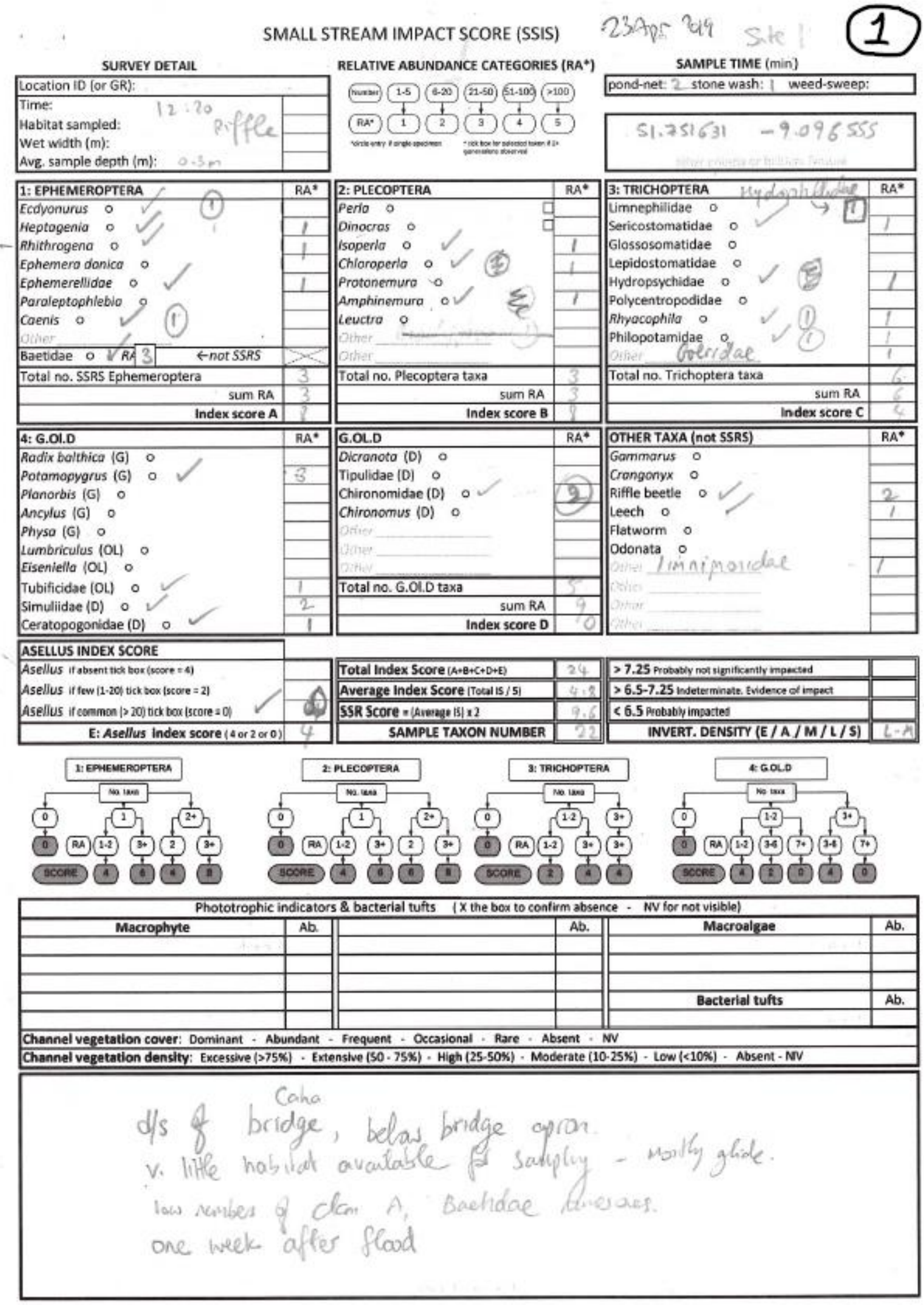
Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

SIMILAR TO L.N.1 SAMPLE. SLIGHTLY LESS SPECIES DENSITY BUT SIMILAR TAXA - NICE SAMPLE AGAIN. CATTLE ACCESS ON L.B. BUT NO SIGNS OF POACHING

General comments:

Figure 2: SSIS sheet from Blue Dot waterbody lough Nastackan (Version D01 of fieldsheet)



SMALL STREAM IMPACT SCORE (SSIS) — 23 Apr 2019 — Site 1 — (1)

SURVEY DETAIL	
Location ID (or GR):	
Time:	12:20
Habitat sampled:	Riffle
Wet width (m):	
Avg. sample depth (m):	0.3 m

RELATIVE ABUNDANCE CATEGORIES (RA*): (Number) 1-5 → RA 1; 6-20 → 2; 21-50 → 3; 51-100 → 4; >100 → 5

SAMPLE TIME (min): pond-net: 2 stone wash: 1 weed-sweep:

51.751631 −9.096555

1: EPHEMEROPTERA	RA*	2: PLECOPTERA	RA*	3: TRICHOPTERA (Hydroptilidae)	RA*
Ecdyonurus ✓ (1)		Perla		Limnephilidae	
Heptagenia ✓	1	Dinocras		Sericostomatidae ✓	1
Rhithrogena	1	Isoperla ✓	1	Glossosomatidae	
Ephemera danica ✓		Chloroperla ✓	1	Lepidostomatidae	
Ephemerellidae ✓	1	Protonemura		Hydropsychidae ✓	1
Paraleptophlebia		Amphinemura ✓	1	Polycentropodidae	
Caenis ✓ (1)		Leuctra		Rhyacophila ✓	1
Other		Other		Philopotamidae ✓	1
Baetidae ✓ RA 3 ← not SSRS		Other		Other Goeridae	1
Total no. SSRS Ephemeroptera	3	Total no. Plecoptera taxa	3	Total no. Trichoptera taxa	6
sum RA	3	sum RA	3	sum RA	6
Index score A	7	Index score B	9	Index score C	4

4: G.OI.D	RA*	G.OI.D	RA*	OTHER TAXA (not SSRS)	RA*
Radix balthica (G)		Dicranota (D)		Gammarus	
Potamopygrus (G) ✓	3	Tipulidae (D)		Crangonyx	
Planorbis (G)		Chironomidae (D) ✓	2	Riffle beetle ✓	2
Ancylus (G)		Chironomus (D)		Leech	1
Physa (G)		Other		Flatworm	
Lumbriculus (OL)		Other		Odonata	
Eiseniella (OL)		Other		Other Limnephilidae	1
Tubificidae (OL) ✓	1	Total no. G.OI.D taxa	5	Other	
Simuliidae (D) ✓	2	sum RA	9	Other	
Ceratopogonidae (D) ✓	1	Index score D	0	Other	

ASELLUS INDEX SCORE					
Asellus if absent tick box (score = 4) ✓		Total Index Score (A+B+C+D+E)	24	> 7.25 Probably not significantly impacted	
Asellus if few (1-20) tick box (score = 2)		Average Index Score (Total IS / 5)	4.8	> 6.5-7.25 Indeterminate. Evidence of impact	
Asellus if common (> 20) tick box (score = 0)	4	SSR Score = (Average IS) x 2	9.6	< 6.5 Probably impacted	
E: Asellus index score (4 or 2 or 0)	4	SAMPLE TAXON NUMBER	22	INVERT. DENSITY (E / A / M / L / S)	L-M

Phototrophic indicators & bacterial tufts (X the box to confirm absence - NV for not visible)					
Macrophyte	Ab.		Ab.	Macroalgae	Ab.
				Bacterial tufts	Ab.

Channel vegetation cover: Dominant - Abundant - Frequent - Occasional - Rare - Absent - NV

Channel vegetation density: Excessive (>75%) - Extensive (50 - 75%) - High (25-50%) - Moderate (10-25%) - Low (<10%) - Absent - NV

Caha
d/s of bridge, below bridge apron.
v. little habitat available for sampling - mostly glide.
low numbers of clean A, Baetidae [illegible].
one week after flood

Figure 3: Field sheet from monitoring point of Caha_020 (Version D01 of field sheet)

Table 1: Comparison of taxa captured my LAWPRO and EPA in Nastackan and Caha

		EPA	LAWPRO	EPA	LAWPRO
	Waterbody Code	IE_NW_40L030400		IE_SW_20C010700	
	Waterbody Name	LOUGH NASTACKAN STREAM_010		CAHA_020	
	Q value status or SSIS Score	High	SSIS 8	Good	SSIS 9.6
	Fieldsheet Date	19/09/2019	11/09/2019	13/06/2019	23/04/2019
A	**Amphinemura**			Single	1
A	**Chloroperlidae**			Few	1
A	**Ecdyonurus**	Common	2	Common	Single
A	**Heptagenia**	Few	1		1
A	**Isoperla**	Few		Few	1
A	**Nemouridae**	Few			
A	**Rhithrogena**			Few	
A	**Rhithrogena semicolorata**	Common	2		1
B	**Baetis muticus**	Few			
B	**Glossosomatidae**			Few	
B	**Goeridae**	Few	1		1
B	**Hydroptila**				1
B	**Leuctra**	Few		Few	
B	**Sericostomatidae**	Few	1	Few	1
C	**Ancylidae**	Common	2		
C	**Baetis rhodani**	Common	2	Numerous	3
C	**Caenis**			Few	1
C	**Ceratopogonidae**			Few	1
C	**Chironomidae**	Few	1	Few	2
C	**Dicranota**	Few		Few	
C	**Eiseniella**	Few	1		
C	**Elmidae sp.**		1		2
C	**Elmis aenea**			Few	
C	**Esolus / Oulimnius aggregation**			Few	
C	**Gammarus**	Dominant	2		
C	**Hydrachnidae**			Few	
C	**Hydraenidae**	Few			
C	**Hydropsyche**	Few	1	Few	1
C	**Lumbricidae**	Few			
C	**Philopotamidae**	Few		Few	1
C	**Polycentropodidae**		1	Few	
C	**Potamopyrgus antipodarum**	Few	1	Common	3
C	**Rhyacophila**	Few			1
C	**Serratella ignita**			Common	1
C	**Simuliidae**	Common	1	Few	2
D	**Hirudinea**				1
E	**Oligochaeta**			Few	
E	**Tubificidae**			Few	1

***Note – Taxa identified by the EPA that would not be separated by LAWPRO are highlighted e.g., EPA - Rhithrogena semicolorata and Rhithrogena are equivalent to LAWPRO - Rhithrogena, EPA - Esolus/Oulimnius aggregation and Elmis aenea are equivalent to LAWPRO - Elmidae sp. (Riffle Beetle)**

Appendix E: LAWPRO Biosecurity Protocol

Biosecurity Guidelines and Protocol

for

Local Authority Waters Programme's Catchment Assessment Team

1st Draft - October 2019

Updated - October 2021

Table of Contents

Definitions

Invasive alien species and pathogens are plants, animals, pathogens or other organisms that are introduced, accidentally or intentionally, into locations outside their native range, normally by humans, that adversely impact on native biodiversity, ecosystem services, the economy or human health.

Biosecurity refers to all practical measures used to manage and prevent the introduction and spread of invasive alien species and pathogens.

Front Cover: Dense stands of Curly waterweed (Lagarosiphon major) and Parrot's feather (Myriophyllum aquaticum) in a pond in Co Waterford.

1. Purpose of the Protocol

These Biosecurity Guidelines and Protocol provides information and guidance to the Local Authority Waters Programme's (LAWPRO) Catchment Assessment Team members and their associates on invasive alien species and pathogens (henceforth IAS). It further provides standardised and practical measures to prevent the introduction and spread of IAS during the normal course of their duties.

The primary focus of the Catchment Assessment Team is to improve water quality in Irish watercourses, working in close association with Local Authorities, State agencies, public bodies, landowners, local communities and others. The execution of this role commonly brings team members into direct contact with IAS, whether these are visible or unseen. This document emphasises the need to ensure that no IAS are transferred during river or lake assessments, habitat surveys or other field operations to locations where they can re-establish or create new IAS populations.

In order to minimise the risk of introducing or spreading IAS, it is important that Catchment Assessment Team members know of the main IAS that are present in and close to watercourses in Ireland and are also aware of those IAS that are problematic in watercourses and riparian habitats in other countries but have not yet been recorded in Ireland. They should be able to identify the main IAS that are likely to be present in and adjacent to watercourses, be aware of the problems they pose for biodiversity and ecosystem function, and the methods by which they can spread and produce new populations.

Invasive alien species and pathogens, or their propagules, are not always visible and can be unintentionally picked up on sampling equipment, boats or trailers, vehicles or PPE and transferred to previously uncontaminated areas. Proper implementation of, and adherence to, the biosecurity measures presented in this Guidelines and Protocol document by members of the Catchment Assessment Team and their associates will minimise the inadvertent introduction and spread of these damaging organisms.

This document is in line with national and international legislative requirements and supports existing biosecurity activities operated by LAWPRO.

2. Current Legislation and Policy relating to Invasive Alien Species and Pathogens in Ireland

Regulations 49 and 50 of the European Communities (Birds and Natural Habitats) Regulations (S.I. 477/2011 - http://www.irishstatutebook.ie/eli/2011/si/477/made/en/print# set out the legal requirements and restrictions in Ireland relating to those IAS that are listed in the Third Schedule (Parts 1 and 2) of that legal document. These lists include many of the species that are currently present in and adjacent to many Irish watercourses. (It is worth noting that Regulation 50 has not yet been commenced by the Minister.)

Regulation 49 deals with the 'Prohibition on introduction and dispersal of certain species' and places restrictions on the introduction of any species listed in Parts 1 and 2 of the Third Schedule. It states that a person shall be guilty of an offence if they 'plant, disperse, allow or cause to disperse, spread or cause to grow' any listed plant in the Republic of Ireland.

A number of the IAS that are 'subject to restrictions' under S.I. 477/2011 are also listed as 'species of Union concern' in the EU Invasive Alien Species Regulations (1143/2014) (http://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pd), which came into law for all Member States (MS) in January 2015. Under these European regulations all MS must manage any of the 49 (soon to be 67) species that are currently listed as being 'of Union concern'. A number of IAS present along Irish watercourses are common to both our national and EU legislation and include: Nuttall's pondweed, Curly waterweed, American skunk cabbage, Giant hogweed, Himalayan balsam and Chilean rhubarb.

The River Basin Management Plan for Ireland (2018 – 2021) formally recognises IAS as a major threat to native biodiversity in Ireland and includes these harmful organisms as significant pressures to the achievement of good water quality conditions. For this reason, a number of 'Principal Actions' relating specifically to IAS have been included in the current Plan, including one directly relating to biosecurity – 'national guidelines for biosecurity will be developed to prevent the introduction and spread of IAS and to mitigate their impacts.' In addition, Ireland's third National Biodiversity Action Plan (2017 – 2021) lists IAS among its 'Targets', stressing the need for the 'development and adoption of biosecurity plans in relevant state bodies'.

3. Invasive Alien Species and Pathogens in Ireland

3.1 Invasive alien species and pathogens currently present in Ireland

The IAS that are most invasive (commonly referred to a high impact IAS) and that currently represent the greatest threat to native biodiversity and ecosystem function in Ireland are listed in the Third Schedule (Parts 1 and 2) of the EC (Birds and Natural Habitats) Regulations 2011 (S.I. 477/2011). A number of these are also included in the EU IAS Regulation (1143/2014). These include species that are well established and continue to proliferate and spread along Irish riparian, marginal and aquatic habitats. Additional descriptions of some of these species can be found in Volume 2 of the Local Catchment Assessment Guidance on Further Characterisation (Version 1, 2018). Prominent among these IAS are:

Animals:

- Zebra mussel (*Dreissena polymorpha*)
- Asian clam (*Corbicula fluminea*)

Riparian/Marginal plants:

- Japanese knotweed (*Fallopia japonica*)
- Bohemian knotweed (*Fallopia x bohemica*)
- Giant knotweed (*Fallopia sachalinensis*)
- Himalayan knotweed (*Persicaria wallichii*)
- Giant hogweed (*Heracleum mantegazzianum*)
- Himalayan balsam (*Impatiens glandulifera*)
- Giant rhubarb (*Gunnera tinctoria*)
- Rhododendron (*Rhododendron ponticum*)
- American skunk-cabbage (*Lysichiton americanus*)

Aquatic plants:

- Curly waterweed (*Lagarosiphon major*)
- New Zealand pigmyweed (*Crassula helmsii*)
- Nuttall’s pondweed (*Elodea nuttallii*)
- Parrot’s feather (*Myriophyllum aquaticum*)
- Fringed waterlily (*Nymphoides peltata*)
- Water fern (*Azolla filiculoides*)
- Floating pennywort (*Hydrocotyle ranunculoides*)
- Water primrose (*Ludwigia grandiflora*)

Pathogens and parasites:

- Crayfish plague (*Aphanomyces astaci*)
- Carp edema virus (CEV).

Of particular concern among the aquatic invasive pathogens that currently threaten our waters and wildlife is the Crayfish plague, which is caused by the fungus-like organism *Aphanomyces astaci.* This pathogen can cause 100% mortality to affected stocks of our protected, White-clawed crayfish (*Austropotamobius pallipes*) populations and has caused the death of tens of thousands of individuals in Irish waters in recent years. It is probable that this pathogen was inadvertently introduced to Ireland on contaminated equipment, possibly by anglers or boaters. In recent years it has caused the closure of a number of rivers in the country.

In addition to the above list, there are three invasive plant species that are not currently included in the Third Schedule of S.I. 477/2014 but that pose a serious and ongoing threat to native biodiversity and habitat function in Irish terrestrial and freshwater habitats. These are Winter heliotrope (*Petasites pyrenaicus*), Montbretia (*Crocosmia x crocosmiifolia*) and Old man's beard (Clematis vitalba).

3.2 Invasive alien species and pathogens not yet recorded in Ireland

There are a number of IAS that have not yet been recorded on the island of Ireland but that pose significant threats to biodiversity and ecosystem function in countries within easy reach of Ireland. In 2017, a workshop was held in the Institute of Technology, Sligo to identify and prioritise those IAS that are most likely to arrive on our shores in the next decade. It is noteworthy that six of the top ten 'horizon scan' species identified by experts at this workshop pose threats to freshwater habitats and species. These are listed below, with their top ten ranking:

1 Signal crayfish (*Pacifastacus leniusculus)*

3 Killer shrimp (*Dikerogammarus villosus*)

4 Salmon fluke (*Gyrodactylus salaris*)

5 Quagga mussel (*Dreissena rostriformis bugensis*) (Note: now present in Ireland. Species alert issued on 9th July 2021[1])

6 Chinese mitten crab (*Eriocheir sinensis*)

10 Topmouth gudgeon (*Pseudorasbora parva*).

[1] Invasive Species Alert for Quagga mussel - National Biodiversity Data Centre (biodiversityireland.ie)

4. Threats Posed by invasive Alien Species and Pathogens

Invasive alien species and pathogens are considered to be one of the major global threats to native biodiversity and are the second leading cause of species extinctions in freshwater habitats. The ecological effects of IAS are often irreversible and, once established, they can be extremely difficult and costly to control and eradicate. The spread of IAS in Ireland and abroad is one of our most urgent nature conservation challenges. The estimated annual cost of IAS on the island of Ireland is €262 million (based on 2013 figures).

Aquatic ecosystems are particularly vulnerable to IAS because of the ease with which they can disperse within and between them, and the high level of human activity (including amenity, recreation and management) on these aquatic resources.

Some examples of the damage that IAS can cause in and adjacent to watercourses include:

- significant biodiversity loss among native animals and plants;
- elimination of threatened or vulnerable species (e.g. the protected White-clawed crayfish by Crayfish plague and Freshwater Pearl Mussel (*Margaritifera margaratifera*) by Asian clam (*Corbicula fluminea*));
- clogging of lakes, rivers, canals and drainage ditches with submerged vegetation, with consequences for flooding, fish migrations and recreation;
- clogging of river corridors with dense stands of marginal and riparian IAS, with serious consequences for flooding;
- bankside erosion and subsidence along river channels caused by the smothering growth of marginal and riparian IAS;
- structural damage to bridges, instream structures or banksides caused by the deeply penetrating roots and rhizomes of some IAS (e.g. Knotweed species, Old man's beard); and
- damage to human health (e.g. burns caused by the sap of Giant hogweed).

5. How Do Invasive Alien Species and Pathogens Spread?

Invasive alien species and pathogens can spread, establish and proliferate very rapidly, using a variety of viable propagules.

Species such as Himalayan balsam, Giant hogweed, Rhododendron and American skunk cabbage spread primarily by seed, all producing large numbers of seeds that can be transported *via* water, wind, animals and human activity. Giant rhubarb, Old man's beard and Montbretia can spread *via* seeds and root or rhizome fragments. The Knotweed species (4) and Winter heliotrope spread primarily by rhizome fragmentation. These rhizomes are highly infectious and even small fragments can grow to establish new populations. These are most commonly dispersed by human activity, where soil that is contaminated with knotweed plant material is excavated and transferred to new and previously uninfested sites.

Most aquatic IAS spread by fragmentation, where small, detached plant fragments float or are carried to new waters on boats, vehicles or machinery, where they can root and establish new populations.

Both the Zebra mussel and Asian clam produce large numbers of tiny free-floating young (veligers), each of which possesses short, sticky threads. These readily attach to PPE, the wheels and undercarriage of vehicles and trailers, water maintenance equipment and plant, and boats. In this manner they can be transferred from one area of river or lake, or from one watercourse to another. *Aphanomyces astaci*, which causes the Crayfish plague, likewise produces large numbers of free-swimming spores that are released into the water and actively seek susceptible hosts.

Most of the plant fragments, veligers and spores produced by aquatic IAS can remain alive out of water, in damp conditions, for at least a few days. These damp conditions can be provided in mud attached to PPE or to the wheels/undercarriages of vehicles, in water wells of boats or even attached to water sampling equipment used during routine monitoring. The following shows the number of days that some high impact IAS that are present in Irish freshwater habitats can survive in damp conditions, out of water:

- Zebra mussel > 5 days
- New Zealand pigmyweed > 22 days
- Asian clam > 30 days
- Crayfish plague up to 21 days.

6. Biosecurity Protocol

Preventing the spread of IAS is significantly more cost-effective and less environmentally damaging than long-term containment, control or eradication. The most effective measure to reduce introduction and halt the spread of IAS is to promote and implement good biosecurity practice.

Invasive alien species or pathogens are not always visible and can be unintentionally picked up on sampling apparatus, PPE, boats or vehicles and transferred to previously uncontaminated areas. The availability of a clear and concise biosecurity protocol for members of the Catchment Assessment Team will minimise the risks of inadvertently spreading these damaging IAS, while also ensuring the implementation of good and hygienic work practices.

This biosecurity protocol applies to all equipment and machinery (including PPE, water sampling apparatus, trays, waders, wellingtons etc) that may be used in the execution of field duties.

All vehicles used for survey work must carry a LAWPRO Cleaning/Disinfection Kit, which should comprise the following:

- sturdy storage box and lid,
- detailed instructions for proper cleaning and disinfection procedure and for preparing the correct disinfection concentration,
- container for clean water (to make extra disinfection solution on-site, as necessary) [LAWPRO have provided a container for virkon to each catchment scientist. The virkon solution is transported in a ~5 litre drum, tipped into the foot bath on-site and then transferred back into the drum for use at the next site. Note boots must be relatively clean going into the disinfectant],
- boot bath (for washing dirty boots or small items of equipment),
- portable or handheld sprayer,
- Virkon Aquatic* tablets or powder, or another proprietary disinfectant**. Virkon tablets have been the main disinfectant used by LAWPRO to date,
- hard-bristle brush,
- absorbent cloths (e.g. J cloths), and
- disposable gloves.

*Virkon Aquatic is a disinfectant that kills a number of fish pathogens and Crayfish plague spores. It is also effective against a number of invasive plant and invertebrate species. It comes in tablet or powder form. It is biodegradable and non-corrosive at working concentrations. However, please note that reliance on Virkon Aquatic for aquatic plants is not fool proof. Crane (2020) found that plants e.g Newzealand pygmyweed could still survive after being treated. We also suggest physically removing plants from equipment and leaving any fragments at site, then using Virkon i.e do full Check, Clean and Dry.

**Disinfectants must be used with care and in strict accordance with the manufacturer's instructions. Disposable gloves should be worn when using the disinfectant solution.

Before embarking on an operation where disinfection will be required, a disinfection solution should be prepared and be available in the portable or handheld sprayer unit. Always have clean water and an ample supply of disinfectant powder or tablets available should you need to replenish your disinfectant during the course of your field day.

Best biosecurity practice at work sites will be achieved by ensuring that the following checks are adhered to when planning and conducting field surveys and operations.

6.1 Pre-Survey Biosecurity Checks

When preparing for local catchment assessments or other field operations, streamside events or outdoor meetings involving entry to water, it is essential that the following biosecurity checks are conducted:

- Check to see if any IAS are present or are likely to be present in the area where work is scheduled. Invasive alien species distribution maps may be viewed on www.biodiversityireland.ie and/or www.bsbi.org, but be aware that undetected or unreported IAS may be present in these areas. (It may be advisable to conduct an advance site survey to determine the presence and extent of any IAS infestations.). LAWPRO have also developed a GIS layer indicating where crayfish plague has been recorded, and this should also be checked in advance.
- Ensure that all PPE, equipment and vehicles (if boats and trailers are used, which is not generally the case at the moment for LAWPRO) are cleaned and/or disinfected prior to arrival on-site.
- It is good practice, where possible, to have equipment that is dedicated solely to watercourses or catchments where IAS are known to reside. LAWPRO have issued a second set of equipment to all teams working in crayfish plague catchments.
- Complete all sampling in one catchment before moving to the next and, work in uncontaminated catchments before entering infested or potentially infested ones. This will avoid or minimise the potential for cross-transfer of IAS between catchments.
- Where possible and practical, conduct operations on watercourses in a downstream direction on order to avoid the potential introduction of IAS into the upper catchment. LAWPRO generally start as a rule from the impacted monitoring site, working in an upstream direction. This may not be possible in catchments with known IAS or known crayfish plague.

6.2 Biosecurity Checks for Field Operations

It is important that all PPE and field equipment used during local catchment assessments are cleaned and/or disinfected according to the procedures below. Cleaning must be conducted before leaving the site of operation or at an appropriate cleaning location and must be conducted before accessing another site.

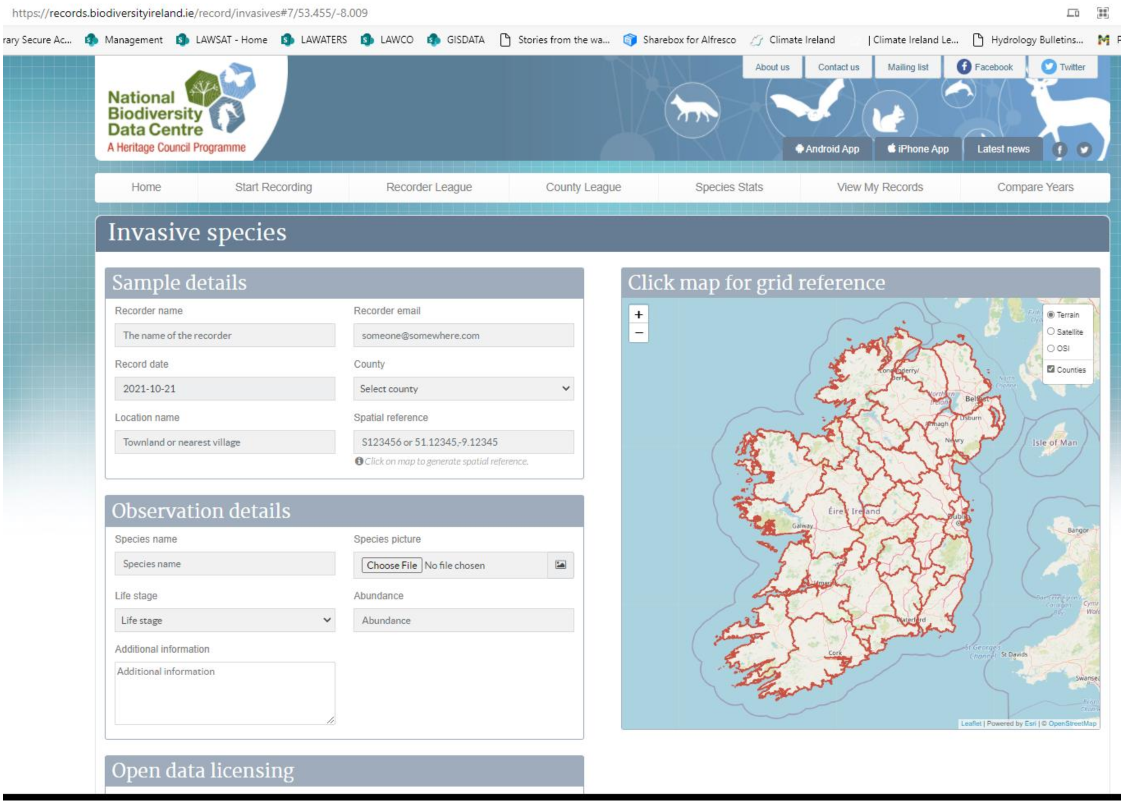
- Before commencing field work, preferably on the morning of each field operation, fill the portable or hand-held sprayer with a 1% solution of Virkon Aquatic (2 tablets or 10g powder in 1 litre of clean water – never use river or lake water to make up the solution) or another proprietary disinfectant. The solution in the sprayer will remain pink while it is still active (normally for between 5 and 7 days).

- On arrival at a sampling site, ensure that vehicles are not parked on or adjacent to obvious IAS stands. Aim to park on hardstanding if possible, in order to keep vehicle wheels clean.

- During sampling, be watchful for any non native crayfish or dead native White-clawed crayfish. If dead WCC are encountered, an immediate report should be made to the NPWS and your line manager should be notified on the day. Immediately report all suspected sightings of non-native crayfish or dead native WCC to the National Biodiversity Data Center to coflynn@biodiversityireland.ie or through the online form Recording System :: Invasive species (biodiversityireland.ie) (see below). Please supply the date of sighting, location name, location coordinates and your contact details. If possible, please supply a photo of the crayfish showing the underside of the claws to aid in verifying the sighting.

- **The current list of rivers affected by Crayfish Plague** are[2]: the **River Bruskey/Erne** (Co Cavan; detected 2015); **River Suir** (Co Tipperary/Waterford, detected 2017); **River Deel** (Co Limerick, 2017); **River Barrow** (Co Carlow 2017); **River Lorrha** (Co Tipperary, 2017); **River Al** (Westmeath, 2018); **River Maigue** (Co Limerick, 2019); **River Clare** (Co. Galway/Mayo, 2019); **River Nore** (Co. Kilkenny, 2019) **River Clodiagh** (Co. Laois/Offaly, 2021). There was also an outbreak in Co. Tyrone in Northern Ireland in 2018.

- All other IAS should be recorded on LAWPRO fieldsheets e.g. Catchment Walk fieldsheet, with a description, location (grid reference/GPS) and good quality photographs, and logged on the National Biodiversity Data Centre webpage. [Recording System :: Invasive species (biodiversityireland.ie)]



Online form for reporting of IAS, including crayfish plague.

- Before cleaning and disinfecting equipment (including PPE) that has come into contact with water or IAS, put on disposable gloves.

- Visually inspect all equipment for evidence of attached IAS material or adherent mud or debris. Remove any such material before cleaning and disinfecting the equipment.

- During inspection and cleaning, pay particular attention to places where the spores, seeds or fragments of IAS could be trapped or concealed, such as the treads of boots or tyres, or water wells in boats.

- Leave any IAS material taken from the equipment on site.

[2] Crayfish plague - Invasives.ie

- Thoroughly rinse the probes of electronic meters with clean or deionised water after use.
- Using the portable or hand-held sprayer, apply the disinfectant solution - to the point of run-off - to boots, buckets, rope, handnets, grapnels and any other equipment that has come into contact with the river, lake or canal water. There is no need to rinse equipment following spraying. For equipment disinfection allow a contact time of 30 minutes. Place equipment in a plastic bag between sites to extend the disinfection period.
- Wipe down all PPE that has come into contact with river, lake or canal water using an absorbent cloth soaked a 1% Virkon Aquatic solution or another proprietary disinfectant.
- For heavily soiled boots and PPE, use the hard-bristle brush to remove mud and debris, and then spray with the disinfectant solution or use the Boot Bath that is provided with the Disinfection Kit.
- Where time permits and it is practical, it is good biosecurity practice to thoroughly air dry equipment following cleaning and disinfection. The use of boiler sheds and designated drying rooms may offer suitable conditions for this.

6.3 Biosecurity Checks for Contractors engaged by LAWPRO

Although LAWPRO currently do not use trailers or boats, we may at some point require contractors to do this work on our behalf or with us. LAWPRO shall ensure that all contractors engaged to carry out field work shall implement these biosecurity protocols:

- Where trailers or vehicles have come into contact with river, lake or canal water, they should be steam-cleaned, under high pressure, with hot water ($\geq$ 45°C) or alternatively power-hosed with cold water and then sprayed with a 1% Virkon Aquatic solution or another proprietary disinfectant. Ensure the wheels, undercarriage and anywhere that IAS could be concealed or where water could be lodged, are cleaned. (This operation can be completed at some roadside garages.)
- On removing a boat from a watercourse, as much water as possible should be removed from all live wells and other water retaining compartments. This should be conducted before leaving the site of operation. Small boats and ribs may be cleaned and disinfected on site. Larger boats should be cleaned and disinfected off-site, as described for trailers and vehicles, above.
- Outboard motors should be flushed (e.g. using a set of ear or flush muffs) with a disinfectant solution before being used in another watercourse.
- Remove disposable gloves and dispose of safely.
- If returning to a depot at the end of the day, it may be more efficient to conduct the more thorough cleaning operations at this facility.

1. **Additional Notes:**

- **Reference material used to develop the Biosecurity Guidelines and Protocol**

This Guidelines and Protocol document was developed by INVAS Biosecurity Ltd. on behalf of LAWPRO and using information from agencies worldwide that operate good biosecurity practice in order to limit the flow of invasive species and pathogens into and within their countries. Experience gained in developing best biosecurity practice for Inland Fisheries Ireland, Irish Water, Waterways Ireland and INVAS Biosecurity Ltd. was used when preparing the current guidance and protocol. In addition, experience gained in implementing the practice and protocol among IFI staff of all grades, throughout the country, was brought to bear.

- **Health & Safety requirements**

All of the activities identified in this document are subject to the requirements of national Health & Safety legislation and must be carried out in compliance with LAWPRO's health & safety policy.

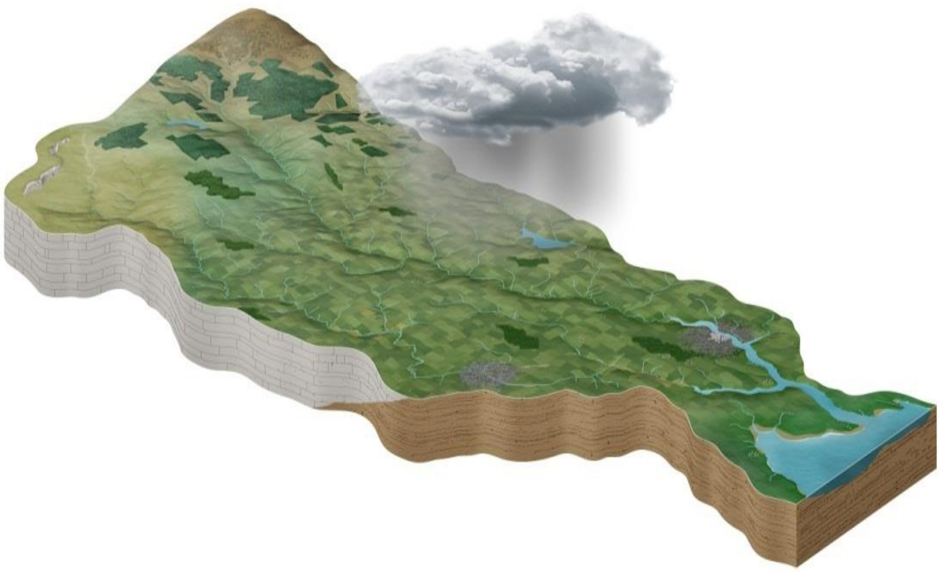
- **Who to contact in LAWPRO for further information on the Biosecurity Guidelines and Protocol document**

If you have any queries regarding the document or wish to report the presence or threats relating to invasive species or pathogens, please contact the following: your Catchment Manager, or Bernie White (Western Region Catchment Manager).

Catchment Science and Management

A Guidance Handbook

Volume 5: Urban Local Catchment Assessments



December 2019

Version no. 1

Preface

In June 2018, the Investigative Assessment Working Group chaired by the EPA developed a five-volume Local Catchment Assessment (LCA) Guidance for the investigative assessment of catchments that have failed, or are at risk of failing, to meet the environmental objectives of the Water Framework Directive. The 2018 Guidance was subsequently collated into a LCA training course delivered by the EPA to staff from the Local Authorities Waters Programme (LAWPRO) and the Agricultural Sustainability Support and Advisory Programme (ASSAP) team, as well as staff from Local Authorities and other public agencies.

The guidance presented in this volume is a companion document to the 2018 LCA Guidance. It focusses on the environmental pressures that are mostly associated with urban areas, i.e. cities and towns, but may also be present in larger population centres within rural areas.

The scope of work of this guidance covers the LCA process for urban areas and outlines how urban pressure data and information from desk studies and catchment walks might be identified, recorded, evaluated and reported. Like rural catchments, urban catchments include diffuse- and point-source pressures. An overview of urban pressures is provided in the 2018 LCA Guidance, but following the conclusions of the LCA training course, the EPA and LAWPRO both considered the need for a more detailed volume for LCAs in urban catchments.

As such, this Urban LCA Guidance builds upon, but does not duplicate, the 2018 LCA Guidance. The latter provides a comprehensive background to LCAs generally, including their role and place in the WFD implementation process, and explains the general LCA planning and implementation process. This is not repeated in the current document, and it is intended and recommended that the current guidance be read as a supplement to the 2018 LCA Guidance for specific instances when urban pressures become relevant to a catchment characterisation or pressure assessment.

This guidance was developed by CDM Smith with the input of the Urban Local Catchment Assessment Working Group.

The members of the working group are:

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1 Introduction

1.1 Objectives of the Urban LCA Guidance

The objectives of the Urban LCA Guidance are to document in greater detail:

- The range of urban pressures types that can affect water quality and aquatic ecosystems.
- Examples of urban pressure types in terms of how they appear in the field.
- The importance of conducting desk studies prior to conducting catchment walks.
- Approaches to the planning and implementation of catchment walks in urban settings.
- How different pressure types can be distinguished from one another by indicator parameters, field observation and/or measurement and monitoring techniques.
- How basic calculations may be useful when assessing individual pressures within an urban footprint. Calculations make use of both existing and new data, both from public bodies and catchment walks.
- Potentially suitable mitigation options that may be considered once significant pressures are identified and verified by the LCA process.
- Possible time lags that are associated with implementing mitigation measures and strategies.
- National and international case studies demonstrating best practice.

1.2 Guidance Structure

The Urban LCA Guidance report is broadly structured in four sections, as follows:

1. A description of the LCA process in urban catchments (which differs in some respects to the rural catchments).
2. A description of the desk study conducted prior to a catchment walk, including an overview of data and information sources as well as an identification of key stakeholders that can be consulted with for specific information.
3. Descriptions of key urban pressures, in turn:
    a. Domestic Misconnections;
    b. Trade Effluent Misconnections;
    c. Urban Runoff;
    d. Storm Water Overflows (SWOs);
    e. Contaminated Land;
    f. Hydromorphological Pressures; and
    g. Other Issues (Fats, Oil and Grease (FOG) and Leaking Sewers).

The following topics are covered for each pressure type:

- Explanation of the pressure (purpose);
- Associated pollutants and indicator parameters;
- Desk study information types and sources;
- Conducting the catchment walk;
- Data and information capture;
- Pressure assessment;
- Possible mitigation actions (measures); and
- Physical time lags for implementation of measures.

4. A description of the technical assessment of the urban pressures and how significant pressures may be identified or verified based on:
   - Measured data (trends and patterns); and
   - Analytical calculations (mixing/dilution and loading);
5. A brief case study illustrating the workflow.

A brief overview of possible mitigation actions and best practice approaches is also provided with links to relevant reference materials:

Appendix 6.1 contains reference materials such as forms and letters referenced in the text; and **Appendix 6.2** contains sample analysis suites for further laboratory analysis of different pressures.

1.3 Specific Linkages with the 2018 LCA Guidance

Most of the 2018 LCA Guidance is relevant to the urban environment, and specific linkages which should be highlighted are:

- **Volume 1: Background, Process and Implementation**
  The entire volume of the 2018 LCA Guidance is directly relevant to the Urban LCA Guidance.

- **Volume 2: Pressures and Catchments Walks**
  An introduction to pressure types is provided, and those with the greatest relevance to urban settings are:
  - Hydromorphological pressures (Section 3),
  - Urban wastewater (Section 4.5), and
  - Small point source pressures (Section 5).

- **Volume 3: Observed Indicator Features and Catchments Walks**
  Visual indicators of potential pollution, such as drains and pipes, are provided. An overview of vegetation species is provided for poor/good drainage which can be an important clue as to pathways of pollutants from standing areas to water bodies. A guide to biodiversity indicators, which are indirectly linked to water quality and the health of aquatic ecosystems, is also provided.

- **Volume 4: Measured Indicator Parameters and Catchment Walks**
  Examples of field methods and techniques used for water level, flow and water quality measurement is provided, specifically:
  - Section 2.4 – stream flow and pipe flow measurements;
  - Section 3 – water quality indicators and temperature;
  - Section 3.3 – general equipment required to carry out the field surveys;
  - Sections 4 through 9 – additional detail on individual water quality indicators, such as visual indicators of pollutants which can be linked to individual pressure types – e.g. sewage fungus (nutrient enrichment/organic impact); and
  - Section 10 – biological indicators and biological assessment techniques for invertebrates, macroalgae and macrophyte (e.g. the Small Stream Impact Score (SSIS)).

- **Volume 5: Catchment Walk Case Studies**
  This volume covers case studies that provide the assessors with practical examples of the use of indicators for characterising waterbodies.

2 Desk Study

2.1 Introduction

The desk study is the starting point of the LCA process and is comprehensively described in the 2018 LCA Guidance. As such, the LCA process is not repeated here, however, it is worth reiterating that in the LCA process, the desk study can be more than a starting point. It is part of an iterative process (summarized in Figure 1). The desk study forms part of the catchment walk assessment as new or updated information becomes available through the catchment walks and/or consultations.

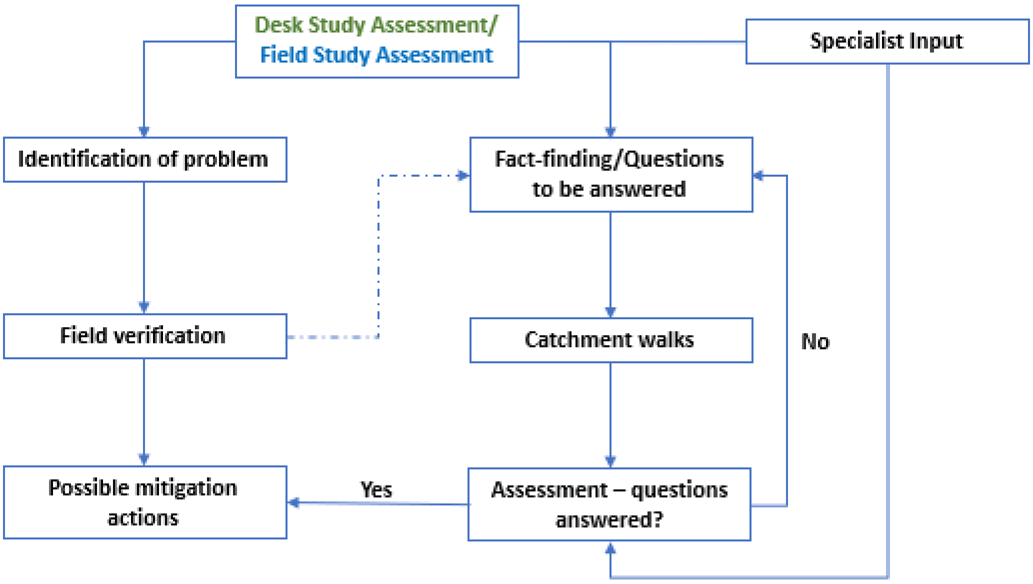

Figure 1: Summary of the Local Catchment Assessment Process

Recommendations on the content and implementation of the desk study are described in detail in the EPA document "Desk Studies for Areas for Action: EPA Recommendations" (version 3, January 2019), which should be read prior to any LCA.

As highlighted in that document, the desk study compiles and integrates the catchment story for each Priority Area for Action (PAA). The Water Framework Direction Application (WFD App) is a management system and this information is recorded in this tool as described in a separate guidance[1]. The WFD App is also used to access WFD-related information and prepare reports as part of the LCA process. The WFD App is accessible to catchment assessors through EDEN[2].

2.2 Sources of Data and Information

Data and information reside with a range of public bodies (stakeholders), including the EPA, Irish Water, Local Authorities, Geological Survey of Ireland (GSI), Office of Public Works (OPW) and Inland Fisheries Ireland (IFI). Table 1 lists the sources and types of data and information available for the urban LCA desk study.

Examples of the information specific to urban areas are shown in the screen shots in Figures 2, 3, 4 and 5.

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[1] http://www.epa.ie/pubs/reports/water/other/wfdapplicationphase1technicaloverview.html
[2] https://wfd.edenireland.ie/

The desk study outputs (i.e. data and information gathered through the desk study) should be presented in GIS format, where possible. Other information sources (e.g. An Post Geodirectory, Google maps, goldenpages.ie) may be used, for example, to identify businesses that may comprise, or contribute to, a pressure.

It is very important to consult with stakeholders for information and to discuss the initial results with Local Authority and Irish Water staff familiar within the catchment area (see Section 2.5). The extent of consultations will be case-specific and will be influenced by data and knowledge gaps. The process is not linear; information may be required at different stages of the assessment.

It is also important at the desk study to capture any mitigation measures that are present for other purposes that could be adopted for multiple benefit. For example, retention ponds in place to mitigate flooding may be developed as wetlands to improve water quality.

Table 1: Summary of Sources of Data and Information Related to Urban Pressures

Source	Data and Information	Pressure (WFD App: Pressure Category/Pressure Subcategory)
WFD App https://wfd.edenireland.ie/ (login needed)	• Water chemistry data • Q data • Characterisation • Mitigation measures • Catchment Maps • Water Quality Status • WFD Risk • WFD Status • Significant Pressures • EPA Licenced Activities (IPD, IEL, Waste licences, Section 4 Discharges, UWWT agglomeration boundaries, UWW Emission points)	• Available information on Pressures and Impacts • Monitoring data (where available) • Water quality status and environmental objectives (where available)
catchments.ie - EPA https://www.catchments.ie/maps/	• Catchment Maps • Water Quality Status • WFD Risk • WFD Status • Significant Pressures • EPA Licenced Activities (IPD, IEL, Waste licences, Section 4 Discharges, UWWT agglomeration boundaries, UWW Emission points)	• *Background*
EPAHydroNet https://www.epa.ie/hydronet/	• River flow and level data • Groundwater level data	• *Background*
Geological Survey of Ireland (GSI) https://dcenr.maps.arcgis.com/home/index.html	• Soil • Bedrock • Subsoil permeability	• *Background*
EPA GIS https://gis.epa.ie/EPAMaps/	• Soils and associated drainage • Subsoil • Land use (Corine 2018)	• *Background* • Trade Misconnections (Urban Run-off/Diffuse Sources Run-off) • Contaminated Land (Industry/IE, IPC, Section 4 Licences)

Source	Data and Information	Pressure (WFD App: Pressure Category/Pressure Subcategory)
	• Aquifer resource potential • Bedrock aquifer • Aquifer vulnerability • IPC, IED Licences, • Discharge Points, • Solvents Regulations • Contaminated Land	
EPA website (waste water) http://www.epa.ie/terminalfour/wwda/index.jsp?disclaimer=yes&Submit=Continue	• Waste Water Discharge Applications & Authorisations • Waste Water Discharge Environmental Information (e.g. AER reports)	• Combined Sewer Overflows (Urban Waste Water/Combined Sewer Overflows)
EPA website (EPA licenced facilities) http://www.epa.ie/terminalfour/ippc/index.jsp?disclaimer=yes&Submit=Continue	• IE/IPC/Waste licence application, licence or environmental information	• Trade Misconnections Urban Run-off/Diffuse Sources Run-off) • Contaminated Land (Industry/IE, IPC, Section 4)
EPA website (historic landfills) http://www.epa.ie/terminalfour/HLF/index.jsp?disclaimer=yes&Submit=Continue	• Historic Landfill Application or Certificate of Authorisation	• Contaminated Land (Waste/Waste)
Local Authority Records	• Misconnection survey data • Surface Water Drainage Network • Section 4 Discharge Licences • Zoning plans • Surface water drainage maps	• Domestic Misconnections (Urban Run-off/Diffuse Sources Run-off) • Trade Misconnections (Urban Run-off/Diffuse Sources Run-off) • Urban Runoff (Urban Run-off/Diffuse Sources Run-off)
Planning Files	• Surface water drainage maps • Foul water drainage maps	• Urban Runoff (Urban Run-off/Diffuse Sources Run-off) • Domestic Misconnections (Urban Run-off/Diffuse Sources Run-off) • Trade Misconnections (Urban Run-off/Diffuse Sources Run-off)
Irish Water GIS, available through Local Authority (login permissions required; to be arranged through Local Authority Service Level Agreement point of contact)	• Drainage Maps showing Combined and Separate Sewer Systems • Foul Drainage Discharge Points • Section 16 Licences	• Domestic Misconnections (Urban Run-off/Diffuse Sources Run-off) • Trade Misconnections (Urban Run-off/Diffuse Sources Run-off) • Urban Runoff (Urban Run-off/Diffuse Sources Run-off) • Combined Sewer Overflows (Urban Waste Water/Combined Sewer Overflows)
OSI https://geohive.ie/	• Historic River Alignments	• Hydromorphology (Hydromorphology/Channelisation)
Inland Fisheries Ireland https://www.fisheriesireland.ie/	• Barrier and other information	• Hydromorphology (Hydromorphology/ Dams, Barriers, Locks, Weirs)

Source	Data and Information	Pressure (WFD App: Pressure Category/Pressure Subcategory)
OPW Flood Plans https://www.floodinfo.ie/map/floodplans/	• Ongoing or proposed flood relief projects	• Hydromorphology (Hydromorphology/Channelisation, Embankments)
OPW https://maps.opw.ie/drainage/map/	• Drainage viewer for drainage and embankment schemes	• Hydromorphology (Hydromorphology/Channelisation, Embankments)
Met Eireann (https://www.met.ie/climate/available-data/historical-data)	• Historical Weather Data	• *Background*

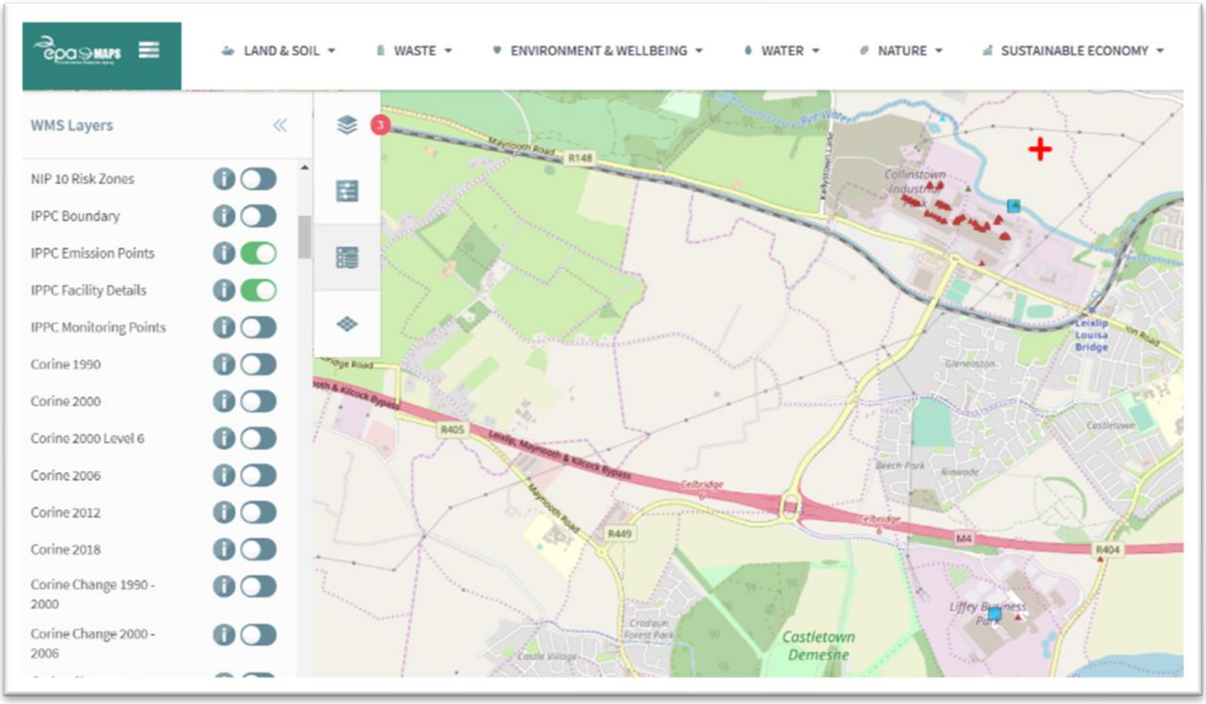


Figure 2: Example of output from EPA GIS with IPC facilities and IPC emission points highlighted

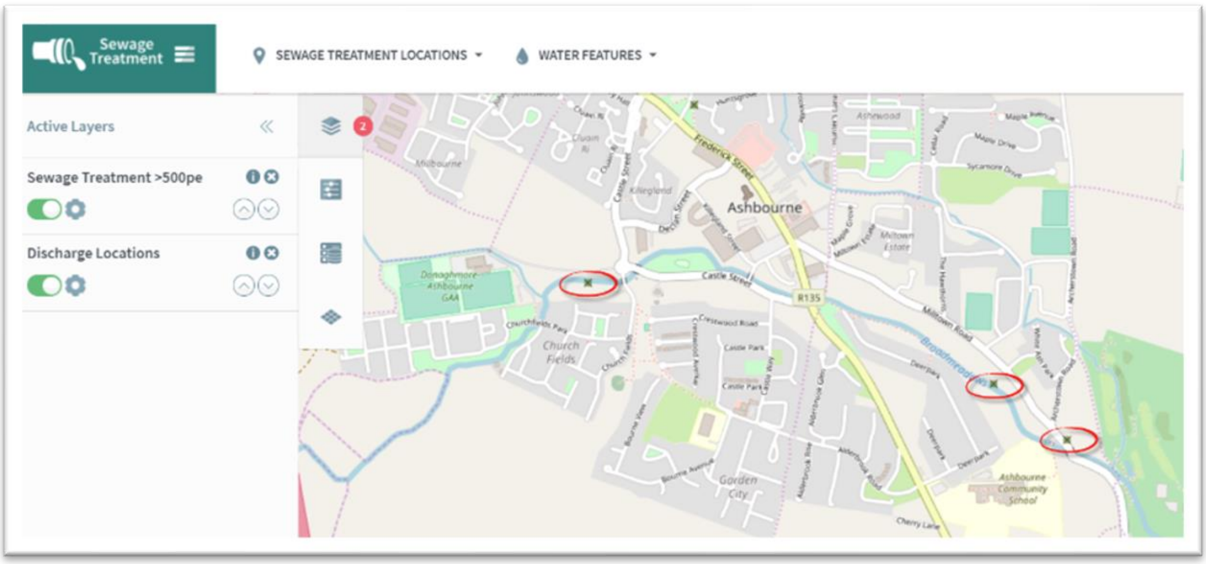


Figure 3: Example of output from EPA GIS with combined sewer overflow discharge points highlighted

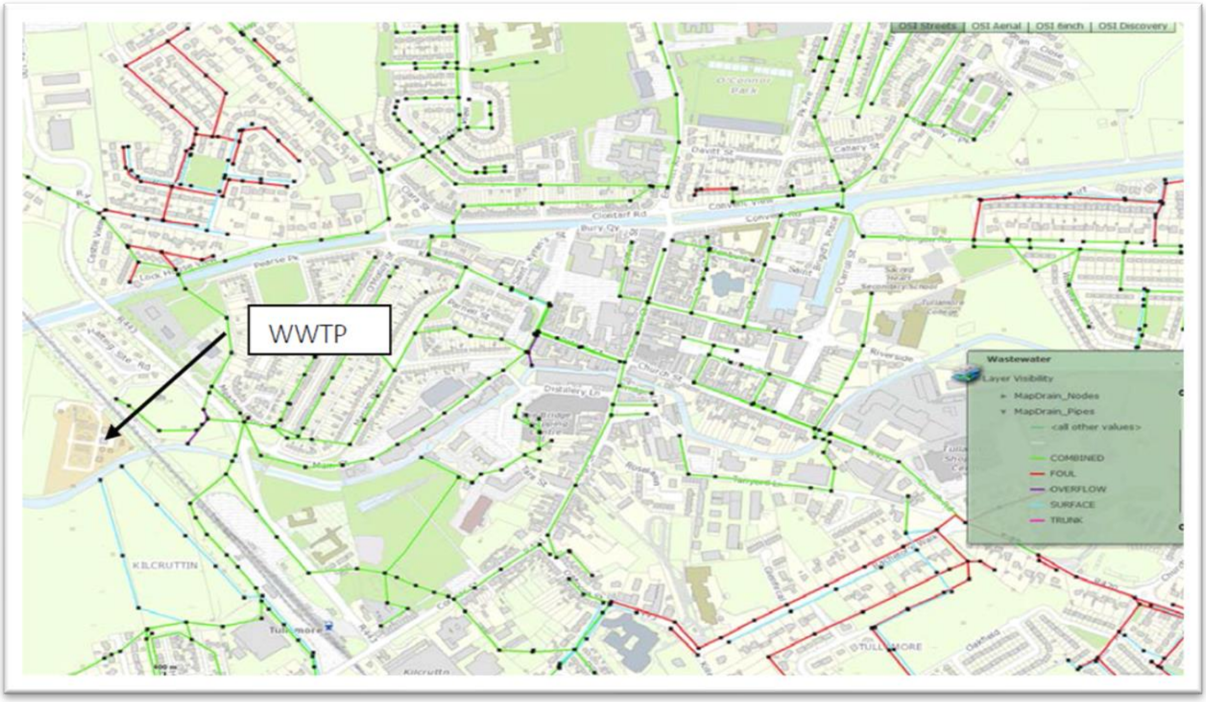


Figure 4: Example of map detailing the collection system in a medium sized town – green is combined system and red is separate foul sewer (From LCA Guidance, Volume 2, Source: Irish Water)

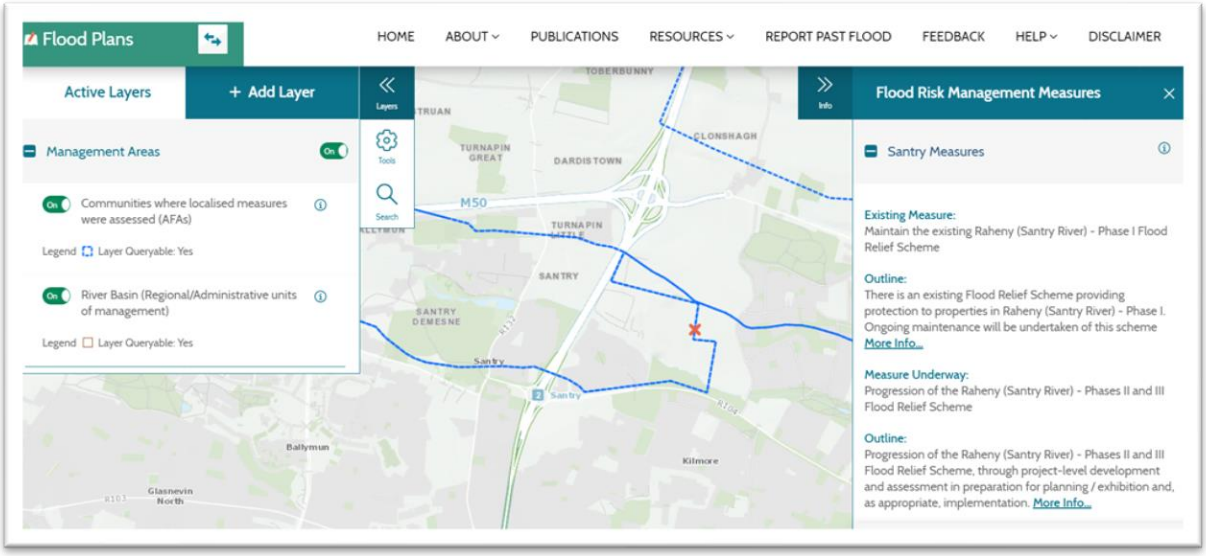


Figure 5: Example of information on active flood control measures at OPW floodinfo.ie

2.2.1 Discharge Licences

A pipe discharge may be licenced or unlicensed. Unlicensed discharges are those that are using the surface drainage system illegally. Licenced discharges will belong to one of the five below categories under the remit of the indicated responsible authority:

1. Section 4 Licence for a private, commercial body to discharge to surface water. The Local Authority is the responsible authority.

2. Industrial Emission/Integrated Pollution Control (IE/IPC) Licence for an industry to discharge to surface water. The EPA is the responsible authority.
3. Wastewater Discharge Licence for Irish Water discharge to surface water. The responsible authority is Irish Water, though issues should be communicated by the assessor to the EPA.
4. Section 16 Licences are for discharge of commercial, industrial trade effluent to the *sewer*. These may be a pressure in catchments where there is a combined sewer system. The responsible authority is Irish Water, though issues should be communicated by the assessor to the Local Authority.

Table 1 contains details of where to locate these licences. Licences that discharge to surface water require details of the discharge location, drainage/pipe drawings, effluent details, of treatment and of monitoring, as part of the licence application.

For Section 4 licences, the limit values are generally specified only for BOD, COD and SS, and not chemical parameters. Local Authorities may however hold monitoring data for nutrients and flow for Section 4 licences. The specifications in licences for commercial and industrial effluents can vary.

IE/IPC licences specify the parameters of the "emissions" or discharges, specifically, the concentration limits (always), permitted volumes (sometimes) and discharge point locations (sometimes). The licence files, available from the EPA licencing website hold the annual, self-monitoring and EPA report monitoring records for the discharge licence as well as compliance notices (i.e. correspondence and Section 25 letters).

2.3 Simple Water Chemistry Calculations

It may be necessary to carry out laboratory analysis of water samples to determine the significant pressures. The results of laboratory analysis can be used in simple calculations to determine the relative effects of pressure (s) on water quality. Also, the information in discharges licences may be used to carry out calculations without water sampling so that their contribution to the stream load can be accounted for. These simple calculations permit direct assessment of the effect of point source discharges on water quality.

The concentration of contaminants in licenced point sources discharges should be compared to the thresholds set out in the relevant licences. Stream water quality data should be compared with the appropriate thresholds, i.e. ecological quality standards (EQSs).

Two types of simple water chemistry calculations will be discussed:

1. Calculation of contaminant loads and
2. Mixing/dilution calculations.

2.3.1 Load Calculations

Laboratory analysis provides the concentration of a parameter, normally as milligrams per litre (mg/L) or micrograms per litre (µg/L). The biology of a stream is conditioned by the concentration of dissolved constituents, including contaminants (as well as other variables such as temperature, water velocity etc.). The assessor must be able to use the laboratory and field data to determine the effect of discharges on the concentration of contaminants in the stream. For this, it is necessary to understand and be able to calculate the "load" of a discharge for any given parameter.

The "load" is the total amount of a parameter contributed to a receiving water body per unit time. That is, the load incorporates the concentration of the contaminant and *volume* of the input *per unit time*. The volume per unit time is called the "flow rate" and typically expressed as litres per second (L/second). The concentrations of contaminants and flow rate may be contained in the licence files or may be determined during the catchment walk, where deemed necessary. Loads are generally expressed in g/day or Kg/day.

Loads from diffuse sources can be determined by taking water samples and stream flow measurements immediately upstream and a short distance downstream of the diffuse input. Where it is not possible to carry out stream flow measurements, median and Q_{95} values (from the OPW, Hydrotool and EPA websites) may be substituted.

The load of any parameter in any water body (including the stream) is calculated as:

$$\text{Load (kg/day)} = [C(\mu g/L) * Q\ (L/day)]\ /\ 1{,}000{,}000{,}000\ ug/kg$$

Where:
C is the concentration of the parameter in the water and
Q is the flow rate.

Note, the conversion factor from L/s to L/d is 84,000 and the conversion factor from mg/L to ug/L is 1000. The units in the formula may be changed as appropriate (e.g. expressed in g/day rather than kg/day by dividing by 1,000,000 µg/g).

The relevance of the load of a contaminant can be explained using a bucket and milk carton analogy, illustrated in Figure 6. Suppose there are two point source inputs to a stream. From the licence files, we know that the concentration of orthophosphate in one of these inputs is 0.75mg/L. We know from sampling during the catchment walk that the concentration of the other input is 1mg/L. Based on the concentration data alone, one would conclude that the latter input with higher concentration (1mg/L) would have a much greater impact on the receiving stream than the former input (0.75mg/L). Now, let's suppose the flow rate (volume/unit time) of the 0.75mg/L input is the equivalent of one 10L bucket per second, and the flow rate of the 1mg/L input is the equivalent of one 1L milk carton per second. The loads of each are calculated as follows:

Figure 6 Contaminant Load Example Illustration

<u>Bucket (10L)</u>

Formula: Load (g/day) = [C(µg/L) * Q (L/day)] / 1,000,000 µg/g
C: 0.75mg/L = 750ug/L
Q: 10L/second = 864,000 L/day
Load (g/day) = [750 * 864,000] / 1,000,000
Load= 648g/day

<u>Milk carton (1L)</u>

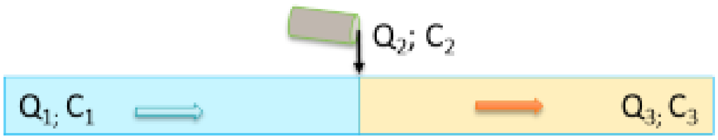
Formula: Load (g/day) = [C(µg/L) * Q (L/day)] / 1,000,000 µg/g
C: 1mg/L = 1000ug/L
Q: 10L/second = 86,400 L/day
Load (g/day) = [1000 * 86,400] / 1,000,000
Load= 86.4g/day

By calculating the load, we see that the amount of contaminant contributed to the stream from the "bucket" discharge (648g/day) is larger than that from the "milk carton" discharge (86.4g/day).

Knowledge of loads of parameters of interest (often nutrients, and particularly ortho phosphorus) is important for assessing if there are load inputs along the channel and thus for prioritising measures. There may not be sufficient data at desk study stage to do load calculations, but such assessments will often take place in the field assessment stage.

2.3.2 Mixing/Dilution Calculations

Mixing/dilution calculations can be used to determine the concentration of the parameter in the receiving waterbody, downstream of an input. This requires data on the concentration of the parameter in the stream and discharge, as well as the stream and discharge flow rates. The logic of mixing/dilution calculations is depicted below:



Where:

Q is flow
C is concentration,
$Q_1;C_1$ is the load in the stream upstream of the discharge,
$Q_2;C_2$ is the load in the discharge, and
$Q_3;C_3$ is the load downstream of the discharge.

The formula for calculating load (Section 2.3.1) may be rearranged to determine "C_3", the concentration of the parameter downstream of the input. This is done as follows:

<u>Load ($Q_3;C_3$)</u>

$Load_3$ (g/day) = [C_3(µg/L)*Q_3(L/day)] / 1,000,000 µg/g

<u>Concentration (C_3)</u>

C_3 (µg/L) = [Load(g/day)* 1,000,000 µg/g]/ Q_3 (L/day)

This C_3 equation may be completed using the upstream and input data as follows:

$C_3 = [(Q_1;C_1)+(Q_2;C_2)]/(Q_1+Q_2)$

For example, if the load of a parameter (e.g. orthophosphate) upstream of an input is 0.03g/day (with flow 350L/s) and the orthophosphate load of the input is 0.001g/day (with flow 50L/s), then the orthophosphate load downstream of the input is 0.031g/day and the flow downstream of the input is 400L/second (i.e., $Q_1 + Q_2$). The concentration of orthophosphate downstream of the input can be calculated as follows:

Formula: C_3 (µg/L) = [$Load_3$ (g/day)*1,000,000 µg/g]/ Q_3 (L/day)

Q_3: 400L/second = 34,560,000 L/day

$Load_3$: 0.031g/day

C_3 (ug/L) = [0.031g/day*1,000,000 µg/g]/ 34,560,000L/day

C_3 = 0.00089ug/L

The concentration of orthophosphate in the steam downstream of the input is 0.0089ug/L.

The upstream data may be acquired from EPA monitoring data or monitoring during the catchment walk. The discharge data may be acquired from the licence files and/or from monitoring during the catchment walk. Mixing/dilution calculations allow the assessor to determine the proportion of various parameters in the stream contributed from licenced and unlicensed discharge points, and also permit direct assessment of the impact of sources on water quality. The downstream concentration (C_3) should be compared with the appropriate thresholds, i.e. ecological quality standards (EQSs).

2.4 Water Quality and “Indicator Parameter”

As reproduced in Table 2 taken from Volume 1 of the 2018 LCA Guidance, water quality indicators for urban pressures can overlap with rural and other pressure types. All urban LCAs must at the desk study stage examine the water quality of the upstream waterbody contributing to the urban waterbody of interest. Within the urban footprint, different urban pressures may have overlapping water quality indicators, as shown in Table 2. Accordingly, deciphering water quality and “significant pressures” in urban areas is not a straightforward task.

Table 2: Urban pressure types and indicator parameters

Pressure	Indicator Parameters
Domestic Misconnections (Section 4 of this guidance)	• COD, BOD, TOC • Ammonia • Faecal coliforms • Phosphorus (washing machine/dishwater) • Anionic surfactants (shower gel/ soap/shampoo)
Trade Effluent Misconnections (Section 5 of this guidance)	• Metals (especially lead, mercury, zinc, copper and arsenic) • Fats, oils and grease (FOG) • COD, BOD, TOC • Phosphorus (detergents) • Anionic surfactants (commercial detergents)
Urban Run Off (Section 6 of this guidance)	• COD, BOD, TOC • Suspended solids • Heavy Metals • Hydrocarbons • Phosphorus
Storm Water Overflows* (Section 7 of this guidance)	• Total suspended solids • COD, BOD, TOC • Total nitrogen, ammonia, nitrate, nitrite • Total phosphate, ortho-phosphate • Chlorine, Sulphate • Metals Copper, Lead, Zinc, Iron, Chromium, Nickel • Calcium, Sodium • PAH • *Escherichia coli* (*E. coli*)
Contaminated Land (Section 8 of this guidance)	• COD, BOD, TOC • Chlorinated volatile organic chemicals (VOCs); • Hydrocarbons; • Semi-volatile organic chemicals; • Polycyclic aromatic hydrocarbons (PAHs); • Total suspended solids; • Metals (especially lead, mercury, zinc, copper and arsenic) • PCBs and dioxins.
Hydromorphology (Section 9 of this guidance)	• N/A

*For the purposes of this guidance, it is assumed that any SWOs that present a significant pressure will discharge both urban runoff and untreated sewage.

Table 3: Table 2-1 from Volume 1 of LCA Guidance

Pressure	Indicator Parameter																	
	Chemical/Physico chemical														Hydromorphological			Comment
	Ammonia	Nitrate	Phosphorus	Microbiology/Pathogens	Temperature	Dissolved Oxygen	Acidisation (pH)	Turbidity & Colour	BOD/COD	Total Suspended Solids	Salinity[1]	Pesticides	Hydrocarbons	Heavy Metals	Flow/Level	Depth/Width	Sediment	
Agriculture	●	●	●	●		●		●	●	●	●	●	●				●	
Hydromorphological alteration			●					●		●					●	●	●	Habitat degradation; increased sedimentation, and mobilisation of nutrients in sediments
Urban Wastewater	●	●	●	●	●	●		●	●	●	●		●	●				
Forestry	●		●				●	●		●		●					●	
Domestic Wastewater	●	●	●	●		●		●	●	●	●	●						
Urban (diffuse and small point)	●		●	●		●	●	●	●	●	●	●	●	●	●		●	
Peat	●					●	●	●	●	●							●	Dissolved organic carbon is also a possible pollutant
Industry	●		●		●			●	●	●	●		●	●				Depends on the nature of industry
Quarries	●			●				●		●	●		●	●	●	●	●	
Mines							●			●				●				Iron especially. Also, poor biological indicators (fish, macroinvertebrates), see Volume 3
Abstractions/flow diversions											●				●	●	●	Saline intrusion in coastal aquifers
Landfills, fly tips	●			●		●		●	●		●		●	●				Dissolved Methane

[1]as Chloride, Sodium Chloride or Electrical Conductivity (Specific Conductivity)

2.5 Consultation

As a general rule, desk studies (which ultimately guide catchment walks) should always involve consultations with Local Authority staff who can provide information on:

- Catchment area for specific surface water discharge points;
- Previous misconnection surveys (domestic & trade);
- Previous misconnection issues (domestic & trade);
- Urban runoff problem areas (blocked drains, illegal use of drains);
- Fly-tipping problem areas near waterbodies;
- SWO/CSO performance;
- Private connections;
- Flap valves, catch pits and water treatment on outlets;
- Planning permissions; and
- Known contaminated sites.

The Local Authority staff can assist in identifying the sub-catchments associated with individual surface water discharge pipes, if this is not available from the drainage GIS mapping. This will inform the catchment assessor on where along the river they will be more likely to encounter, for example, domestic misconnections than trade misconnections, as shown in Figure 7.

Ideally, and depending on the issues at hand, the consultation staff should accompany the assessors during parts of the catchment walk. The identification of surface water discharge pipes can require assistance (even when they are marked on maps). This is because in summer months, vegetation in urban catchments can make finding pipes or pressures challenging.

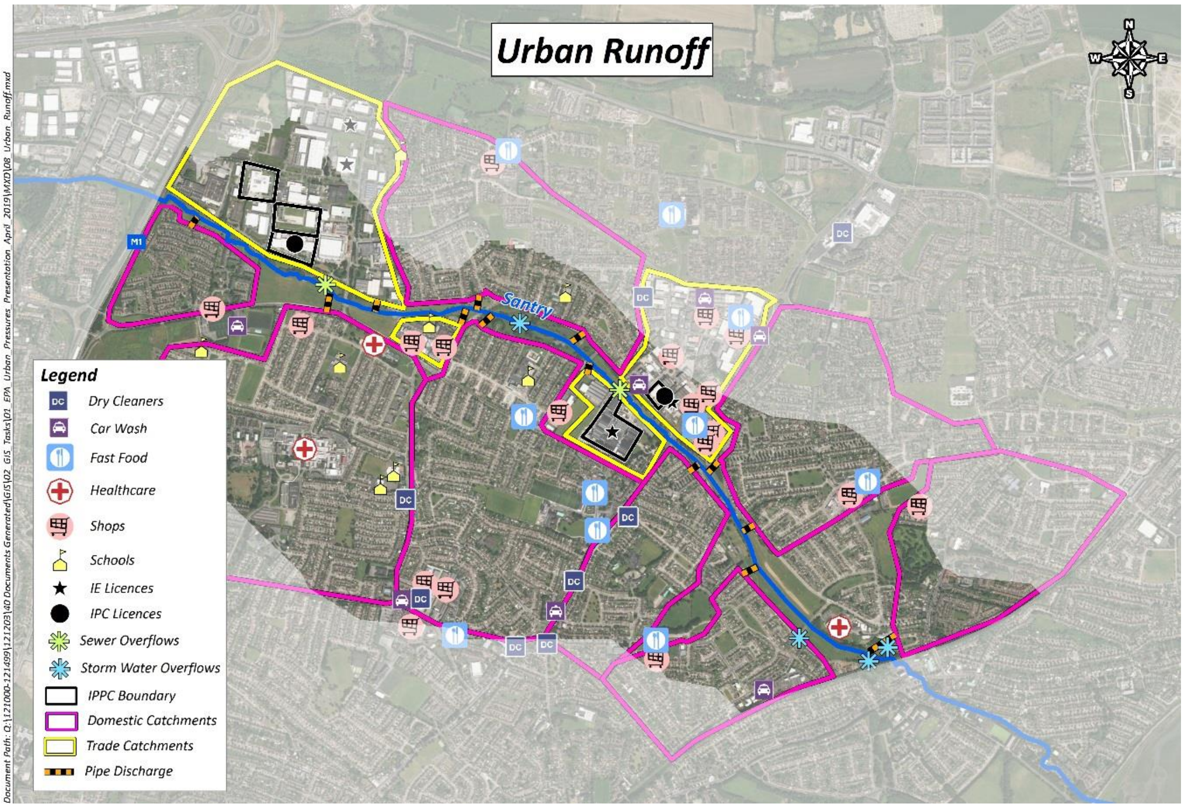


Figure 7: Example of GIS mapping generated during a desk study

2.6 Summary

Local Catchment Assessments in urban environments are challenging and the desk study forms a starting point by providing an overview of the issues. The desk study information is essential for creating a conceptual model of the waterbody and determining what potential pressures exist in the catchment. The output of the desk study will generally be a list of pressures that *do* exist in the catchment, and possibly also a list of pressures that *may* exist in the catchment. Both lists are verified during the catchment walk and the relative significance of the pressures is assessed. The desk study helps focus the catchment walk by giving assessors an indication of what to expect at different locations, the scale of the catchment walk and possible sampling that may be required.

A certain minimum level of data is needed for all urban Local Catchment Assessments, and these are identified below as a generic base-level list. Some of this information relating to the receptor and pathway information (list 1) is contained in the Desk Study for Areas For Action Guidance. List two contains information that is additionally required for desk studies in urban catchments.

List 1

- SSIS or Q-value[1];
- Nutrient concentrations (NH_4^+, ortho-phosphorus, total organic nitrogen (TON) as a minimum as part of WFD monitoring)[1];
- WFD status (and details of contributors to less than good status, where relevant)[1];
- WFD ecological status;
- Flow data (median and Q_{95});
- Significant pressures already identified.

List 2

- Details of EPA IPC/IE/Waste licences and associated discharges/emissions;
- Details non-EPA licensed discharges (Section 4, Section 16);
- Estimated number of combined sewer overflows (CSOs);
- Location of waste water treatment plants/pumping stations;
- Estimated number of urban drainage pipes;
- Flow data (median, Q_{50}, Q_{95});
- Approximate area and location of main landuse (residential, commercial, industrial);
- Relevant historic land use (industrial, legacy landfills); and
- Hydromorphological alterations;
- Relevant mitigation measures for other projects (e.g. flood mitigation schemes);
- Urban drainage infrastructure;
- Upstream pressures.

[1]Ideally, indicative values for upstream and downstream of catchment, at least.

The objective of the desk study is to gather the above base level data, as a minimum. Where some of this data does not exist (as may be the case for water bodies with a WFD risk classification of "*Review*"), it should be considered a priority to ascertain this information/data during the catchment walk.

3 Overview of Catchment Walks in Urban Settings

3.1 Introduction

The local catchment assessor will be in the river receptor, so focus should be on what they can tell from the waterbody and how this information can be used to find the source and pathway linking it to the river.

Due to the density and variety of pressures that will naturally exist in urban environments, the density of indicator parameters in urban catchments will normally be much greater than in the rural catchments. Further, there may be many gradual and/or abrupt changes in the indicator parameters over short spatial scales. As a result, added attention, time and documentation will generally be required for water bodies in urban catchments relative to rural catchments to fully locate, identify, describe and understand the significant pressures. GPS coordinates should be recorded for all field observations and reproduced on GIS map(s) to develop an understanding of the catchment and thus pressures.

The methodology of catchment walks has been discussed in Volumes 2, 3, 4 and 5 of the LCA Guidance. Most of this information is transferable to the urban environment; however, there are a small number of additional items of guidance for conducting catchment walks that are specific to the urban setting, namely:

1. Timing & duration of catchment walks;
2. Substrate indicators;
3. Water quality parameters; and
4. Hydromorphology.

The toolbox used during catchment walks contains two types of tools, the "primary tools" and "secondary tools". As shown in Table 4, the primary tools have no/low associated cost while the secondary tools have an associated cost. In general, the secondary tools should be used only after the primary tools have been exhausted.

Table 4: The Toolbox

Stage	Primary Tools	Secondary Tools
During Catchment Walk	▪ Thermal imaging ▪ Stream flow data using float method ▪ Point discharge flow data using bucket and stop watch ▪ Structural indicators (e.g. pipes, mana-made hydromorphological structures; ▪ Water quality indicators (Field water quality parameters (pH, temperature, dissolved oxygen, specific conductivity); ▪ Biological indicators; ▪ Substrate and sediment indicators; ▪ Water visual indicators; ▪ SSIS indicators; and ▪ Ecosystem and habitat indicators.	▪ Laboratory analysis of water samples for nutrients (ortho-phosphate (also referred to as molybdate reactive phosphate (MRP), ortho-P and soluble reactive phosphate (SRP)), ammonia and total organic nitrogen (TON)) ▪ Laboratory analysis of water samples for other targeted suites (e.g. TPH, heavy metals) ▪ Laboratory analysis of sediment samples ▪ Stream flow data using a flow meter stream ▪ HACH Pocket Colorimetry ▪ In-situ Autosamplers ▪ Fluorometer and cotton balls used to detect optical brightener in water from laundry detergents)

The “structural indicators” in the primary tools refers to a physical structure that must exist in order for the pressure to exist. For example, for hydromorphological pressures to be present, there must be some man-made structure in the stretch. Similarly, a pipe must be present in order a pressure that require a point source discharge (licenced industrial discharge /unlicensed trade or domestic misconnection/urban drainage/SWO) to be a pressure in the stretch. Where this primary structural indicator is absent, the associated pressure can be discounted.

3.2 Timing & Duration of Catchment Walks

Catchment walks are discussed in Volume 1, Section 4.2 of the LCA Guidance. For urban LCA, the timing of the catchment walks is relevant. In general, heavy rainfall makes access to urban rivers difficult, and most discharge pipes may be submerged. Thus, more information will be gathered during dry weather conditions than wet weather conditions for some pressures (domestic misconnections, trade misconnections and contaminated land). Conversely, some pressures need rainfall in order to be evident (urban runoff and combined sewer overflows).

The timing of the rainfall event is also important. Particularly, urban runoff should be sampled during the “first flush” (i.e. the first 20 minutes or so of rainfall following a dry period). The logistical constraints of this timeframe may necessitate remote monitoring with autosamplers or continuous monitoring probes.

Seasonal considerations are also important in this context as undertaking catchment walks during the period late spring to early autumn period benefits from lower flows and longer dry periods but has the drawback of increased vegetation and coverage.

Diurnal timing will be relevant for some pressures, e.g. domestic misconnections may be more easily identified in mornings and evenings when households are more likely to be using appliances. For trade misconnections, working hours are more relevant.

Catchment walks in urban environments are challenging – the assessors can expect to cover perhaps 700-800 metres if working alone or twice that (up to 1.5km) if working in pairs (there will be variations depending on the waterbody, but this should be taken as an average for planning purposes).

3.3 Stream bed Indicators

Stream bed indicators (substrate and biology) that may be observed and should be noted during catchment walks are dealt with in Volume 3 of the LCA Guidance: Observed Indicator Features and Catchment Walks. Also, LAWPRO are producing a methodology for the visual assessment of sediment, to be available in Autumn 2019 (*LAWPRO Sediment Visual Assessment Methodology*). However, there are several additional aspects to this in the context of the urban catchment. These centre around siltation/sedimentation of the stream bed and rapid alterations in the biology over short spatial distances associated with acute pollution. Note, the substrate is the non-living material on the stream bed on which living organisms (biology) grow. Substrate may comprise of, for example, sediment (boulders, cobbles, gravels, sand, silt, clay), made ground (in the case of hydromorphological alterations such as channelization) and bedrock.

3.3.1 Sedimentation of the Stream bed

A stream may have a high fine sediment load (i.e. sand, silt or clay) due to pressures further upstream, or pressures within the urban catchment (such as urban runoff), leading to siltation. Depending on the energy of the river system, such loads may settle out from the water column and be deposited on the stream bed. This can lead to excessive sedimentation (Figure 8). This issue can occur for example, where fine sediment particles are washed with a power washer or transported by heavy rain from a building site into an urban drain. However, it may also be associated with hydromorphological pressures such as physical modification to the river channel (e.g. widening of the stream, as a flood defence measure) which reduce the rivers ability to transport sediment due to the reduction in flows.

Figure 8: Excessive levels of fine sediment deposited on the stream bed (i.e. sedimentation) due to urban runoff, exacerbated by widening of the stream (hydromorphological pressure). Note, the section of stream bed shown is ~10cm^2 total area.

3.3.2 Alterations to the Stream bed over Small Spatial Scale

The application of small stream impact scores (SSISs) may be limited in urban streams as, often, the macroinvertebrate community will be impoverished for the entire stretch due to the multiple pressures frequently encountered in urban streams (particularly hydromorphological pressures). Additional pressures throughout the stretch may not result in any obvious change in the macroinvertebrate community, limiting the utility of observations of the macroinvertebrate community.

In urban catchments, creating a visual profile of stream bed indicators through photographs may provide an informative tool to allow the assessors to create a conceptual model of the pressures and dynamics of the system. Assessors should observe, describe and photograph all changes in the stream bed, which comprises the substrate (non-living material such as sediment, bedrock, made ground etc.) and associated biology (e.g. biofilms, macroalgae etc.). These observations may include changes in sediment not expected for habitat or river type (e.g. particle size), changes in degree of fine sediment deposition, algal cover/community, and presence of non-algal cover (microbial tufts). The *Local Catchment Assessment Volume 4: Measured Indicator Parameters – Catchment Walks* and Appendix B contained within (*Field Guide - Biological Indicators*) should be used to help create this stream bed profile.

Figure 9 through Figure 11 illustrate how stream bed indicators can help create a picture of the form of pollution and pathways and provide clues as to the possible pressure(s) at play. Figure 9 shows an upstream location, where the substrate looks as expected in a relatively healthy, unpolluted stream. The mottled colour of the gravel is clearly visible and not obscured by excessive algal growth or fine sediment deposits. This generally indicates low phosphate concentrations (below the EQS) in the stream (as primary production or algal growth is generally limited by phosphate availability in streams). However, the assessor should check for unusual coloration of the substrate, absence of any living macroinvertebrates or other organisms, healthy and diverse bank vegetation and the presence of the "slimy" microscopic community on the substrate to ensure that the visibility of the mottled stream bed is not the result of toxicity in the water which is inhibiting growth, as might occur if there were heavy metal or chemical inputs from an industry, for example.

Figure 9: Clean gravel substrate visible, indicating a relatively healthy substrate.

Figure 10 shows an unlicensed discharge flowing through a concrete culvert that enters the stream, just downstream of the location of Figure 9. The substrate, which is concrete, is not visible as it is covered with green macroalgae and white slime (possibly sewage fungus). The green macroalgae and white slime on the substrate indicates that the culverted water contains contaminants and is thus acting as a pathway for contaminants to the stream. Excessive macroalgae is an indicator of elevated phosphate and sewage fungus is generally more indicative of organic pollution. Elevated phosphate in this discharge was later confirmed with laboratory analysis; the concentration or ortho-phosphate was 0.08 mg/L, relative to EQS annual average concentration of 0.035 mg/L. It should be noted that fixed, immobile sediment will naturally accumulate more growth due to the absence of movement/rolling. Notwithstanding this, the indicators on fixed substrate can still provide valuable information about pollution sources, pathways and types.

Figure 10: Unlicensed discharge flowing through a concrete culvert that enters the stream, just downstream of the location of Figure 9.

Figure 11 shows the stream bed downstream of the urban catchment (approx. 2km downstream of the locations of Figure 9 and Figure 10). The biology clearly demonstrates that there are significant pressures on this waterbody. There is a thick (approx. 2-4 cm) mat of microbial tufts (algae, cyanobacteria, heterotrophic microbes, and detritus) on the bedrock substrate, which is itself not visible due to the excessive algal and bacterial growth. The long length of the tufts may indicate that there has previously been significant algal growth, suggesting that the system may be in the latter stages of eutrophication (i.e. the phosphorus that caused the initial growth has been consumed and this depletion has the resulted in senescence of the macroalgae). This indicates that there may have been large additions of phosphorus that are no longer entering the system. Further consultation following the local catchment assessment revealed that less than three weeks previously there had been an unlicensed discharge of untreated sewage from a WWTP located approx. 3km upstream. Chemical analyses also identified phosphate inputs from other sources, most notably domestic misconnection, industrial and trade misconnection and urban runoff exacerbated by hydromorphological pressures including channel widening.

Figure 11: Stream bed downstream of the urban catchment (approx. 2km downstream of the locations of Figure 9 and Figure 10) covered in a thick (approx. 2- 4 cm) mat of microbial tufts (algae, cyanobacteria, heterotrophic microbes, and detritus).

Biological parameters (rapid assessment, SSIS, visual assessment of algae, Q-scores) are key indicators and, as such, should be prioritised. However, where an urban waterbody is impacted along the entire stretch, possibly by upstream pressures, the changes in biological indicators may not be perceptible. In such cases, biological indicators may not be useful in pinpointing the impacts of significant pressures. Instead, water quality and water chemistry parameters, informed by the desk assessment, may be more appropriate.

3.4 Water Quality Parameters

Water quality parameters should be recorded for all point sources. This data will contribute to decision making regarding the relative significance of point sources and water quality sampling. Water quality parameters provide direct information about the water quality of the stream (see Volume 4 of the LCA Guidance: Measured Indicator Parameters).

Changes in stream water quality parameters (temperature, specific conductivity, dissolved oxygen and pH) can be useful in locating the position of inputs to a stream. Sufficient water quality data should be collected to provide a profile of each key parameter for the surveyed stretch of the river. In urban catchments, these parameters should be recorded at approx. 10-20-metre intervals for the complete stretch under survey. Where there are jumps/marked changes in any parameter, the survey should be carried out at smaller intervals to locate the cause of the jump (normally an input).

Table 5 and Table 6 illustrate the importance of this approach. Table 5 and **Error! Reference source not found.**show the typical profile of stream water quality parameters for the first 240m section surveyed. Note, assessors always walk upstream rather than downstream to prevent disturbance of sediments and water that might confound observations and sampling. From the graph, as the assessor moves upstream there is a gradual increase in temperature and conductivity starting at ~105 metres. There is a sharp drop off and return to typical stream values between 165 and 180 meters. This indicates that there is an input between 165 and 180 metres. The effect of this input is apparent in the water quality data, though gradually decreasing due to dilution, between 180 and 105 metres. Between 105 and 0 metres, the effect of the input is no longer apparent in the water quality data, due to dilution. From Table 4, this change is mirrored in the dissolved oxygen data though the tail of the effect is shorter, i.e. the oxygen returns to ~ normal conditions by 135m. Table 6 and Figure 13 demonstrate how monitoring the water quality parameters at smaller intervals can allow the assessor to pinpoint the exact location of the input. In this case, the source was a discharging pipe located at 182m, as indicated by the large change in values of parameters.

Table 5: Water quality profile measured at 15-meter intervals over a 200-metre stretch of stream from most downstream initial point (0 metres) to 240 metres upstream.

Distance from initial downstream point (m)	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (% saturation)
0	7.58	10.09	259	106
15	7.88	9.12	239	105
30	7.87	10.41	240	101
45	7.96	9.32	243	107
60	7.46	9.10	285	105
75	6.84	9.97	208	109
90	7.66	9.60	238	105
105	7.36	9.47	200	103
120	7.75	9.61	254	108
135	7.58	10.50	270	101
150	7.53	11.20	350	96
165	6.99	12.10	480	89
180	6.70	13.70	510	85
195	6.89	10.26	216	107
210	7.42	9.22	221	108
225	8.07	9.96	244	100
240	7.67	9.26	208	100

Figure 12: Specific conductivity and temperature profile over 240 metres stretch of stream.

Table 6: Water quality profile measured at 1-metre intervals over 15 metre stretch of stream to locate point of input. Input occurs at 182 metres (highlighted yellow).

Distance from initial downstream point (m)	pH	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (% saturation)
180	6.70	13.70	510	85
181	7.50	14.00	510	74
182	7.5	14.14	530	71.6
183	7.51	10.11	219	101
184	7.61	9.03	279	107
185	6.86	10.09	210	106
186	7.95	10.35	300	104
187	6.98	10.40	254	101
188	6.99	12.10	300	89
189	7.67	9.26	208	100
190	6.89	10.26	216	107
191	7.34	9.37	280	107.5
192	7.32	10.23	220	103.4
193	7.26	10.46	289	104.6
194	7.31	9.98	272	101.3
195	7.95	10.35	300	104

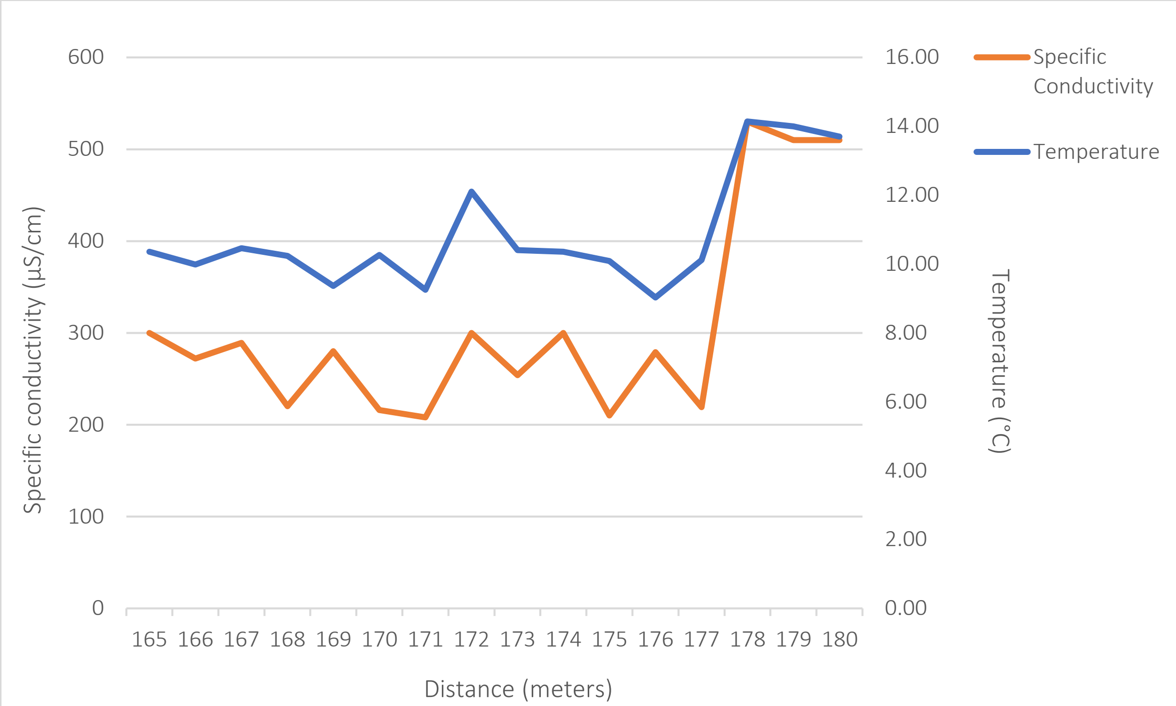


Figure 13: Graph of refined specific conductivity and temperature profile, measured at 1-metre intervals from 180 metres to 195 metres upstream of initial point to locate the point of an input (occurring at 182 m).

3.5 Hydromorphological Pressures

Hydromorphological pressures in the context of catchment walks are discussed in Volume 2 of the LCA Guidance: Pressures and Catchment Walks, Section 3, Catchment Walks – Hydromorphological pressures. While this topic is already covered in detail and the guidance previously presented applies to the urban setting, hydromorphology warrants a mention in this section for two reasons. Firstly, by their nature, hydromorphological pressures (other than invasive plant species), which are often put in place to serve human populations (e.g. road culverts, weirs), are likely to occur in higher densities in urban than in rural catchments. Secondly, the types and forms of hydromorphological pressures that may be encountered in the urban environment are many and varied. These may include for example, the construction of structures within the river channel, physical modification to the river channel or other alterations to the bank and riparian zone for civic, domestic or aesthetic purposes.

Hydromorphological pressures can have significant effects on the water body and consequently impact the ability of the waterbody to reach the WFD objectives. This issue is discussed in more detail in Section 9 and Section 11.

3.6 Summary

The baseline information that should, in so far as possible, be gathered during the catchment walk using the primary tools from the assessor's toolbox are:

- Observations of stream bed biological indicators (algae, macrophytes, black due to anoxia for substrate);
- Observations of stream bed substrate indicators (e.g. scouring, sedimentation (refer to *LAWPRO Sediment Visual Assessment Methodology,* available from Autumn 2019));
- Observations of hydromorphological pressures (in-channel barriers or structures, concreted river beds, hard bank engineering or recently constructed flood defences);

- Observations of the stream water e.g. oil slick, foam, presence of straw or saw dust, discoloration, turbidity;
- Observations of ecosystem and habitat indicators (invasive species, biodiversity indicators);
- Water quality indicators (dissolved oxygen, pH, temperature and conductivity);
- Detailed description of all pipes (both discharging and dry);
- Detailed description of all point and diffuse pathways and inputs (e.g. ditches);
- Description of surrounding land uses that adds to, or amend, desk study information; and
- SSIS assessments (where possible and informative).

The baseline information which, if not already available, should be gathered during the catchment walk using the secondary tools from the toolbox are:

- Nutrient concentrations upstream and downstream of catchment (NH_4^+, ortho-phosphorus, TON);
- Q-value data (this may necessitate engaging an external specialist); and
- Stream flow data (this may require in-stream measurements using sophisticated water flow meters).

Where the above information has been gathered and indicates more than one significant pressure, the assessor should use secondary toolbox tools to identify the significant pressure. Such methods will normally consist of laboratory analysis for indicator analytes/parameters that are specific to the pressures. This is discussed further in Section 11.

4 Domestic Misconnections

4.1 Purpose

This section provides an overview of domestic misconnections. A domestic misconnection is where drainage from a home has been connected to the wrong part of the sewer network. These misconnections can be either:

- a foul water misconnection to a surface water system whereby sewage is discharged directly to a river, stream or the sea (e.g. a washing machine connected to the rainwater drains). This is the most relevant type of misconnection for this guidance as it directly impacts water quality; or
- where clean and uncontaminated rainwater enters foul sewers rather than discharging to surface or ground waters. With these misconnections there can be indirect pollution due to an increase in sewerage overflows.

Misconnections are described in detail in Volume 2, Section 5.3 of the LCA Guidance. The experience of the Dublin Local Authorities is that approximately 8% of homes are misconnected in areas with separate sewers, although this estimate may be significantly higher (up to 20%) in specific areas.

The key factor specific to urban areas is that sewer systems in urban areas are either 'separate' (one for foul, one for surface water – these are areas built after approximately 1965-1970 in Ireland), or 'combined' (one sewer conveying foul and surface water, usually with an overflow for excess flow). Some areas are partially separated with foul and surface water from rear of buildings going into partially separated sewers and other surface water runoff going into the surface water sewer. Evidence of misconnections during catchment investigations will only be found on systems with separated foul sewer and surface water drainage networks. This distinction needs to be clearly identified during the desk study in consultation with Local Authority staff and Irish Water.

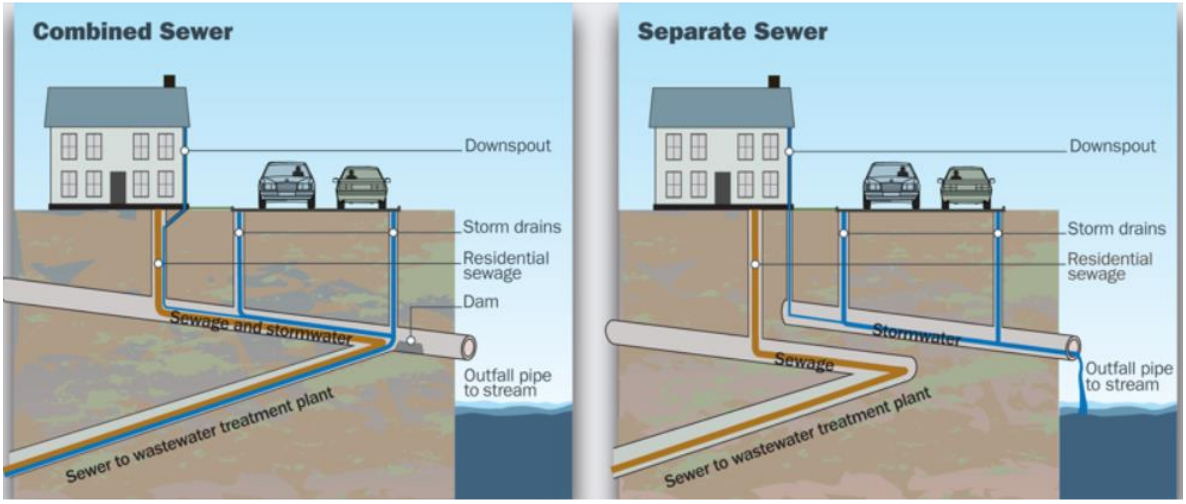


Figure 14: Combined and Separate Systems Explained

4.2 What are the associated water pollutants impacting water quality?

Misconnections cause direct or indirect pollution and adversely affect the water quality, amenity uses and biodiversity of waterbodies. Small watercourses and bathing waters in urban areas are particularly impacted. The principal water quality impacts include:

- Pollutants from sewage (where the misconnection involves a toilet) including nutrients like phosphorus and nitrogen, pathogens (faecal coliforms), sewage derived debris, oxygen depleting organic matter and compounds (notably ammonia) and toxins, some of which are of concern because of their persistent nature.

- Pollutants from washing machines and dishwashers, notably phosphorus but also nonyl-phenols (NPs) and their ethoxylates (NPEs) which are restricted under EU legislation. These chemicals are commonly found in imported clothing and released into the aquatic environment via clothes washing.
- Aesthetic characteristics in urban watercourses are adversely affected by misconnections especially due to sewage derived debris. These visual impacts are often made worse in drier weather when sewage fungus or the effects of eutrophication become more apparent.

A summary of the source-pathway-receptors for domestic misconnections is shown in Table 7.

Table 7: Domestic Misconnections Source-Pathway-Receptor Summary

Source	Pathway	Receptor
Washing Machines (Detergents) Dishwashers (Detergents) Sinks Toilets (Wastewater)	Surface Drains Sewer Network	Waterbody

4.3 Local Catchment Assessments

4.3.1 Desk Based Assessment

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

It is not easy to estimate the extent to which domestic misconnections will be an issue at desk study phase until a catchment walk is completed; however, during the desk study, the following specific information should be identified:

- Drainage maps showing combined and separate sewer systems (from Irish Water GIS, refer to Section 2). Investigations should focus on areas of the catchment where separate surface water systems discharge into the waterbody. This distinction needs to be clearly identified during the desk study.
- The catchment serving individual surface water discharge pipes should be identified from the drainage maps, even if tentatively. This will require assistance from Local Authority staff with knowledge of the catchment.
- If no drainage maps are available, Local Authority drainage staff should be consulted regarding identifying which areas are on combined or separate systems and the locations of surface water discharge points.
- Areas along river stretches that are predominantly domestic in nature should be marked on maps (i.e. not many businesses or no industrial estates) to help distinguish potential misconnections from individual pipes.
- Information through discussion with Local Authority drainage staff on any previous misconnection surveys. This will allow previous experience of Local Authority staff to be incorporated into planning the fieldwork. Often, they will have a good sense of areas particularly impacted by misconnections, and will know if and when misconnection surveys were previously undertaken (and how successful they were).

4.3.2 Catchment Walks

Section 5.3.1 of the LCA Guidance presents extensive photography and pointers for conducting catchment walks where domestic misconnections may be an issue.

Catchment walks within urban waterbodies will frequently identify domestic misconnections as a potential significant pressure. However, often this will be only one of multiple pressures and narrowing the problem down to domestic misconnections may not be easy. Identification, investigation and monitoring of discharge points that are potential significant pressures is valuable data. To assess the impact of misconnections on the waterbody the following should be undertaken:

1. Ecological impact in the stream – refer to Volume 4 of the LCA Guidance.
2. Dry weather surveys: surface water pipes should not be discharging during dry weather and a discharge during this period usually indicates a misconnection, though there may be other reasons, e.g. a burst water supply main. Visual assessment may give a clue as to the nature of the misconnection, e.g. a misconnected washing machine may show suds in the discharge or ragging may evidence sewage discharge. While chemical analysis may help identify these things, the initial priority is to confirm whether the dry weather discharge appears to be domestic in nature and different to the trade misconnections discussed in Section 4.
3. Record pipe location: following the catchment walk, mapping and cross-referencing of discharges during dry weather surveys with drainage maps and locations will help distinguish between discharges which are more likely to be domestic misconnections, trade misconnections (see Section 4) or other issues. Section 4.3.3 discusses the data that should be captured during catchment walks.

4.3.3 Data that should be captured

Table 8 shows the information on domestic misconnections that should be captured during catchment walks.

Table 8: Data Collection – Domestic Misconnections

Specific Information	General Information
♦ Number of pipes discharging into the river ♦ Location of pipe (GPS reference); ♦ Type/purpose of pipe (if known); ♦ Photograph; ♦ Whether discharging or not; ♦ If discharging, measure flow; ♦ If discharging, measure field parameters such as pH, temperature, dissolved oxygen and conductivity; ♦ If discharging, take sample for analysis; ♦ Identification of sewage fungus – grows in response to excessive nutrients in the water ♦ Identification of discoloration or coloured discharge – washing machine? ♦ Identification of grease and fat – kitchen waste? ♦ If not discharging, whether evidence of recent discharge. ♦ Record the condition of the substrate ♦ Presence of biological indicators e.g. algae ♦ Colour and smell of the water e.g. presence of oil films on the water surface	♦ Any changes to catchment and/or waterbody boundaries identified in the desk study ♦ General gradients from surrounding landscapes ♦ Record any hydromorphological pressures e.g. new drainage systems, flood defences ♦ Pathway indicators ♦ Land use of the surrounding area ♦ Any roads surrounding the vicinity ♦ Invasive species

All pipes should be mapped in GIS, with discharging and dry pipes identified, as shown in Figure 15. Where available, surface water drainage catchments and infrastructure should be included (an example shown in Figure 4) to help identify if misconnections are domestic (or trade).

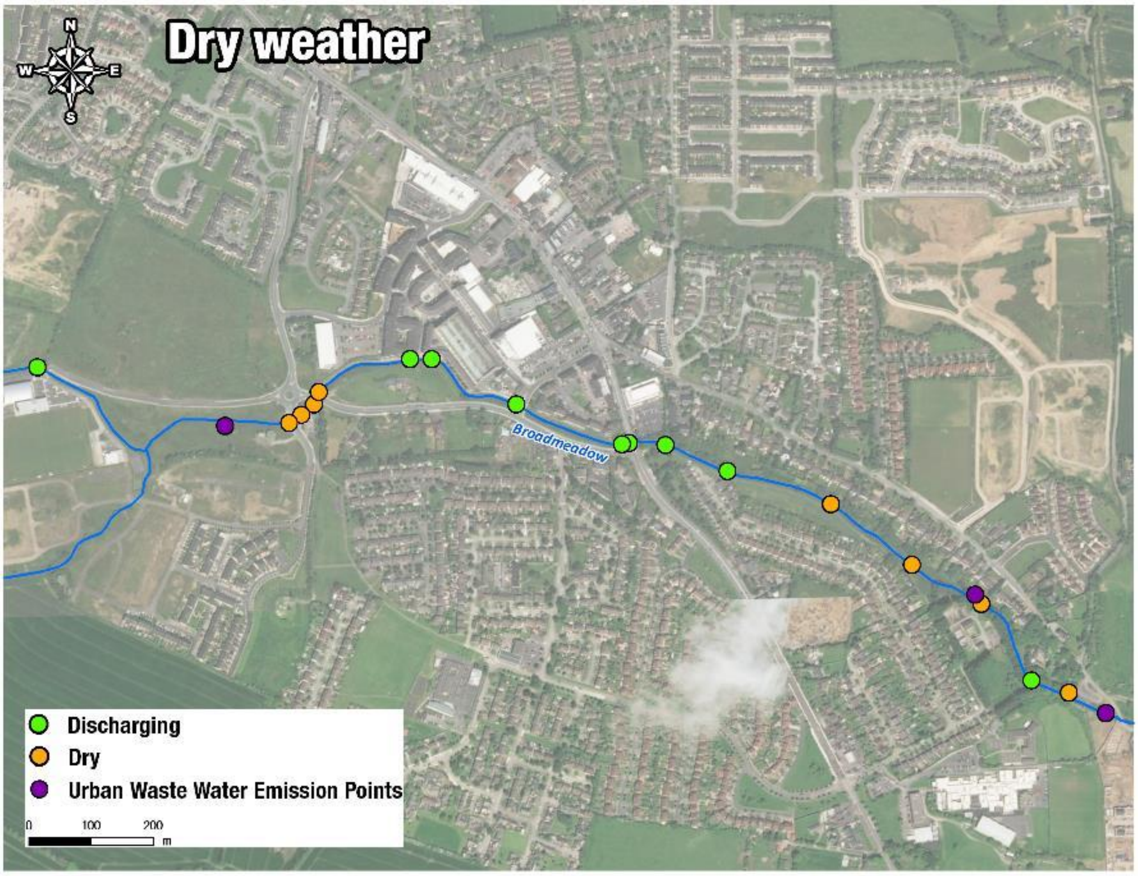


Figure 15: Example of mapping of surface water discharge points

4.4 Next Steps and Potential Mitigation Options

Following identification of pipes from potential misconnections, the issue will be referred to the Local Authority for further assessment. Further sampling may be required to distinguish domestic misconnections from trade misconnections (see Section 5 of this guidance) or other discharges to the surface water drainage network (mainly urban runoff, see Section 6 of this guidance). Suggested additional analysis suites for these water quality issues are included in **Appendix 6.2**.

The principal mitigation measure is finding and resolving the misconnections. This usually involves on the ground investigations to identify and rectify misconnection problems from discharge points with suspected misconnection problem.

The most common and least expensive method of detection involves using drainage maps to conduct manhole inspections and sampling whereby every accessible manhole is inspected (from receptor to source) and sampled (where necessary) until there is no evidence of contamination. The source is likely to be located in this vicinity. A flow measurement at each manhole is also beneficial in identifying inputs to the system. Dye testing can be employed to confirm that the source of contamination is located in a specific property (some Local Authorities may use dye testing to confirm the source of a misconnection in every case). Once a misconnection is identified, the Local Authority may then write to the homeowner advising of the misconnection and requiring it to be remedied (see letter templates in **Appendix 6.1**). While it would be unusual for a prosecution to arise in Ireland for a domestic misconnection, if this did occur, it would be under Section 3 of the

Local Government (Water Pollution) Act 1977, as amended, where it is an offence to cause or permit polluting matter to enter waters.

The process of finding misconnections can be labour-intensive as urban catchments can involve hundreds of properties. However, once identified, most drainage rectifications are relatively low cost and the cost is borne by the property owner.

Other, more strategic and long-term approaches include addressing issues such as sewer maintenance, capacity improvements and removing surface water misconnections from foul sewerage systems. There is also evidence that activities based on behaviour change and awareness raising can be effective. This has resulted in other jurisdictions (especially in the fully privatised UK water sector) investing in public awareness and other techniques to encourage householders to be aware of when they have a misconnection and to ensure that relevant trades (e.g. plumbers) know how to plumb new appliances to the correct part of the drainage system. Some Irish Local Authorities give talks/workshops in schools about rivers, water quality and misconnections.

4.5 Physical time lags associated with implementing mitigation measures and strategies

Resolving the problems caused by misconnections takes time, especially at the catchment level. Whilst investigating misconnections is still essential in some areas, surveys are expensive and difficult. The nature of pollution from misconnections also means that regulatory and legal remedies cannot be solely relied on to address the problem. Ongoing checks are needed to prevent problems re-occurring.

Approaches based on education and awareness-raising are needed to complement investigation work to remove misconnections. Experience suggests that only sustained campaigns are effective in the long-term. Generally, time lags associated with implementing mitigation measures and strategies can be summarised as:

- As individual misconnections are identified and resolved, there will be small but accumulative improvements in water quality.
- While it takes time to achieve improvements, catchment-based find and fix programmes can make steady progress.
- More significant improvements may be achieved depending on the type of misconnection identified and if it is close to the waterbody.
- Where progress it not evident, it may be because misconnections are one of several similar problems in the urban catchment contributing to poor water quality (e.g. urban runoff, trade effluent misconnections and SWOs).

4.6 Best Practice

There is no best practice guidance with respect to addressing domestic misconnections, but individual Local Authorities have significant experience of these investigations. Additionally, the Dublin Urban Rivers LIFE project has received EU funding through the LIFE programme to carry out mitigation works on the Griffeen River and the Carrickmines stream. The aim of the project, which began in 2019, is to improve water quality and make domestic misconnection inspection quicker and cheaper by using a GIS-based approach. This will consist of approximately 12,000 door to door inspections and using the obtained data to develop a decision-making tool.

More extensive information is available in the UK, where coordinated approaches between regulatory bodies, water companies and other stakeholder groups has resulted in both extensive studies and development of best practice in addressing the issue and communicating with relevant groups.

- The **UK National Misconnections Strategy Group** is a partnership of organisations working together to reduce water pollution caused by misconnections. One of the main aims of the campaign - to raise public awareness - was achieved by setting up a website educating the public about water pollution, types of misconnections and how they can become more aware to tackle the problem. The website is user friendly and gives a step by step approach to investigate the different areas in a property that can contribute to a misconnection. http://www.connectright.org.uk/
- A good example of community groups being involved in addressing the problems caused by misconnections was the '**Great Cheadle Hulme Easter Hunt**' (for misconnections), where residents forewarned by a local information campaign checked their own plumbing and emailed the Healthy Rivers Trust if they found a misconnection.
- The **Thames Water Surface Water Outfall Programme** was delivered by a dedicated five-member environmental protection team who visited nearly 170,000 properties, finding 3.35% of properties with misconnected appliances: 22% washing machines and 19% kitchen sinks. Some 750 misconnected toilets were identified. The programme was broken into smaller projects varying in size of 300 – 10,000 properties, taking between 6 weeks and 2.5 years.

5 Trade Effluent Misconnections

5.1 Purpose

Trade effluent misconnections are similar to domestic misconnections in that drainage has been connected to the wrong part of the sewer network. These misconnections can be from businesses, industry or constructions sites and their impacts on water quality are different to those from domestic misconnections. As with domestic misconnections, these directly impact the waterbody in areas with separate sewer systems.

Misconnections are described in detail in Volume 2, Section 5.3 of the LCA Guidance. The legislative position for trade misconnections is different to domestic misconnections as discharge of wastewater to surface water or groundwater is licenced under Section 4 of the Local Government (Water Pollution) Act 1977 (and known as a "Section 4 discharge"). Section 4 discharge licences are issued by Local Authorities, and guidance is provided by EPA for assessing and authorising applications for discharges to both surface water[3] and groundwater[4].

Discharge of trade effluent to the sewer is licenced under Section 16 of the Local Government (Water Pollution) Act 1977 (known as a "Section 16"). These are issued by Irish Water[5] and the conditions set out in Trade Effluent Discharge to Sewer Licences. Trade effluent misconnections should be referred to the Local Authority in the first instance (who may refer it on to Irish Water if it involves breach of a Section 16 licence).

5.2 What are the Associated Pollutants Impacting Water Quality?

Trade effluent is any liquid waste other than domestic wastewater and stormwater that discharges from a business premises to the public sewer. Trade effluent may contain chemicals, detergents, heavy metals, nutrients and fats, oils and grease (FOG).

A broad range of impacts from trade effluent misconnections are possible and the scope for contamination is significant. As trades use characteristically different chemicals, the impacts on the receiving waterbody will reflect the chemical used by the trade. For example, petrol stations may release petrol, oil and greases if they are not captured before entering the surface water drains. Other premises might use solvents and detergents, which must be carefully control so that spillages are contained before they enter the surface drain. In some cases, the impacts may be similar to domestic misconnections.

A summary of Source-Pathway-Receptor for trade effluent misconnections is shown in Table 9.

Table 9: Source-Pathway-Receptor Summary: Trade Effluent Misconnections

Source	Pathway	Receptor
Discharges from Trade/Business Premises (e.g. oil, grease, solvents, chemicals)	Surface Drains Sewer Network Direct Discharge	Waterbody

[3] EPA Guidance for Surface Water Discharges: https://www.clarecoco.ie/services/environment/forms/discharge-to-surface-water-guide-to-the-application-17414.pdf

[4] EPA Guidance for Groundwater Discharges: http://www.epa.ie/pubs/reports/water/ground/dischgw/

[5] https://www.water.ie/for-business/trade-effluent/

5.3 Local Catchment Assessments

5.3.1 Desk Based Assessments

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

As with domestic misconnections, the extent to which trade effluent misconnections are an issue cannot be established until a catchment walk is complete. However, the following specific information should be identified during the desk study:

- ♦ Drainage maps showing combined and separate sewer systems (from Irish Water GIS, refer to Section 2). As there will be no trade effluent misconnections in areas with combined systems, investigations should focus on areas where separate systems exist. This distinction should be clearly identified during the desk study.
- ♦ The catchment serving individual surface water discharge pipes should be identified from the drainage maps.
- ♦ If no drainage maps are available, discussion with Local Authority drainage staff to identify which areas are on combined or separate systems.
- ♦ Areas along the river stretch that are predominantly non-domestic in nature should be marked on maps (i.e. petrol stations, industrial estates or shopping centres).
- ♦ Information through discussion with Local Authority drainage staff on any previous misconnection surveys in the catchment. This will allow previous experience of Local Authority staff to be incorporated into planning the catchment walk. Often, they will have a good sense of areas particularly impacted by misconnections (both domestic and trade) and will know if and when misconnection surveys were previously undertaken (and how successful they were).
- ♦ In consultation with Irish Water, identification of businesses which should have a Section 16 Trade Effluent Discharge to Sewer Licence, i.e.:
  - Premises where manufacturing or processing of chemicals or metal finishing takes place;
  - Premises where food and drink manufacturing take place;
  - Hotels, guesthouses and B&Bs;
  - Caravan parks;
  - Nursing homes;
  - Hospitals;
  - Hair and Beauty Salons;
  - Dentists;
  - Launderettes & Dry Cleaners;
  - Airports, bus and train stations;
  - Public houses;
  - Restaurants, cafés and takeaways;
  - Universities, colleges, amenity and heritage centres; and
  - Service stations and/or car wash.
- ♦ Review of available Section 16 licences, which should include:
  - The nature, composition and volume of the trade effluent discharge;
  - The method of treatment, the location of discharge and the periods during which discharge may be made; and
  - The taking and analysis of trade effluent samples and the trade effluent records that must be kept.

5.3.2 Catchment Walks

Catchment walks within urban water bodies will regularly identify trade effluent misconnections as a potential significant pressure. Often this will be only one of multiple pressures impacting on the urban waterbody and narrowing the problem down to trade misconnections may not be easy. The following should be undertaken to assess the impact of trade misconnections on the waterbody:

1. Assess the ecological impact on the stream – refer to Volume 4 of the LCA Guidance.
2. Dry weather surveys: surface water pipes should not be discharging during dry weather surveys; a discharge during this period usually indicates a misconnection or illegal activity (though there may other causes, e.g. a burst water supply main). Visual assessment may give a clue to the nature of the misconnection, e.g. discoloured discharge, discharge with an odour, oily discharges, etc. The initial priority is to confirm if dry weather discharges are trade or domestic misconnections (Section 2).
3. A visual assessment of the discharge pipe to assess gross contamination, noting: flow, odour, colour, turbidity, floatables, deposits, stains, vegetation growth, flap valve, silt traps and damage to the structure.
4. Where, based on biology as another reliable indicator (e.g. high flow of perceptibly heavily polluted water), a discharge is deemed likely to be a significant pressure, a water sample of the discharge in addition to an upstream and downstream sample may be collected to confirm the level of contamination and assists in identifying the source of pollution.
5. Record Pipe Location: following the catchment walk, mapping and cross referencing of discharges during dry weather surveys with drainage maps and locations will help distinguish between discharges which are more likely to be trade misconnections, domestic misconnections (see Section 4 of this guidance) or other issues.

5.3.3 Data that should be captured

Table 10 shows the information on trade effluent misconnections that should be captured during catchment walks.

Table 10: Data Collection – Trade Effluent Misconnections

Specific Information	General Information
♦ Number of pipes discharging into the river ♦ Location of pipe (GPS reference); ♦ Type/purpose of pipe (if known); ♦ Photograph; ♦ Whether discharging or not; ♦ If discharging, measure flow; ♦ If discharging, measure field parameters such as pH, temperature, dissolved oxygen and conductivity; ♦ If discharging, take sample for analysis; ♦ Identification of grease and fat – kitchen waste? ♦ If not discharging, whether evidence of recent discharge. ♦ Record the condition of the stream bed (biology, and composition and structure of substrate) ♦ Presence of biological indicators e.g. algae ♦ Colour and smell of the water e.g. presence of oil films on the water surface	♦ Any changes to catchment and/or waterbody boundaries identified in the desk study ♦ General gradients from surrounding landscapes ♦ Record any hydromorphological pressures e.g. new drainage systems ♦ Pathway indicators ♦ Land use of the surrounding area ♦ Any roads surrounding the vicinity ♦ Invasive species

All pipes should be mapped in GIS, with discharging and dry pipes identified. Where available, surface water drainage catchments and infrastructure should be included (an example shown in Figure 4) to help identify if misconnections are trade (or domestic).

5.4 Next Steps and Potential Mitigation Options

All discharges from trade/industry to surface water must hold a Section 4 licence or EPA IPC/IE licence. Unlicensed discharges, i.e. trade misconnections, should be referred to the Local Authority for further assessment. The Local Authority may then refer the issue to Irish Water in certain circumstances. If the Local Authority trace the source to a blocked sewer overflowing to a surface water or a wrongly connected sewer connecting to surface water network, this it would be referred to Irish Water.

Further sampling may be required to distinguish trade from domestic misconnections (see Section 4 of this guidance) or other discharges to the surface water drainage network (mainly urban runoff, see Section 6 of this guidance). Suggested additional analysis suites are included in **Appendix 6.2**.

The principal mitigation measure is finding and resolving the misconnections. This may involve the below:

- Where there is evidence of trade effluent misconnections (or any misconnections), all Section 4, Section 16 and IPC/IE licences within the catchment area should be reviewed.
- Inspections of commercial premises and checking of compliance with Section 4 and Section 16 licence requirements; this is not done routinely or uniformly across Local Authority areas.
- Manhole inspections and sampling/flow measurements, dye testing, CCTV inspection and smoke testing. The least expensive of these methods involves using drainage maps to conduct manhole inspections of every accessible manhole (from receptor to source) coupled with water sampling/flow measurements (where necessary). Dye testing can be used to confirm the source of contamination (e.g. business, house etc.).
- Trade effluent misconnections may be deliberate or accidental. Awareness and education campaigns are an important component of addressing misconnections. General advice to business includes removal, relocation or substitution of potentially polluting materials and protection against leaks and spills. For example, colour coding of surface and foul drains can help management at businesses and trades (however, there are no standard approaches for this in Ireland).
- The planning process has an important role with respect to ensuring trade effluent connections are correct. The design of the site drainage (as well as other issues such as storage (of chemicals for example), waste management and location of discharge points) should be inspected at the planning stage to ensure that it is appropriate and sufficient in general, but specifically that the discharge points and connections are correct. Currently, inspections of surface water drainage networks are not completed following construction.

5.5 Physical time lags associated with implementing mitigation measures and strategies

Resolving the problems caused by misconnections takes time, especially at the catchment level. Whilst investigating misconnections is still essential in some areas, surveys are expensive and difficult. The nature of pollution from misconnections also means that regulatory and legal remedies cannot be solely relied on to address the problem. Ongoing checks are needed to prevent problems re-occurring.

Approaches based on education and awareness-raising complement investigation work. Experience suggests that only sustained campaigns are effective in the long-term. Generally, time lags associated with implementing mitigation measures and strategies can be summarised as:

- When individual misconnections are identified and resolved, there will be small but accumulative improvements in water quality.
- While it takes time to achieve improvements, catchment-based "find and fix" programmes can make steady progress.
- More significant improvements may be achieved where the misconnection is contributing large loads of contaminants to the waterbody and/or is close to the waterbody.
- Where amelioration is not evident, it may be because misconnections are one of several similar problems contributing to poor water quality in the urban catchment (e.g. urban runoff, trade effluent misconnections, leaking sewers particularly pressurised sewers and SWOs).

5.6 Best Practice

The EPA and Irish Water guidance available for ensuring that Section 4 and Section 16 discharges are undertaken correctly is cited above. UK guidance on Industrial and Commercial Pollution Prevention[6], known as "Getting Your Site Right", includes a range of practical design and operational advice aimed at minimising the potential for pollution from trades and businesses.

[6] https://web.anglia.ac.uk/estates/downloads/environment/ISO14001/03-Guidance/Pollution%20Pays%20Document.pdf

6 Urban Run Off

6.1 Purpose

Urban runoff is a broad term which covers all flow (other than misconnections) from urban landscapes into surface water drainage systems that goes directly, and untreated, to waterbodies. Urban runoff can carry a wide range of contaminants such as litter, food, human, bird and animal waste, vehicle fluids, industrial pollutants, fertilizers and pesticides. Urban runoff can impact aquatic life, pose human health risks and contribute to localized flooding. Local Authorities are responsible for managing urban runoff.

6.2 What are the associated water pollutants impacting water quality?

A wide range of problems can arise from urban runoff, depending on the source of the runoff, including:

- **Runoff from vehicles**: resulting in heavy metals (especially cadmium, copper, lead and zinc), polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds and "conventional" pollutants such as total suspended solids, total dissolved solids, etc. entering waterbodies through surface drainage;
- **Outdoor or home car-washing:** resulting in contaminated water and, in particular, PAHs entering waterbodies;
- **Animal contamination:** resulting in faecal deposits from birds, dogs and horses entering waterbodies;
- **Private Drain Blockages:** resulting in inadvertent discharge of wastewater to surface water drains;
- **Illegal dumping:** ranging from fly-tipping to abandoned vehicles, and resulting in a range of potential impacts to waterbodies depending on what is dumped. More information on this is contained in Volume 2, Section 5 and Section 7.3.6 of the LCA;
- **Contaminated runoff:** resulting from spillages of hydrocarbons (oil, petrol, diesel etc.), paint and chemicals, metals from car engines, domestic car washing, dumped rubbish etc. Spillages in industrial estates can be a hazard also. More information on this is contained in Volume 2, Section 5.3.3 of the LCA;
- **Malfunctioning underground attenuation systems:** resulting in release of stagnant contaminated water until pumps are repaired;
- **Temporary or short-term activities:** from, for example, construction activities that use the surface drainage network and result in increased sediment load to waterbodies during rainfall (these are supposed to be controlled); spills and leakage from construction equipment or products (these are supposed to be bunded); and, contaminated construction/industrial wash water. More information on this pressure is contained in Volume 2, Section 5.3.4 of the LCA; and
- **Combined Sewer Overflows**: discussed in Section 6 of this guidance.

The water quality issues that may arise from urban runoff can be summarised as:

- Pollutants from foul sewage;
- Oil, grease, and chemicals from motor vehicles;
- Pesticides and nutrients from lawns and gardens;
- Viruses, bacteria, and nutrients from animals (especially dogs and horses) and birds (especially geese and seagulls);
- Road salts;
- Heavy metals from motor vehicles and other sources; and
- Aesthetic issues from litter and dumping.

Suggested analysis suites for these water quality issues are included in **Appendix 6.2**. A summary Source-Pathway-Receptors for Urban Runoff is shown in Table 11.

Table 11: Source-Pathway-Receptor Summary – Urban Runoff

Source	Pathway	Receptor
Urban Runoff	Surface Drains (Sewer Network)	Waterbody

6.3 Local Catchment Assessments

6.3.1 Desk Study

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

During the desk study, the following specific information should be identified:

- Drainage maps showing combined and separate sewer systems (from Irish Water GIS, refer to Section 2). There will be little evidence of urban runoff in areas with combined systems, except at overflows. Thus, for this pressure, the catchment walk should focus on areas where the systems are separate.
- The catchment serving individual surface water discharge pipes should be identified from the drainage maps, even if only tentatively.
- If no drainage maps are available, discussion with Local Authority drainage staff should identify which areas are combined and separate systems.
- Any drainage management issues in the catchment should be determined through discussion with Local Authority drainage staff. This will allow the previous experience of Local Authority staff to be incorporated into planning the catchment walk. Often, they will have a good sense of areas impacted (e.g. problems with dumping).
- Information through discussion with Local Authority parks staff on areas where animals are kept (e.g. horses in urban parks) or inland feeding grounds for birds (e.g. Brent geese feeding grounds are found at several urban locations across the Greater Dublin Area).

6.3.2 Catchment Walks

The following should be undertaken to assess the impact of urban runoff on the waterbody:

1. Assessment of the ecological impact on the stream – refer to Volume 4 of the LCA Guidance.
2. Dry weather surveys: surface water pipes should not be discharging during dry weather surveys. Discharging pipes during dry weather indicates a misconnection or, potentially, an illegal activity (amongst other reasons, e.g. a burst water supply main).
3. First flush surveys: solids and spills, swept up by rain, sit in surface water drains and pipes and eventually are flushed to the river in the first 20 or so minutes of heavy rainfall. These first flushes (i.e. the first 20 minutes or so of rainfall following a dry period) are particularly toxic after a dry spell. Capturing and sampling first flush flows can provide important information on the types of urban runoff being captured by specific surface drainage catchments. Give the logistical constraints, remote monitoring using autosamplers or continuous monitoring probes may be required to monitor first flush events.
4. It is not uncommon during catchment walks to “discover” pipes which are not present on any maps - i.e. maps cannot always be trusted. All surface water drainage pipe outlets of 225mm (9 inch) or above should be investigated if possible.

6.3.3 Data that should be captured

Table 12 shows the information that should be recorded during catchment walks.

Table 12: Data Collection – Urban Runoff

Specific Information	General Information
♦ Number of pipes discharging into the river ♦ Location of pipe (GPS reference); ♦ Type/purpose of pipe (if known); ♦ Photograph; ♦ Whether discharging or not; ♦ If discharging, measure flow; ♦ If discharging, measure field parameters such as pH, temperature, dissolved oxygen and conductivity; ♦ If discharging, take sample for analysis; ♦ Identification of grease and fat – kitchen waste? ♦ If not discharging, whether evidence of recent discharge. ♦ Record the condition of the stream bed (biology, and composition and structure of substrate) ♦ Presence of biological indicators e.g. algae ♦ Colour and smell of the water e.g. presence of oil films on the water surface	♦ Any changes to catchment and/or waterbody boundaries identified in the desk study ♦ General gradients from surrounding landscapes ♦ Record any hydromorphological pressures e.g. new drainage systems ♦ Pathway indicators ♦ Record the presence of hedges and riparian areas. ♦ Any roads surrounding the vicinity ♦ Invasive species

GPS coordinates should be recorded for presence of any of the above mentioned as this data can be used in mapping the area.

6.4 Next Steps and Potential Mitigation Options

Urban runoff issues should be referred to the Local Authority for further assessment. Further sampling may be warranted to distinguish urban runoff from domestic or trade misconnections or to characterise the main polluting components of the runoff. Suggested analysis suites for these water quality issues are included in **Appendix 6.2.** Water sampling will be most informative when it captures the “first flush”.

Managing urban runoff is a complex. While engineered solutions have long been used (designed to move urban stormwater away from the built environment), these have become less popular as the pace of urban development has outstripped the rate at which the engineered solutions can be installed, even in Ireland. The use of natural water management tools, known as Green Infrastructure, has become best practice for urban water management. This manages surface water impacts by reducing and treating it at its source using vegetation, soils, and other natural components. Sustainable Urban Drainage Systems (SUDS) are a component of Green Infrastructure that have been used in Ireland (particularly the Greater Dublin Area) since the completion of the Greater Dublin Strategic Drainage Study in 2005.

The International Union for Conservation of Nature (IUCN) infographic shows the broad range of infrastructure available for natural water management.

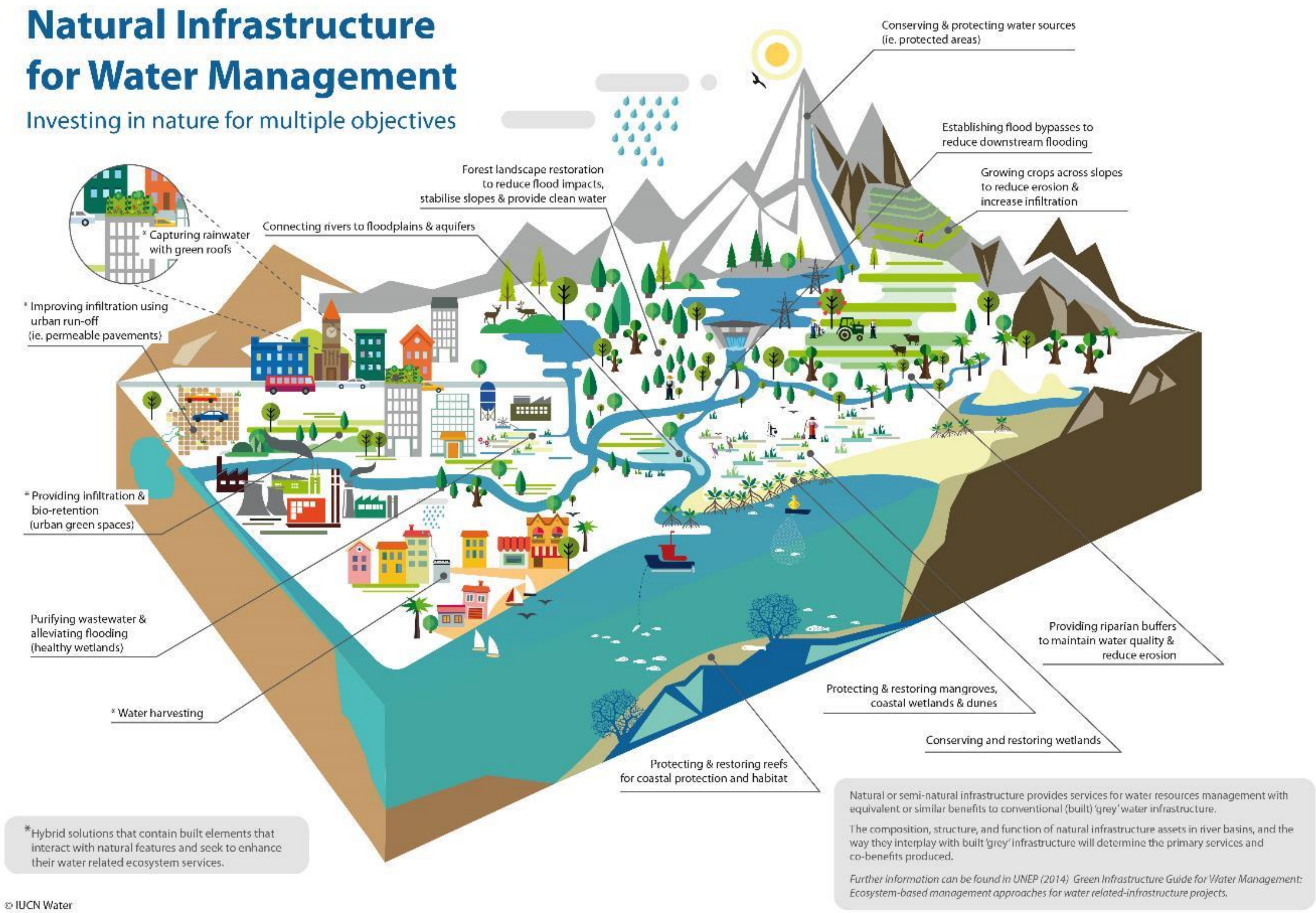


Figure 16 Natural infrastructure for water management Source: IUCN (as part of 'WISE-UP to Climate' project). See http://www.iucn.org/theme/water/our-work/wise-climate

6.5 Physical time lags associated with implementing mitigation measures and strategies

Time lags will vary depending on the extent of the pollution sources but in general measures take an extended period to implement. In practice, management of urban runoff will be an ongoing issue with incremental improvements. Once a mitigation measure has been implemented in a sub-catchment draining to a particular outfall (e.g. adequate green infrastructure is constructed throughout the sub-catchment), the result should be observed quickly in terms of monitoring the discharge from that pipe. There should be no discharges in certain (low) rainfall events, reduced discharge in higher intensity rainfall events up to the design consideration, and a greater lag.

6.6 Best Practice

Ireland's experience with best practice management of urban runoff using Green Infrastructure and SUDS to manage urban runoff has focussed on specific projects. Many involve constructed wetlands and a good example of this is the Tolka Valley Park project undertaken by Dublin City Council http://www.create-ireland.ie/images/pdfs/Tolka-Valley-Park-ICW-Collins-and-McEntee-Feb-2009.pdf. Dun Laoghaire–Rathdown County Council has developed a Green Infrastructure Strategy (2014), which is a good model, albeit developed in a context where water management is not the focus but an (important) element of the strategy: https://www.dlrcoco.ie/en/parks-outdoors/parks-plans-and-policies.

An extensive body of best practice literature and practical experience of managing urban runoff with Green Infrastructure is being developed worldwide. The Green Infrastructure approach is thoroughly explained at the USEPA website: https://www.epa.gov/green-infrastructure/learn-about-green-infrastructure . Other useful reference material includes:

- EU Strategy on Green Infrastructure http://ec.europa.eu/environment/nature/ecosystems/strategy/index_en.htm
- IWA (International Water Association) http://www.iwa-network.org/learn/green-infrastructure-for-water-wise-cities/
- Philadelphia Green Cities Clean Waters Programme https://www.phila.gov/water/sustainability/greencitycleanwaters/Pages/default.aspx
- CIRIA (UK Construction Industry Research and Information Association) SUDS Manual https://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx
- Natural Water Retention Measures (NWRM) http://nwrm.eu/urban

7 Storm Water Overflows

7.1 Purpose

This section provides an overview of storm water overflows (SWOs) (also referred to as combined sewer overflows or CSOs). These are structures which allow excess sewage to be diverted from the combined sewer system either directly into a receiving waterbody or indirectly via a surface water drainage system during rainfall events. They are a common feature in urban drainage systems in Irish cities and towns, particularly those with older networks. Note, while SWOs may discharge urban runoff only, it is assumed that any SWOs which is a significant pressure discharges both urban runoff and untreated sewage.

Overflows are described in detail in Volume 2, Section 4.4 of the LCA Guidance. In summary, a SWO is a licenced intermittent discharge, i.e. they discharge under a licence issued by the EPA[7] into a specificed receiving water.

7.2 What are the associated water pollutants impacting water quality?

Many SWOs were built over 50 years ago. Their capacity can be exceeded by the sewage flow (e.g. from increased numbers of properties in the network when a town grows), increased infiltration to the sewers and heavier rainfall than the structures were designed for. When SWOs consistently spill, it can cause direct or indirect pollution and adversely affect the water quality, amenity uses and biodiversity of water bodies. The principal water quality impacts include:

- Pollutants from foul sewage including nutrients like phosphorus and nitrogen, pathogens (bacteria and viruses), sewage-derived debris, compounds associated with oxygen depletion (notably organic matter and ammonia) and toxins from trade effluents in the sewer, some of which are of concern because of their persistent nature.
- Pollutants from urban runoff, notably phosphorus.
- Aesthetic services in urban water bodies are adversely affected by SWO spills, especially due to sewage derived debris. These visual impacts as well as smells and odours are often worse in drier weather when sewage fungus or the effects of eutrophication become more apparent.

A summary Source-Pathway-Receptors for SWOs is shown in Table 13.

Table 13: Source-Pathway-Receptor Summary – Combined Sewer Overflows

Source	Pathway	Receptor
SWOs (diluted wastewater)	Surface Drains Direct Discharge Surcharged Manholes	Waterbody

7.3 Local Catchment Assessments

7.3.1 Desk Based Assessment

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

Field investigations of SWOs should be planned and undertaken in consultation with Local Authority operations staff and Irish Water. Catchment assessors should note that there are risks involved

[7] Further information can be found at http://epa.ie/licensing/watwaste/wwda/. An example of an EPA licence (for Bray) is included at http://www.epa.ie/licences/lic_eDMS/090151b2804edff0.pdf

when dealing with sewers, culverts, etc. in urban areas and these should be discussed with experienced Local Authority operations staff and Irish Water prior to fieldwork.

The following information should be identified in advance of the catchment walk:

1. **Locations of SWOs**: these can be identified in advance of catchment investigations using GIS mapping available on the EPA website, https://gis.epa.ie/EPAMaps/SewageTreatment (Figure 3 shows discharges in Ashbourne, Co. Meath). Note that unmapped SWOs that are known or suspected to exist can occur in urban areas. Hence, it is not always possible to map every SWO during a desk study (unmapped possible SWOs found in the field should be recorded).
2. **Receiving water**: is it designated sensitive /protected / at risk?
3. **Performance:** Information through discussion with Local Authority drainage staff and Irish Water staff on the performance of the overflow (e.g. incidents or excessive overflow events, or output from event monitors, if installed).

Where it is observed during the catchment walk that a SWO(s) may be a significant pressure, the following specific information should be identified:

1. **Review of AERs:** each year the licence holder (normally Irish Water) submits an Annual Environmental Report (AER) to the EPA describing the performance of the scheme against the licence[8]. (NB: Irish Water has been working on improving the veracity of the evidence base used for AERs for and recommend only using the latest AERs for any analysis, i.e. the 2018 AERs onwards).
2. Review of Irish Water data: Irish Water has begun SWO monitoring at some locations as part of a SWO Assessment Programme. Additional information may be available for certain SWOs.

7.3.2 Catchment Walks

Catchment investigations near SWOs may identify evidence of pollution, for example decreased dissolved oxygen and increased faecal coliforms (from analysis of samples), but also visible evidence of problems such as sewage derived debris.

Identification of SWOs (and other discharge points) with potential contamination is valuable data and catchment investigations have an important role to play in recognising and reporting pollution events and polluting outfalls.

1. SWOs shown on the EPA GIS should be confirmed in the field to identify them from any other potential point source inputs.
2. Upstream and downstream river assessment of impact, if any, should be carried out.
3. Sampling and analysis should be undertaken where there is an impact in the area downstream of the SWO. SWOs should normally only be actively discharging during wet weather conditions. It may not be possible to collect samples during wet weather.
4. If a SWO is spilling during dry weather conditions, there is an issue that should be investigated by Irish Water. Sites that are found to be spilling during dry weather conditions should automatically be considered a problem for further investigation.

7.3.3 Data that should be captured

Table 14 shows the information that should be recorded during catchment walks.

[8] An example for Bray is included at this link http://www.epa.ie/licences/lic_eDMS/090151b280670e30.pdf.

Table 14: Data Collection – SWOs

Specific Information	General Information
♦ Number of pipes discharging into the river ♦ Location of pipe (GPS reference); ♦ Type/purpose of pipe (if known); ♦ Photograph; ♦ Whether discharging or not (this should only be happening in wet weather); ♦ If discharging, measure flow; ♦ If discharging, measure field parameters such as pH, temperature dissolved oxygen and conductivity; ♦ If discharging, measure field parameters upstream and downstream; ♦ If discharging, take sample for analysis; ♦ If discharging, take upstream and downstream samples for analysis; ♦ Any manholes in vicinity of river bank, upstream of discharge point (upstream on pipe), note evidence of manhole cover popping, debris/ragging etc. ♦ If not discharging, whether evidence of recent discharge. ♦ Record the condition of the stream bed (biology, and composition and structure of substrate) ♦ Presence of biological indicators e.g. algae ♦ Colour and smell of the water e.g. presence of oil films on the water surface	♦ Any changes to catchment and/or waterbody boundaries identified in the desk study ♦ General gradients from surrounding landscapes ♦ Record any hydromorphological pressures e.g. new drainage systems ♦ Pathway indicators ♦ Land use of the surrounding area ♦ Any roads surrounding the vicinity ♦ Invasive species

7.4 Next Steps and Mitigation Options

Mitigation of underperforming SWO discharges is the responsibility of Irish Water.

Possible mitigation options related to urban wastewater systems are discussed in Section 4.5 of the LCA Guidance. A potential SWO issue identified during a catchment walk is likely to continue to be an issue until it is addressed by Irish Water, and this may take time. This is because the mitigation of SWOs is not a standalone task, and the whole agglomeration needs to be assessed to examine flows and loads, before mitigation measures can be defined (often involving modelling). This takes time and depends on the extent of the wastewater network (for example, the Greater Dublin Strategic Drainage Study (GDSDS)[9] completed in 2005 took several years to complete). Interim measures to improve performance can also be considered, including maintenance. However, there are no easy solutions as SWOs are normally part of the older elements of the network and options can be limited.

The performance of SWOs in many urban areas is being assessed by Irish Water as part of a programme of detailed studies and investigations known as Drainage Area Plans (DAP). A DAP involves data collection (including physical inspections, flow monitoring, etc.), modelling, risk assessment and the development and design of options for improvement, i.e. to ensure compliance with the relevant licence for the discharge. DAPs involve a significant amount of fieldwork, modelling and assessment and the Irish Water programme is currently being undertaken on a

[9] http://www.greaterdublindrainage.com/gdsds/

phased basis. These DAPs will result in engineering options for improvement that will then be assessed as part of Irish Water's investment programme and prioritized.

As with Urban Runoff (see Section 5), increased use of sustainable urban drainage systems (SUDS) is an important means of reducing flows to sewer and therefore reducing the frequency of SWO spills. This was a key recommendation implemented by the seven Greater Dublin Local Authorities following completion of the GDSDS. However, its applicability will vary on a catchment by catchment basis and the DAP process will examine this as one of a range of potential mitigation measures.

7.5 Physical time lags associated with implementing mitigation measures and strategies

SWO improvement strategies for urban areas can take years of investment and improvement to deliver outcomes which result in significant water quality improvements, reflecting the extent of investment needed to increase sewer and treatment capacity.

7.6 Best Practice

Extensive study has also been undertaken of best practice in monitoring of SWO performance and spill events, and this has been captured in an EPA research report[10].

[10] EPA Research Report 240: Technologies for Monitoring, Detecting and Treating Overflows from Urban Wastewater Networks Authors: David Morgan, Liwen Xiao and Aonghus McNabola (2018) http://www.epa.ie/pubs/reports/research/water/Research_Report_240.pdf

8 Contaminated Land

8.1 Purpose

This section provides an overview of contaminated land issues with respect to water quality impacts. These can occur in different ways, for example from unauthorised waste-related activities, historical activities, leakages or accidental spillages of chemicals. There is currently no specific contaminated land policy in Ireland and therefore no legislation in place to deal with it specifically. There is, however, an Integrated Pollution Control (IPC)/Industrial Emissions Directive (IED)/Waste licencing process enforced by EPA. This process ensures that active facilities endeavour to not cause pollution and promptly address any polluting events.

Overall, pollution from contaminated land is not as significant an issue in Ireland as in some other European countries. Nonetheless, there are a significant number of existing or legacy sites with the potential to impact water quality. In urban areas, petrol stations are the most common sources of potential contamination as shown in Figure 17. There are also a significant number of legacy landfill sites, many of which are located in urban areas. There are also other non-industrial sites where the nature of the activities have the potential to contaminate land, e.g. dry cleaners. Some of these are covered by Local Authority regulations, e.g. Solvents Regulations.

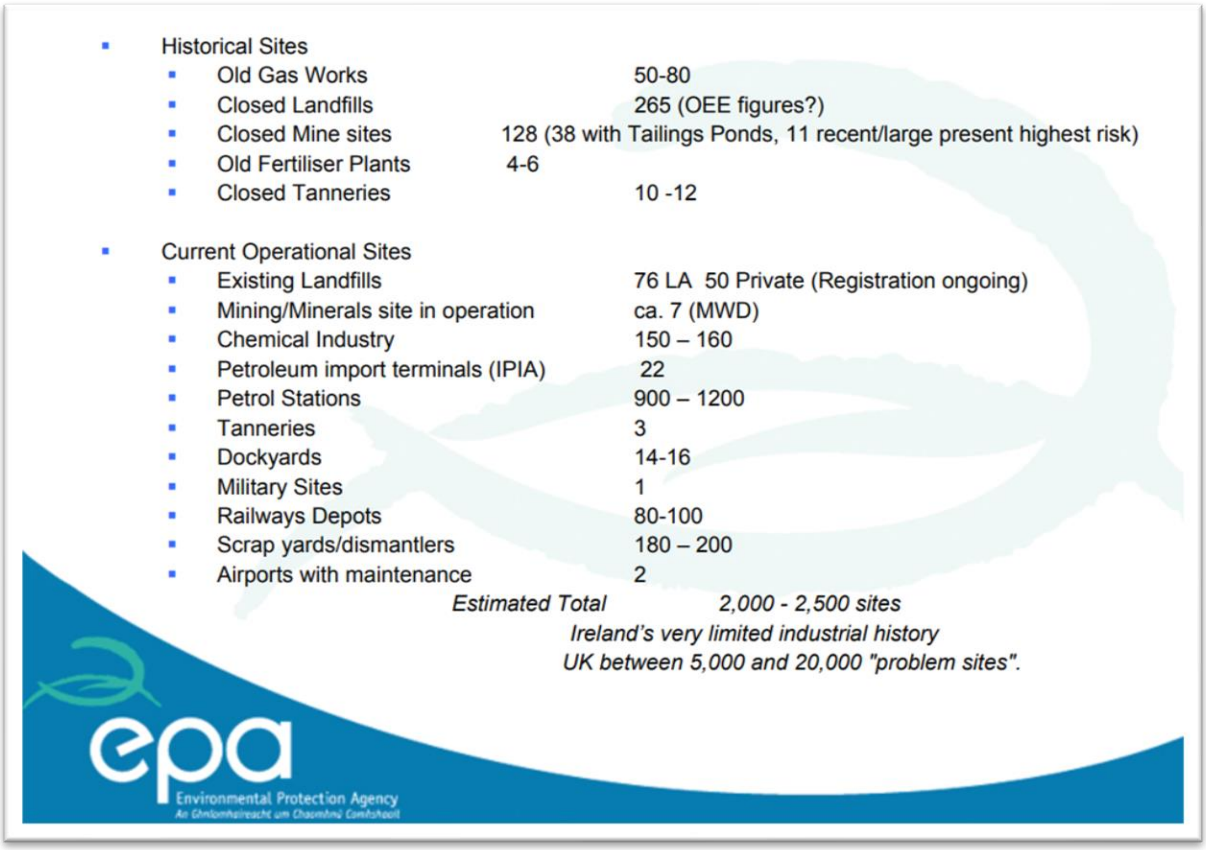


Figure 17: Overview of Ireland's potential contaminated sites (Motherway, 2009)

Note, there are now only five (open) landfills[11]. The number is much lower in 2019 than provided in Figure 16 by Motherway (2009), but the closed landfill sites exists.

[11]https://www.epa.ie/irelandsenvironment/waste/

8.2 What are the associated water pollutants impacting water quality?

A broad range of water quality problems can arise from contaminated land, depending on the type of facility involved. Of the licenced sites that have been identified as significant pressures on groundwater, most are landfills or chemical/surface coating sites. Chlorinated hydrocarbons (CHCs) and leachate (containing oils, heavy metals, etc.) are the most frequent types of contamination at such sites.

Sampling and analysis plays a bigger role in determining the presence of pollution from contaminated land. For contaminated land, laboratory analysis which identifies evidence of the following parameters can be used to refine the source of the problem:

- Chlorinated volatile organic chemicals (VOCs);
- Petroleum Hydrocarbons;
- Semi-volatile organic chemicals;
- Polycyclic aromatic hydrocarbons (PAHs);
- Metals (especially lead, mercury, zinc, copper and arsenic); and
- PCBs and dioxins.

Suggested additional analysis suites for these water quality issues are included in **Appendix 6.2**.

A summary Source-Pathway-Receptors for contaminated land is shown in Table 15.

Table 15: Source-Pathway-Receptor Summary – Contaminated Land

Source	Pathway	Receptor
Contaminated Land	Surface Drains Riverbanks Ground Aquifers	Waterbody

8.3 Local Catchment Assessments

8.3.1 Desk Study

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

Contaminated sites and their impact on local water quality are often well known or subject to regulatory processes. However, smaller or new problems can fly below the radar until detected, often during local catchment assessments. Therefore, during the desk study phase, an attempt should be made to identify any known contaminated sites and sites with the potential for contamination.

- Using the EPA website, facilities with IPC/IED/Waste licences or registered under the Solvents Regulations can be identified in advance (example shown in Figure 2).
- Any business covered under the Emissions of Volatile Organic Compounds from Organic Solvents Regulations (referred to as the Solvents Regulations) should be identified. These include dry cleaners and vehicle refinishing companies which carry out original coating of road vehicles or trailers. Activities using more than 10 tonnes per annum of solvents require an IPC licence from the EPA[12].
- Other businesses with the potential to have contaminated land (or former businesses in the cases of abandoned sites) should be identified. Examples include old service stations or factories.

[12] http://www.epa.ie/air/airenforcement/solvents/

- Information on issues with contaminated land along the river should be gathered through discussion with Local Authority drainage staff.

8.3.2 Catchment Walks

While some contaminated sites will be well known, and the impact of pollution can be seen in the river, catchment walks will also occasionally turn up evidence of new contamination or indicators of potential problems. In the case of contaminated land:

5. Oily or discoloured water at locations other than near surface drains is of interest. This is evidence of a problem at some location. The extent of the issue needs to be investigated.
6. Sampling and analysis should be undertaken where possible, both at the site of the issue, and upstream and downstream.
7. An attempt should be made to identify potential sources of the problem near the problem, i.e. sites or homes with home heating oil tanks.

8.3.3 Data that should be captured

All incidents of water pollution from contaminated land should be reported to Local Authorities, as are potential enforcement issues. Table 16 shows the information that should be recorded during catchment walks.

Table 16: Data Collection - Contaminated Land

Specific Information	General Information
♦ Condition of biological indicators e.g. algae ♦ Colour and smell of the water e.g. presence of oil films on the water surface ♦ Photograph; ♦ Record the condition of the substrate ♦ Number of pipes discharging into the river (if any) ♦ Location of pipe (GPS reference); ♦ Type/purpose of pipe (if known); ♦ Whether discharging or not; ♦ If discharging, measure flow; ♦ If discharging, measure field parameters such as pH, dissolved oxygen and conductivity; ♦ If discharging, take sample for analysis; ♦ If not discharging, whether evidence of recent discharge from pipe, or through difference in the condition of stream /stream bed upstream and downstream of pipe.	♦ Any changes to catchment and/or waterbody boundaries identified in the desk study ♦ General gradients from surrounding landscapes ♦ Record any hydromorphological impacts e.g. new drainage systems ♦ Pathway indicators ♦ Land use of the surrounding area ♦ Any roads surrounding the vicinity, and road drainage ♦ Invasive species

8.4 Next Steps and Potential Mitigation Options

There are 809 facilities across Ireland with either an IED, IPC or Waste licence. Unlike some of the other urban pressures discussed in this guidance, identification of pollution at these licenced sites is an immediate enforcement issue, whether by EPA (in the case of IPC/IE/Waste licenced facilities) or Local Authorities (in the case of non-EPA licenced facilities such as dry cleaners, petrol stations, leakage heating oil tanks, etc.)[13].

[13] Further information regarding the EPA's approach to contaminated land, and regulations for identifying, assessing and remediating unregulated local authority landfills can be found at http://www.epa.ie/enforcement/contaminatedland/

However, additional analysis may be necessary to identify or confirm what or where the problem is. The options for analysis will depend on what is found in the field, and include:

- Potential landfill sites: COD, conductivity, iron, nitrate, ammonia, phos
- phorus, total hardness (Ca & Mg), sodium (Na), chloride (Cl-), calcium (Ca) and magnesium (Mg).
  - COD, conductivity, nitrate and phosphorus, particularly, will generally be high.
- Manufacturing sites: depending on process, but analysis of all metals and chlorinated VOCs, PCBs and dioxins, PAHs and emerging contaminants such as PFAS; and
- Potential petrol station contamination: petroleum hydrocarbons (PHC) and chlorinated VOCs.

Suggested additional analysis suites for these water quality issues are included in **Appendix 6.2**.

Remediation of abandoned sites with no licence holder or sites which do not fall within the IPC/IE process depends on the type of contamination identified. In the event of significant contamination, progressing from identification to remediation and improvement of water quality can be a slow process. These include historic landfills sites in private or local authority ownership, which are currently the subject of Government funding for further investigations according to an EPA Code of Practice[14].

Once a need for soil remediation is recognized, the best available technology is selected. This technology considers the:

- nature, toxicity, and origin of the contaminant;
- present and potential hazard related to the degree of contamination;
- chemical and physical characteristics of the soil;
- land use;
- time available for remediation;
- community acceptance,
- and a cost-benefit analysis.

Contaminated soil can be managed, monitored or remediated. In cases where contaminated soil is remediated, this continues to be commonly managed using "traditional" techniques, e.g. excavation and off-site disposal, but other in-situ and ex-situ remediation techniques for contaminated soil can be applied depending on specific site conditions.

8.5 Physical time lags associated with implementing mitigation measures and strategies

The time lags associated with implementing mitigation measures and strategies depends on the type and extent of contamination. Localised contamination from a leaking tank should be possible to resolve quickly and easily, especially if it is detected early. However, for more complex sites, it can take years for the process of identification, through to remediation, through to improvement of water quality. Most contaminated sites in Ireland could be remediated where sufficient funding is made available. The urgency with which this happens tends to be based on the significance of the pollution caused and the risk posed by the contamination, or more realistically, the value of the land for further uses, particularly when the site is in private ownership. This generally applies in urban areas, where many recent examples exist of major remediation projects allowing previously

including the document "Guidance on the Management of Contaminated Land and Groundwater at EPA Licensed Sites" and Environmental Risk Assessment for Unregulated Waste Disposal Sites, and associated Guideline Template Reports.

[14] Environmental Risk Assessment for Unregulated Waste Disposal Sites (EPA, 2007) and associated guidance for assessing unregulated historic landfill

contaminated lands to be redeveloped, e.g. former gasworks and other facilities in Dublin docklands.

8.6 Best Practice

Extensive best practice exists for remediation of contaminated land; however, much of it is site and contaminant specific. The EPA guidance documents referenced in the text present the most accessible guidance relevant to the types of situations likely to be found during catchment assessments.

9 Hydromorphological Pressures

9.1 Purpose

Hydromorphology considers the physical character and water content of water bodies. Appropriate hydromorphological conditions support aquatic ecosystems (i.e. hydromorphological elements such as water flow and bed substrate provide physical habitat for biota such as fish, invertebrates and aquatic macrophytes). Hydromorphological pressures, or physical modification, was identified as the second most significant pressure across Ireland, as outlined in the River Basin Management Plan for 2018-2021. There exist a number of national and international projects that seek to location and characterise hydromorphological pressures. These projects include the Amber Database (https://amber.international/european-barrier-atlas/) and RECONNECT Project (http://www.ucd.ie/reconnect/); the data from both of these feeds into the IFI database listed in Table 1. In urban settings, the range of hydromorphological alterations and their impacts can be extensive.

A National Hydromorphology Work Programme was outlined in the River Basin Management Plan (RBMP) for 2018-2021 (See Figure 18). The near-term priorities include the development and implementation of hydromorphological condition assessment tools for all surface waterbody types, and improving the knowledge of hydromorphology-ecology relationships. Developing the evidence base to support the hydromorphology work programme is a key priority for the second RBMP cycle. These outputs will be vital in supporting the remaining work items, including the identification and implementation of appropriate measures. A National Hydromorphology Working Group has been established to support the hydromorphology work programme, comprising representatives of public bodies with an interest in hydromorphology including inland fisheries Ireland (IFI) and the office of public works (OPW).

A significant programme of work is being undertaken by the stakeholders involved in addressing this key urban pressure (e.g. development and implementation of hydromorphological condition assessments). It will take time before this evolves into the development of an appropriate measures programme and then into the actual implementation of mitigation measures. Furthermore, **the emphasis at this point is on making improvements in water quality in urban catchments, as these are fundamental to creating suitable conditions for hydromorphological improvements to be effective.**

The remainder of this section provides high-level guidance for catchment assessors, focussing on the issues they are likely to encounter during local catchment assessments and what information can usefully be collected at this time. Volume 2, Section 3 of the LCA Guidance discusses hydromorphological pressures (impacting rivers) in more detail.

The impacts, on rivers for example, which arise due to hydromorphological pressures in urban areas include:

- Alteration of the sediment regime– sediment is vital for ecosystem functioning. Altering channel dimensions (i.e. deepening and widening), creating impoundments or reducing natural sources (i.e. bank protection) can lead to an imbalance in the system. Sediments contain nutrients such as nitrogen and phosphorus. If sediment with a high nutrient content is deposited on the channel bed, it can alter the chemical quality of the water.
- Alteration of the flow regime – flow allows for the movements of sediment, wood, biota and for the creation and maintenance of habitat. Flow regulation can impact these processes, by altering the quantity and dynamics of flow conditions. Furthermore, reduced flows may lead to the deposition and accumulation of fine sediment on the river bed. Unsustainable water abstractions affect the amount of water available and are an increasing problem in urban due to pressure for domestic and commercial uses.

- Fish migration – connectivity throughout the catchment is vital for the movement of fish. Manmade barriers, such as culverts, weirs, dams and bridges, affect the migration of fish along rivers which has resulted in a significant reduction in species across our waterbodies.

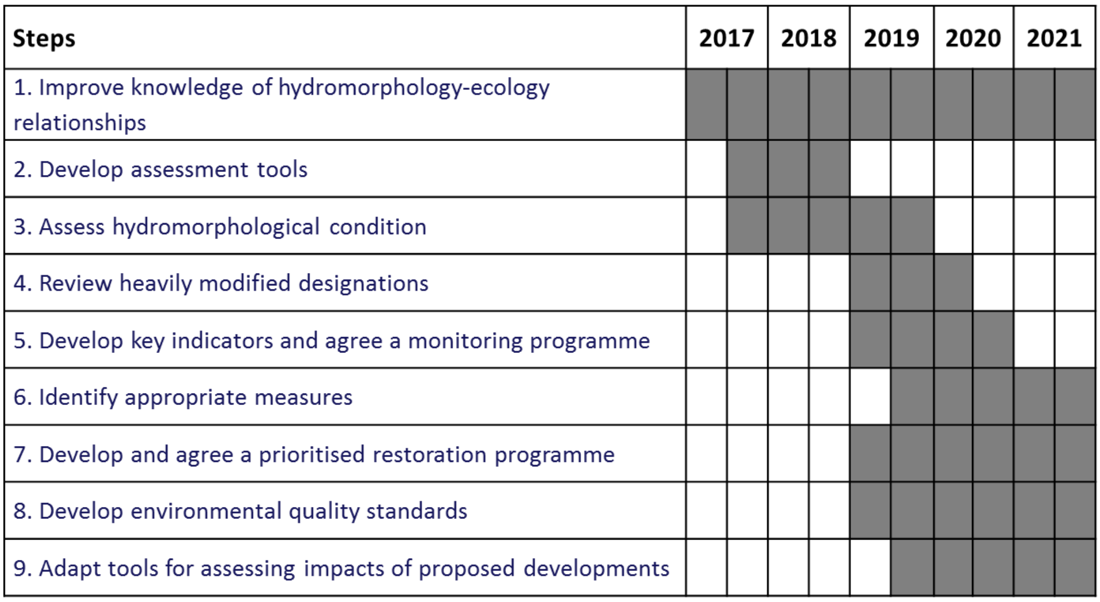


Figure 18: High level timeline for the national hydromorphology work programme

The Morphological Quality Index (MQI) tool (see Figure 19) is being adapted for use in Ireland's river systems by the EPA Catchments unit for the assessment of river hydromorphological condition. The tool uses GIS and remote sensing to provide a national overview of hydromorphological condition. The output will allow the identification of areas that should be targeted for further investigation and/or measures. This output can support and inform the work of the Local Authority Waters Programme. Also, observations of significant hydromorphological pressures and issues from the local catchment assessment can feed into the national hydromorphological work plan. There are also morphological condition assessment tools for lakes (Lake MImAs (Morphological Impact Assessment)) and transitional and coastal water bodies (TRAC HQI (Hydromorphological Quality Index)).

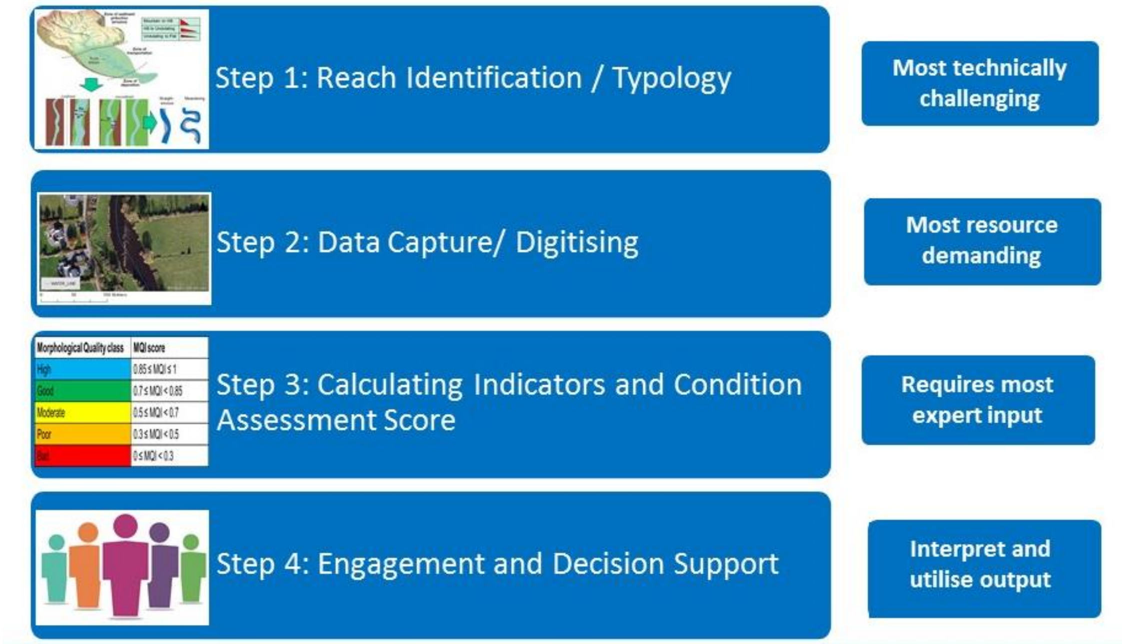


Figure 19: Assessment of River Hydromorphological Condition: Morphological Quality Index (MQI)

Heavily modified waterbodies (HMWBs) will also be an issue in urban catchments. These are "substantially changed in character as a result of physical alterations by human activity" (e.g. from the creation of dams for drinking water supply or power generation, channel modification for navigation or flood protection). The environmental objective for HMWBs is "Good Ecological Potential" and good chemical status. Future work by the National Hydromorphology Working Group will review these designations, taking into consideration the evolving guidance from the European Commission, supporting the classification of Ecological Potential (i.e. a measure of ecological quality compared to the maximum quality achievable without impacting either the service provided by the physical alteration or the wider environment[15]).

9.2 Local Catchment Assessments

9.2.1 Desk Based Assessment

An overview of the desk study is included in Section 2 and general guidance on desk studies is provided in Volume 5 of the LCA Guidance.

Prior to the catchment walk, a good sense of the extent of hydromorphological pressures in the catchment can be identified from a review of:

- Comparing historical maps with aerial imagery (this can be done easily using the OSI geohive website https://geohive.ie/).
- Identifying ongoing or recently completed flood relief/defence schemes (OPW website: www.floodinfo.ie) and OPW drainage viewer for drainage and embankment schemes - https://maps.opw.ie/drainage/map/;
- Location of existing barriers (in consultation with Inland Fisheries Ireland, who are also participating in a European barrier atlas programme known as the Amber project. https://amber.international/european-barrier-atlas/ and River Obstacle App used by the EPA funded RECONNECT project http://www.ucd.ie/reconnect/.

[15] Definition from Natural Scotland in 2009. Natural Scotland, 2009. *Chapter 4: Heavily modified and artificial water bodies*. The river basin management plan for the Scotland river basin district 2009-2015

9.2.2 Catchment Walks & Data that should be captured

Catchment walks in urban rivers will identify many potential hydromorphological pressures but recording all potential hydromorphological pressures is not necessary at this time, considering the status of the national hydromorphology work programme. It will be sufficient to note in the desk study that it is a local catchment assessment in an urban environment, confined by walls, culverted, channelised, modified, etc. However, the catchment walks can capture valuable data to improve site specific knowledge of particular significant issues.

The important issues to capture during catchment walks are obvious significant hydromorphological pressures: **in-channel barriers or structures; concreted river beds; hard bank engineering or recently constructed flood defences; evidence of significant siltation within the river channel; severe undercutting of banks; and extreme scouring within the vicinity of discharge pipes**. Barriers or structures, for instance, can alter hydromorphological conditions and impede the movement of water, sediment (e.g. coarse sediment such as gravel, cobble and boulders (refer to *LAWPRO Sediment Visual Assessment Methodology*, available Autumn 2019)) and aquatic species. Examples include dams, weirs, pipe and utility crossings, sluices, culverts, fords, heritage structures and bridge aprons. Many are no longer in use (e.g. mill infrastructure) or perform no function (e.g. so-called ornamental weirs). The extent of this issue is currently under investigation through a number of projects (e.g. the EU funded AMBER project and the EPA funded RECONNECT project) and the Inland Fishers Ireland National Barriers Assessment Programme, an element of the current River Basin Management Plan[16]. The variety of structures, barriers or other infrastructure that might be found in rivers is wide (see examples in Figures 19 through 23).

The other issue worth recording are the lengths of channelised (i.e. straightened, deepened, and/or widened) or culverted river. In urban areas across Ireland, this has been a very common river management technique until relatively recently, when the extent of its impacts became clear, not only from a hydromorphological perspective (i.e. altering the flow and sediment regime) but also with respect to increasing the risk of flooding. Start and end points should be recorded (this will also be visible on catchment mapping).

Figure 20: Example of culverted section of river

[16] https://www.fisheriesireland.ie/Fisheries-Research/the-amber-project.html

Figure 21: Example of Pipe Support across River

Figure 22: Example of "Ornamental" Weir

Figure 23: Example of Culverted Bridge

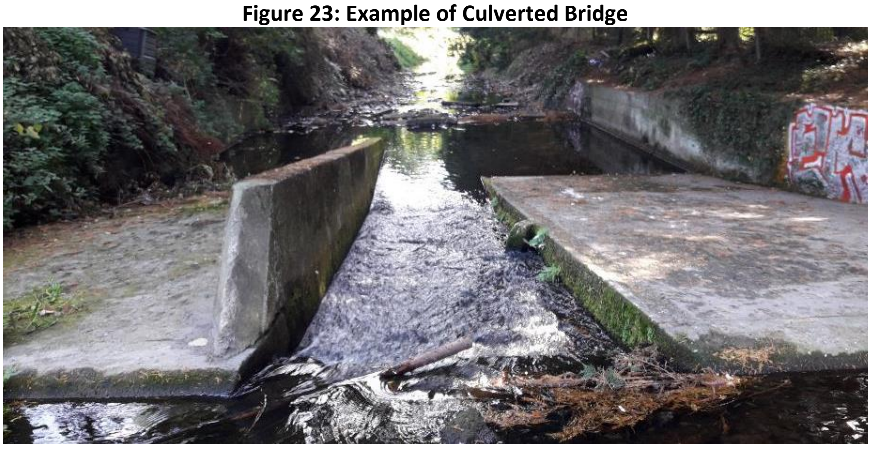


Figure 24: Example of old structure (perhaps on old mill structure) not removed from river

Figure 25: Example of sewer infrastructure acting as a hydromorphogical pressure

10 Other Issues

10.1 Introduction

Two other issues were identified with the potential to indirectly impact water quality. These are discussed briefly in the following sections.

10.2 Fats, Oils & Greases (FOG)

When fats, oils and grease (FOG) are poured down drains they cool and accumulate in the pipes restricting flow in the drainage network. The accumulation of FOG in pipes impacts water quality indirectly by impacting sewer performance (or blocking them) and can result in increased overflows from SWOs (see Section 7 of this guidance), thus resulting direct water quality impacts.

Removal of FOG from pipes is very expensive and labour intensive. For example, Dublin City Council removal of a FOG blockage in Clontarf in 2012 that cost an estimated €150,000 (DCC, 2012). In 2008 Dublin City Council launched a FOG programme to manage discharge of FOG effluent produced by food service establishments. Under the FOG programme all food establishments are required to apply for the discharge to sewer licence under Section 16 of the Local Government (Water Pollution) Act 1977 as amended in 1990. Since 2014, Irish Water monitor and issue licences for the FOG programme[17] and for Section 16 trade effluent licences across Ireland. Studies have demonstrated how the implementation of the FOG programme in 2008 decreased the number of blockages in Dublin from 1,000 to 50 per year[18].

As part of the FOG programme, inspections are undertaken to check that food premises have appropriately sized and regularly serviced grease traps and undertake proper disposal of waste oil. Currently the FOG programme is not implemented on a national basis, however under Section 16 all trade effluent generating sectors are required to hold a licence for discharge.

FOG can also enter water bodies through Misconnections (Section 4 and Section 5 of this guidance) and Urban Runoff (Section 6 of this guidance). If FOG pollution is identified in surface drainage networks or within waterbodies it may be due to incorrect storage of FOG waste at a food business (or a trade misconnection). If the waste is not stored in secured containers it can be knocked over or during heavy rainfall events can be washed down surface drains. If FOG enters the waterbody, it can form thin biofilm layers on the water surface limiting oxygen absorption and creating high levels of BOD as it decomposes.

10.3 Ragging

The increased use of 'wet wipes' and other sanitary products in recent years has also contributed to significant blockages in sewers as these products tend not to decompose. The clogging of pumps within the sewer network from these products is known as "ragging"; this is a significant modern problem for Irish Water[19] and utilities everywhere.

10.4 Leaking Sewers

Leaking sewers can be a problem in urban areas across Ireland and are caused by old pipe networks, structural faults, operational faults, excavations and freezing weather conditions. Leaking sewers occur in both foul and surface drainage systems but infiltration is normally a much more significant problem than exfiltration from sewers. Infiltration of groundwater reduces sewer capacity and can result in increased overflows from SWOs. It can also allow introduction of contamination to surface

[17] https://www.water.ie/for-business/trade-effluent/fats-oils-and-grease/

[18] https://www.ucd.ie/biosystems/research/researchprojects/fog/

[19] https://www.water.ie/wastewater/issues/think-before-you-flush/

networks from sources such as waste sites, septic tanks, service stations, chemicals, de-icers, polluted precipitation and vehicles. These can the enter the waterbody during SWO spills and cause direct water quality impacts. When infiltration from the sewers occur, these pollutants can enter groundwater and impact water quality. Many arterial combined sewers follow the river sometimes on both sides in urban areas. Many of these are directly behind the quay walls which in older urban areas are permeable, so that any leakage from them does not have far to go to reach the waterbody.

CCTV inspections were carried out as part of the Greater Dublin Strategic Drainage Study to test the hydraulic performance[20]. This concluded that exfiltration is very difficult to identify except for a major breakage and these leakages tend to be masked by larger infiltration flows which is regarded as a problem on a national scale.

There are numerous sources of inflows and infiltration (I/I), as shown in Figure 26. Where it is an issue, addressing leaking sewers will be a decision for Irish Water based on their investment priorities but reduction of inflow and infiltration may include re-direction of inflow sources to separate surface water systems, sealing of manhole covers, rehabilitation or replacement of sewers.

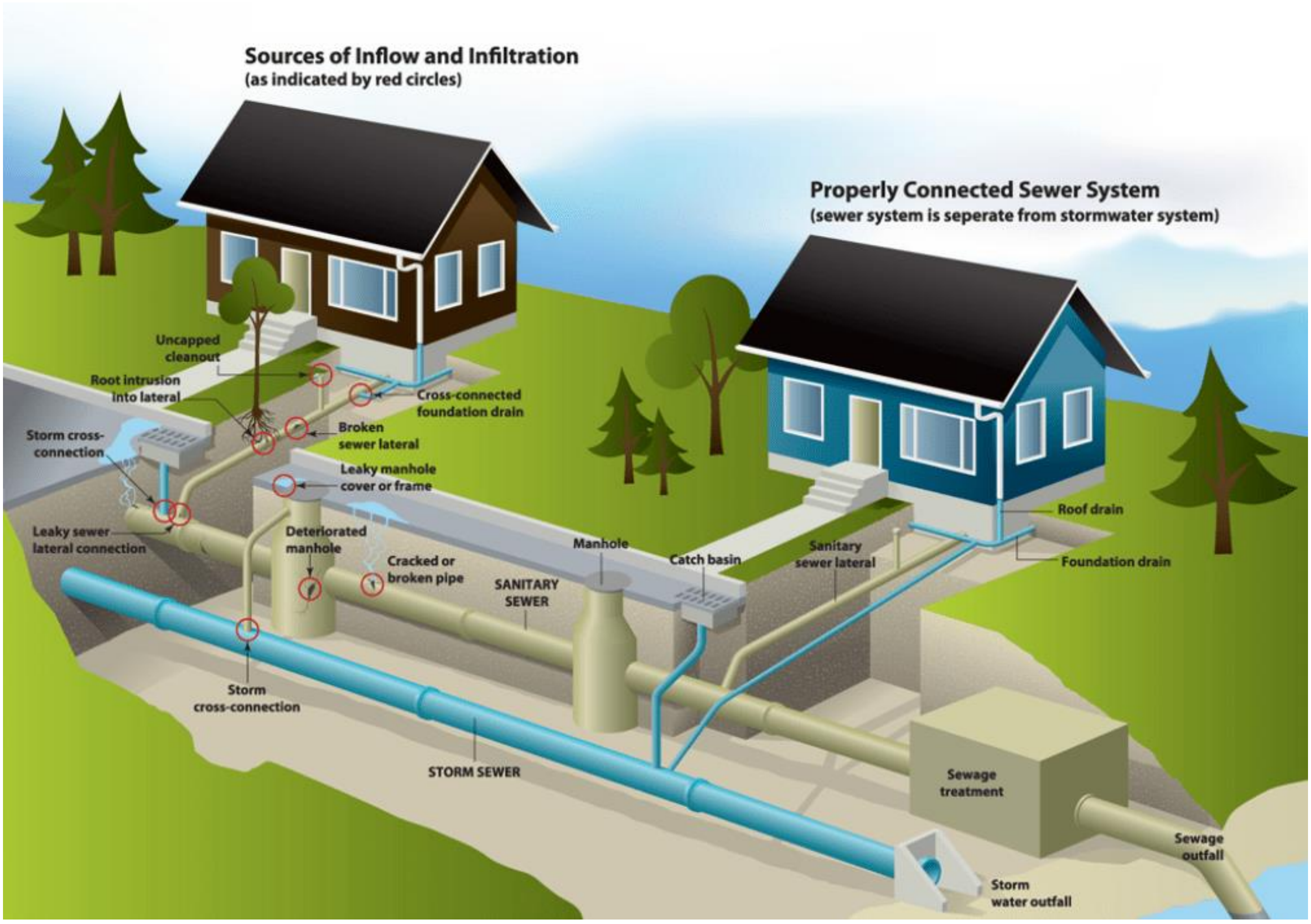


Figure 26: Sources of Inflow and Infiltration (USA Northwestern Water & Sewer District, 2019)[21]

20 http://www.dublincity.ie/sites/default/files/content/WaterWasteEnvironment/WasteWater/Drainage/GreaterDublinStrategicDrainageStudy/Documents/Vol%204%20-%20Chapter%202%20-%20Inflow%20and%20Infiltration.pdf

21 https://www.nwwsd.org/what-we-do/sewer/inflow-infiltration/sources-of-i-i/

11 Catchment Walk Assessment and Determining Significant Pressures

11.1 Introduction

This section discusses how to carry out the catchment walk assessment and identify the significant pressure(s). A catchment walk assessment is carried out after the desk study and catchment walk. This workflow (desk study, catchment walk, catchment walk assessment) will be an iterative process for many urban catchments, given the range of issues to consider. The purpose of the catchment walk assessment is to process, synthesize, interrogate and interpret the information and data from the desk study and catchment walk. Interpretation of data to determine the significant pressures takes place during the (final iterations of the) catchment walk assessment.

The basic workflow and outputs of the catchment walk assessment are presented in Figure 25.

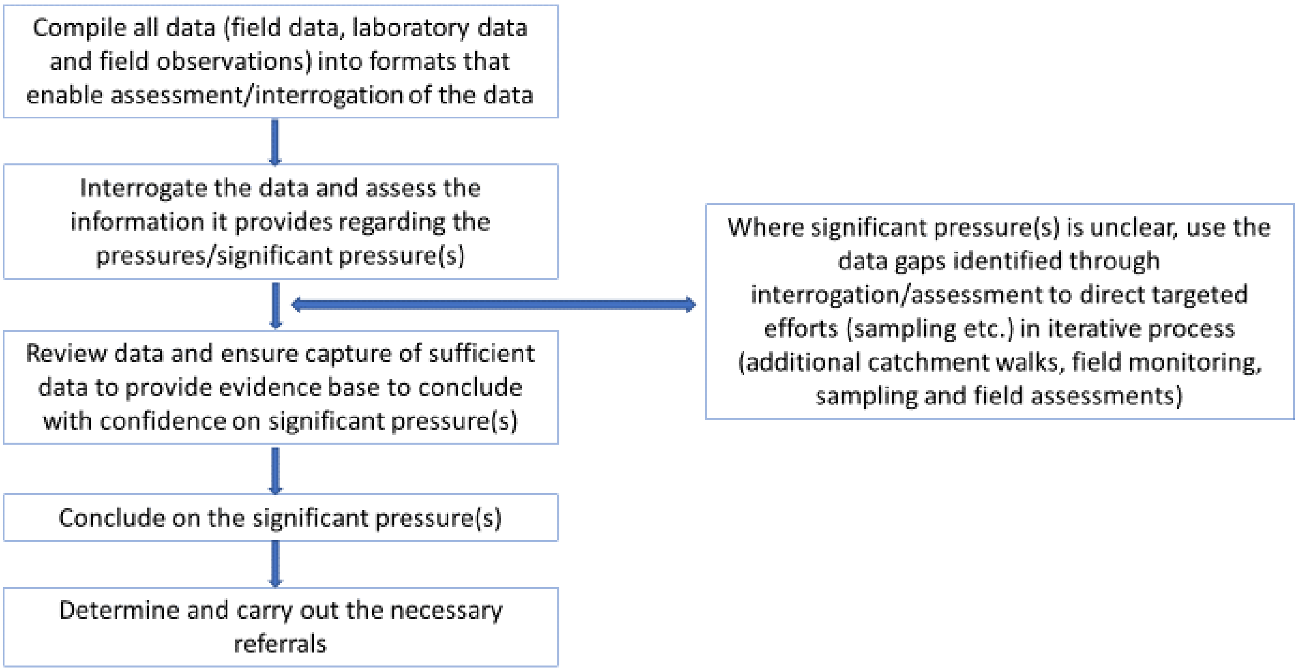


Figure 27 Workflow and Outputs of Catchment Walk Assessment

This section presents:

- Considerations when identifying significant pressures (Section 11.2);
- The indicators of significant pressures (Section 11.3);
- Assessing pressures and determining the significant pressure(s) using the assessor's primary tools (Section 11.4);
- Assessing pressures and determining the significant pressure(s) using the assessor's primary tools (Section 11.5); and,
- Referring significant pressures (Section 11.6).

This section references information presented in other volumes of the guidance as well as other sections of this volume of guidance. In general, this information will not be presented again unless (a) there exist differences between the existing guidance and the requirements for an urban catchment (for previous volumes of guidance), (b) the information is discussed in a new context for the purposes of its use in an urban setting or (c) the information is particularly significant. Table 17 shows the specific references to other volumes and sections of the LCA Guidance. Assessors should also refer to *LAWPRO Sediment Visual Assessment Methodology*, available from Autumn 2019.

Table 17: References to LCA Guidance in this Section

Section in this Guidance	Volume of LCA Guidance	Section of LCA Guidance
Subsections 11.2 through 11.4	Volume 1: Background, Process and Implementation	▪ Section 2.3 Overview of Significant Pressures Nationally ▪ Section 2.4 Indicator Parameters
	Volume 2: Pressure and Catchment Walks	▪ Table 2-1 BOD Values for Various Organic Effluents and Wastes ▪ Section 3, Catchment walks – Hydromorphological Pressures ▪ Section 3.3.1 Channnelisation ▪ Section 3.3.4 Invasive/alien plant species ▪ Section 3.3.5 Barriers ▪ Section 3.3.6 Bank protection ▪ Section 3.3.7 Flood Protection
	Volume 3: Observed Indicator Features and Catchment Walks	▪ Section 4 Biodiversity Indicators ▪ Section 3 Thermal Imaging
	Volume 4: Measured Indicator Parameters	▪ Section 2 Stream Flow ▪ Section 3 Water Quality Indicators – temperature and thermal imaging ▪ Section 4 Water Quality Indicators - Dissolved oxygen ▪ Section 5 Water Quality Indicator – pH ▪ Section 6 Water Quality Indicator – Specific Electrical Conductivity ▪ Section 7 Water Quality Indicators – Turbidity ▪ Section 8 Water Quality Indicator – Sediments ▪ Section 9 Water Quality Indicator – Nutrients, Section 10 Biological Indicators) ▪ Appendix B - Field Guide – Biological Indicators
Section 11.5	Volume 2: Pressures and Catchment Walks	▪ Section 3, Catchment walks – Hydromorphological Pressures: Table 3-2 Hydromorphological Pressures – Possible Mitigation Options ▪ Section 4, Catchment Walks – Urban Wastewater Pressures: Table 4-3 Urban Wastewater – Possible Mitigation Options ▪ Section 5 Catchment Walks – Diffuse and Small Point Urban Pressures: Table 5-1 Urban and Small Point Pressures – Possible Mitigation Measures

11.2 Considerations when Identifying Significant Pressures

As per Volume 1 of this guidance, a “significant pressure” is any pressure that on its own, or in combination with other pressures, that may lead to a failure to achieve one of the WFD objectives of “at least Good Status”. Significant pressures only arise in *At Risk* water bodies. Once a pressure is designated as ‘significant’, mitigation actions are needed to mitigate known impact(s).

11.2.1 Upstream Pressures

In some cases, there may be a significant pressure(s) upstream of the urban catchment. In such cases, the upstream significant pressure should be listed as a significant pressure impacting the urban waterbody.

11.2.2 Multiple Significant Pressures

Significant pressures are those which will prevent a waterbody from meeting its WFD objectives. In some urban waterbodies, there will be multiple significant pressures. All significant pressures must be addressed for a waterbody to achieve its WFD objectives.

11.3 Indicators of Significant Pressures

Each pressure is characterised by a set of indicators (Table 18). Where this set of indicators exist, it can be said with high confidence that this is a significant pressure.

The WFD status of rivers is underpinned by the ecological status based on biological indicators. Indeed, a river waterbody cannot be assigned a WFD status in the absence of biological data. Thus, assessors should first and foremost consider the information provided by the biological indictors for determining the significant pressures.

The indicators are divided into those determined using the primary tools, and those determined using the secondary tools, from the assessor's toolbox. Initially, the assessor should use the primary tools in the toolbox to determine the significant pressure(s), where possible. Secondary tools should be employed where there is uncertainty regarding the significant pressure(s) based on the primary tools.

11.4 Determining the Significant Pressure(s) using the Assessor's Primary Tools

The indicators for each pressure, based on the primary tools in the assessor's toolbox, are detailed in Table 18. The information contained in Table 18 will often be sufficient to determine the significant pressure(s). Table 19 presents the *subset of indicators* that will be most useful for discerning between any two suspected significant pressures (compared to Table 18 which details *all* indicators for each pressure).

Some pressures have similar indicators based on the assessor's primary tools. In such cases, further investigation and use of secondary tools will be required to determine the significant pressure(s). Pressures which have similar indicators are highlighted blue in all tables throughout this section, where relevant. Methods for assessing the pressures with similar indicators are provided in Section 11.5.

Table 18 Indicators Associated with each Pressure using the Primary Tools

Pressure	Water quality indicators*	Algal indicators	Structural indicators	Nutrient indicators**	Stream bed indicators	Water indicators	Ecosystem and habitat indicators
Domestic Misconnection	▪ SEC: Elevated (500 to 2,000 µS/cm) ▪ DO: low (<80% saturation) ▪ pH: 6.5 to 10 ▪ Temperature: elevated relative to stream	▪ Sewage fungus ▪ Eutrophication algae: *Cladophora spp.*, filamentous green algae	▪ Pipe (flowing at least sometimes during dry weather)	▪ Increase in P, TON and (possibly) ammonia concentration in dry weather ▪ Decrease in P, TON and (possibly) ammonia concentration relative to dry weather (due to dilution)	▪ Possible scouring under pipe	▪ Thermal imaging ▪ Ragging ▪ Floatables ▪ Smell of detergent ▪ Foul smell	▪ Nettles in vicinity of pipe indicate phosphorus inputs
Trade Misconnection	▪ SEC: Elevated (500 to 2,000 µS/cm) ▪ DO: low (<80% saturation) ▪ pH: 6.5 to 10 ▪ Temperature: elevated	▪ Altered algal community, highly dependent on the composition of the trade effluent	▪ Pipe (flowing at least sometimes during dry weather)		▪ Possible scouring under pipe	▪ Thermal imaging ▪ Water may be coloured (milky, other)	▪ Nettles in vicinity of pipe indicate phosphorus inputs
Urban Runoff	▪ No change in any parameter during dry weather monitoring (or negligible, due to other less significant pressures) ▪ During wet weather: ▪ SEC: Low generally < 200 µS/cm) ▪ DO: low (<80% saturation) ▪ pH: 6.5 to 8.5 ▪ Temperature: elevated relative	▪ Impoverished algal growth in areas otherwise suitable for algal growth. ▪ Eutrophication algae: *Cladophora spp.*, filamentous green algae	▪ Pipe (always dry during dry weather) or (significant) area hard standing close to waterway with <5m buffer	▪ Increase in P (from sediments), decease in TON (due to assimilation with no input) during dry weather ▪ Increase in P (from additions and sediment), no change in ammonia and variable TON during wet weather ▪ No decrease in load (remains the same or increases) due to additions of nutrient as well as water	▪ Sedimentation/ siltation (in areas where hydromorphological modification decreases flow velocity) ▪ Possible scouring under runoff pipes	▪ Thermal imaging ▪ No observable water indicators at time of dry weather sampling	

Pressure	Water quality indicators*	Algal indicators	Structural indicators	Nutrient indicators**	Stream bed indicators	Water indicators	Ecosystem and habitat indicators
	to stream but generally lower than trade and domestic misconnections						
Storm water overflows	▪ None observable at time of dry weather sampling or during wet weather due to dilution	▪ Algal evidence of pulse nutrient additions, i.e. eutrophication followed by senescence of eutrophic algae and development of epiphytic periphyton	▪ Pipe (always dry during dry weather)	▪ Increase in P (from sediments), decrease in TON (due to assimilation with no input) during dry weather. ▪ Increase in NH_4, P ▪ and TON during storm weather sampling	▪ Evidence of pulse additions of high nutrient concentrations – microbial tufts on substrate	▪ Thermal imaging ▪ No observable indicators at time of dry weather sampling	
Contaminated land	▪ SEC: Elevated, up to 10,000 µS/cm) where landfill leachate inputs ▪ DO: very low (<40% saturation) ▪ Temp: similar to/same as stream (due to dilution)			▪ Much elevated NH_4 (up to 490 mg N/L) ▪ P elevated but less so than for domestic misconnections or wet weather SWO sampling			
Hydromorphological pressures			▪ Artificial in-channel features, artificial features on the bank/riparian zone		▪ Sedimentation		▪ Invasive plant species

* Based on measurement in immediate vicinity of diffuse sources inputs and direct measurement of points source inputs, during dry weather unless otherwise stated.

** Change in stream nutrient data between upstream and downstream.

Table 19: Subset of Indicators that will be most Useful for Discerning between any Two Suspected Significant Pressures

Pressure	Trade Misconnection	Urban Runoff	Combined Sewer Overflows	Contaminated land	Hydromorphological pressures
Domestic Misconnection	Algae, Nutrient data	Artificial structures, Nutrient data	Algae, Artificial structures, Nutrient data,	Artificial structures, Nutrient data, Water quality	Artificial structures, Nutrient data
Trade Misconnection	-	Artificial structures, Nutrient data	Algae, Artificial structures, Nutrient data,	Artificial structures, Nutrient data, Water quality	Artificial structures, Nutrient data
B Urban Runoff	-	-	Algae, Artificial structures, Substrate and sediment	Nutrient data, Water quality	Artificial structures, Nutrient data
Combined Sewer Overflows	-	-	-	Artificial structures, Nutrient data, Water quality	Artificial structures, Nutrient data
Contaminated Land	-	-	-	-	Artificial structures, Nutrient data

*Blue highlight indicates overlap in the form of the primary indicators for two pressures.

The assessor may use Table 18 to help establish the pressures that exist but may still struggle to discern which of these are significant. In these cases, the assessor should carry out pairwise comparisons of the relevant pressures using the subsets of indicators detailed in Table 19. A "yes/no flow chart" approach of the indicators should be used to carry out the pairwise comparisons of the potentially significant pressures. Four examples of this methodology are presented in Figure 28 through Figure 30. Note, "nutrient data" refers to the concentration of nutrients present (mg/L) unless otherwise indicated throughout Figures 28 to 30.

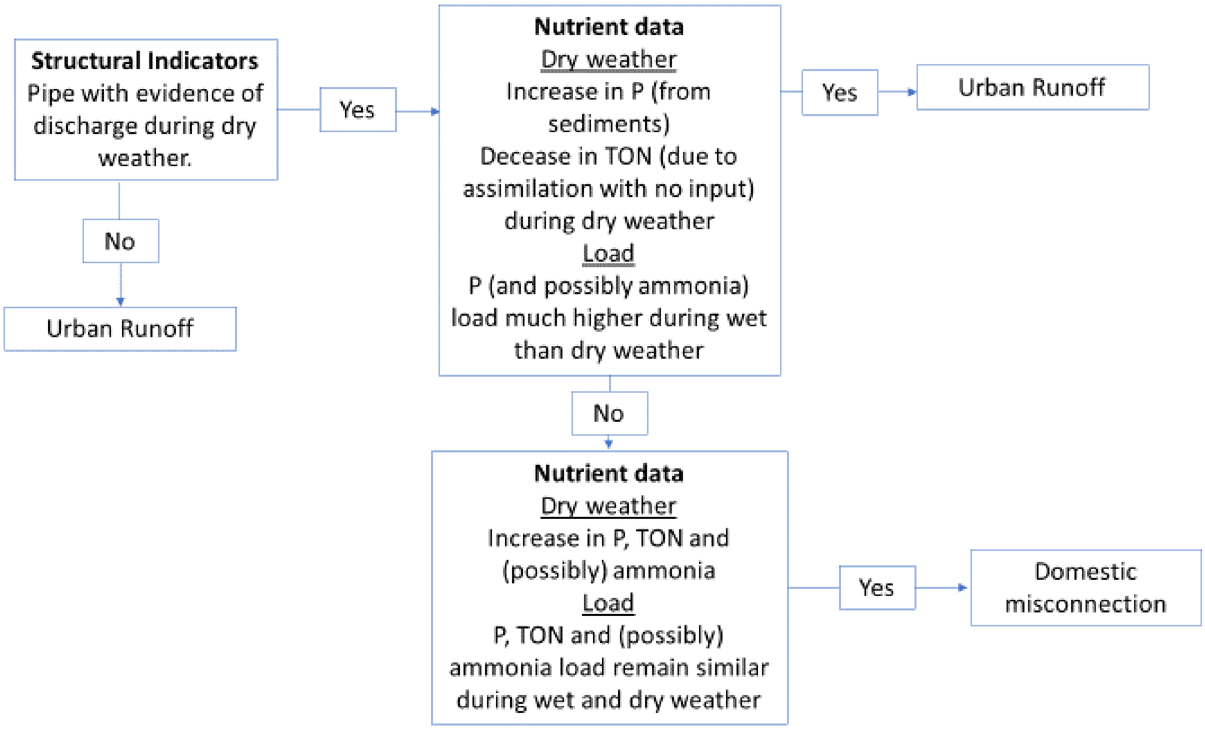
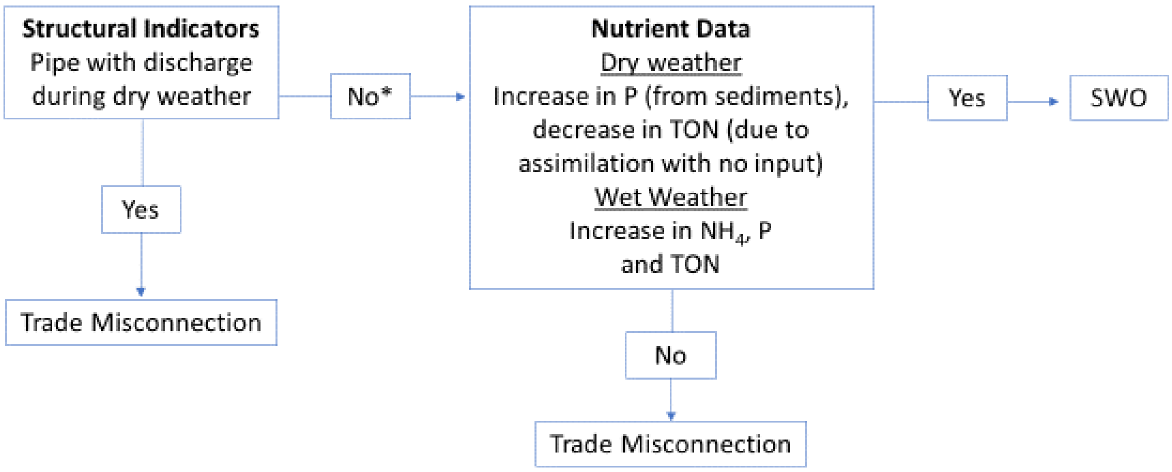


Figure 28 Determining the Significant Pressure where Urban Runoff and Domestic Misconnections Pressures Exist



*Pipe present but not discharging at time of survey

Figure 29 Determining the Significant Pressure where SWOs and Trade Misconnections Pressures Exist

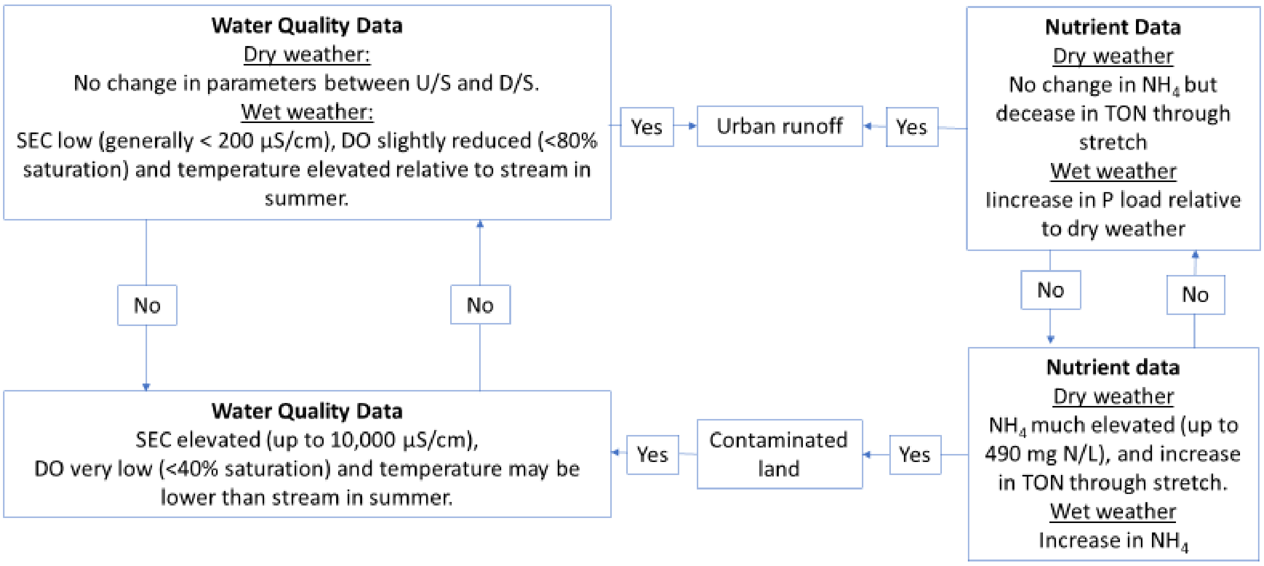


Figure 30 Determining the Significant Pressure where Urban Runoff and Contaminated Land Pressures Exist

11.5 Determining the Significant Pressure(s) using the Assessor's Secondary Tools

The section provides guidance on how to determine the significant pressure(s) when there is uncertainty or overlap in the indicators when using the primary tool (highlighted blue in tables). In such cases, the assessors should use secondary tools from the toolbox, primarily:

1. Laboratory analysis and calculations; and
2. Consultations with external specialists.

The WFD status of rivers is underpinned by the ecological status, based on biological parameters. Indeed, a river waterbody cannot be assigned a WFD status in the absence of biological data. Information provided by the biology should be the first focus for assessors. In some urban catchments, however, there may not be a gradient in biological conditions as the biology will be heavily impacted throughout the entire stretch. In such instances, it will be necessary to use other indicators. Laboratory water chemistry analysis will often be the most useful technique. There is a vast array of water chemistry parameters that may be analysed.

In freshwater environments, primary production is often limited by the availability of phosphate. Additions of phosphate can result in prolific algal growth and eutrophication. Therefore, the concentration of phosphate in the stream and of phosphate contributions from the various pressures, is of importance. If the concentration of phosphate in the water is below the ecological quality standard (EQS) at the upstream monitoring point and above the EQS at the downstream monitoring point, this increase in phosphate may lead to prolific growth of opportunistic green macroalgae and possible eutrophication. The Ecological Quality Standards (EQS) are regulatory estimations of threshold levels at which no adverse ecological effects are expected. Details of the EQS thresholds for surface freshwater bodies can be found in S.I. No. 272/2009 - European Communities Environmental Objectives (Surface Waters) Regulations 2009.

Where there are increases in phosphate, and a number of pressures that input phosphate, changes in biology downstream of the inputs should be used to determine the relative impact/inputs from the sources. These biological observations (visual, SSIS, stream bed biological indicators etc.) will help focus the assessors on the pressures with the biggest impact.

Where, from biology, the relative P inputs are unclear, laboratory analysis of water samples may be required. This analysis should quantify the biologically available phosphate, i.e. ortho-phosphate (ortho-P)/molybdate reactive phosphate (MRP)/soluble reactive phosphate (SRP). Water sampling should be coupled with discharge/stream flow monitoring to permit load calculations.

Table 20 lists the most frequently analysed water chemistry parameters for each pressure. Nutrient concentrations can be used to determine the impact of inputs using simple calculations (Sections X and Y). Nutrient concentrations will often be sufficient to determine the significant pressure, however, in some cases, there may still be uncertainty. In such cases, some level of fingerprinting may be required. Indicator parameters (or marker species) are chemical constituents or ingredients which, in theory, can be used to identify (or "fingerprint") different pressure types. The relatively commonly used compounds for fingerprinting are contained in Table 20. They include, for example, those associated with human digestion (caffeine and E. coli) to identify SWOs attached to combined systems and domestic misconnections. In some cases, persisting uncertainty may necessitate more specific (and generally, costlier) analyses. A comprehensive list of water chemistry parameters associated with each pressure is contained in Appendix 6.2.

Analysis of stream sediment may also be useful as contaminants associated with some pressures accumulate in the sediments. For example, some metals or PAHs from trade misconnections or contaminated land can accumulate in sediments. As this is relatively specialised, assessors should consult with an in-house expert to determine the most appropriate sediment analysis suite. Where it is still not possible determine the significant pressures, it may be necessary to seek advice from external specialists or use other novel techniques.

Table 20 presents the indicators, using the secondary tools, that can be used to identify each significant pressure. There is no additional benefit in providing textual discussion for every pairwise comparison in Table 20. However, the three pairs of pressures whose indicators overlap when using the primary tools, and thus secondary tools will generally need to be employed, are discussed below.

Table 20: Indicators for Differentiating Between Pairs of Pressures and Determining the Significant Pressures using the Secondary Tool in the Assessor's Toolbox - Water Chemistry Data

Pressure	Trade Misconnection	Urban Runoff	Storm Water Overflows	Contaminated land	Hydromorphological pressures**
Domestic Misconn-ections	Domestic misconnection: *E. coli*, caffeine, COD (300-1000 mg/L), BOD (150-500 mg/L), phosphate, ammonia, TON Trade misconnection: Anionic surfactants, TSS	Domestic misconnection: *E. coli*, caffeine, COD (300-1000 mg/L), BOD (150-500 mg/L), phosphate, ammonia, TON Urban runoff: TSS, hydrocarbons, heavy metals	Domestic misconnection: *E. coli*, caffeine, COD (300-1000 mg/L), BOD (150-500 mg/L), phosphate, ammonia, TON SWOs: TSS, hydrocarbons, heavy metals, TOC	Domestic misconnection: *E. coli*, caffeine, COD (300-1000 mg/L), BOD (150-500 mg/L), phosphate, TON Contaminated land: Heavy metals, hydrocarbons, sulphate, ammonia	Domestic misconnection: *E. coli*, caffeine, COD (300-1000 mg/L), BOD (150-500 mg/L), phosphate, ammonia, TON
Trade Misconn-ections	-	Trade misconnection: Anionic surfactants, BOD, ammonia, phosphate Urban runoff: TSS, hydrocarbons, heavy metals	SWOs: *E. coli*, caffeine, phosphate, ammonia, hydrocarbons, TSS, heavy metals, ammonia, TOC Trade misconnection: Anionic surfactants, TSS, BOD	Contaminated land: Heavy metals, hydrocarbons, sulphate, ammonia Trade misconnection: Anionic surfactants, TSS, BOD, phosphate, ammonia	Trade misconnection: Anionic surfactants, TSS, BOD, phosphate, ammonia
Urban Runoff	-	-	Urban runoff: TSS, hydrocarbons, heavy metals, phosphate SWOs: *E. coli*, caffeine, phosphate, ammonia, TOC	Urban runoff: TSS, phosphate Contaminated land: Heavy metals and hydrocarbons (much elevated), sulphate, ammonia	Urban runoff: TSS, hydrocarbons, heavy metals, phosphate
Overflows	-	-	-	SWOs: *E. coli*, caffeine, phosphate, ammonia	SWOs: *E. coli*, caffeine, phosphate, ammonia, BOD, COD
Contaminated Land	-	-	-	-	Contaminated land: Heavy metals and hydrocarbons (much elevated), sulphate, phosphate, ammonia

*Blue highlight indicates overlap in the form of the primary indicators for two pressures. ** Hydromorphological pressures have no water chemistry indicators, unless associated with sedimentation, in which case, phosphate during dry weather.

11.5.1 Distinguishing between Domestic Misconnection and Trade Misconnections

It can be difficult to distinguish domestic misconnections and trade misconnections as both present as pipes that are flowing (at least sometimes) during dry weather. Trade misconnections will not normally contain parameters associated with the human gut (i.e. *E. coli*). Thus, analysis for *E. coli* can be used to distinguish between domestic and trade misconnections. Trade misconnections may contain anionic surfactants, elevated total suspended solids (TSS) and biochemical oxygen demand (BOD) from cleaning and other processes. The presence of elevated BOD in the absence of *E.coli* may indicate a trade misconnection and vice versa. Complications may arise when there is elevated *E. coli* and some of the trade effluent parameters – this may indicate a misconnection of the foul and process water from an industry or trade.

11.5.2 Distinguishing between SWOs and Urban Runoff

It can be difficult to distinguish SWOs from point urban runoff as both pipes are expected only to flow in wet weather (and be dry during dry weather). Their indicator parameters may also overlap. As SWO discharges contain (diluted) untreated domestic wastewater, SWO discharges normally contain analytes associated with humans, including human digestion (*E. coli*, caffeine and ammonia) and domestic process water (i.e. from washing - phosphate and total organic carbon (TOC)). As SWOs will also contain a portion of urban runoff, the indicators associated with the domestic wastewater will prove most useful in distinguishing these two pressures. Thermal imaging may also prove useful in determining the location and extent of SWOs, and both point and diffuse urban runoff.

11.5.3 Distinguishing between Trade Misconnections and Contaminated Land

Indicators associated with trade misconnections and contaminated land may overlap. Where there are structural indicators associated with trade misconnections and also an area of contaminated land, water chemistry analysis may be useful. Useful water chemistry analysis includes heavy metals, hydrocarbons, sulphate, anionic surfactants, TSS, BOD, phosphate and ammonia. Flow measurements should be taken of the discharge(s) and stream upstream and downstream pressures. Load calculations (Section 11.7.1) should be used to determine the relative contribution of each pressure to the contaminant load in the stream.

11.6 Hydromorphological pressures as a Significant Pressure

All significant pressures must to be addressed, however, some pressures are more actionable than others. The most relevant of the pressures in this context is hydromorphology. As presented in Figure 2-1 of Guidance Volume 1 (shown as Figure 31), hydromorphological pressures are (after agriculture) the significant pressure in the largest number of river water bodies nationally; it is the significant pressure in 329 of the “*at risk”* river water bodies nationally (2015).

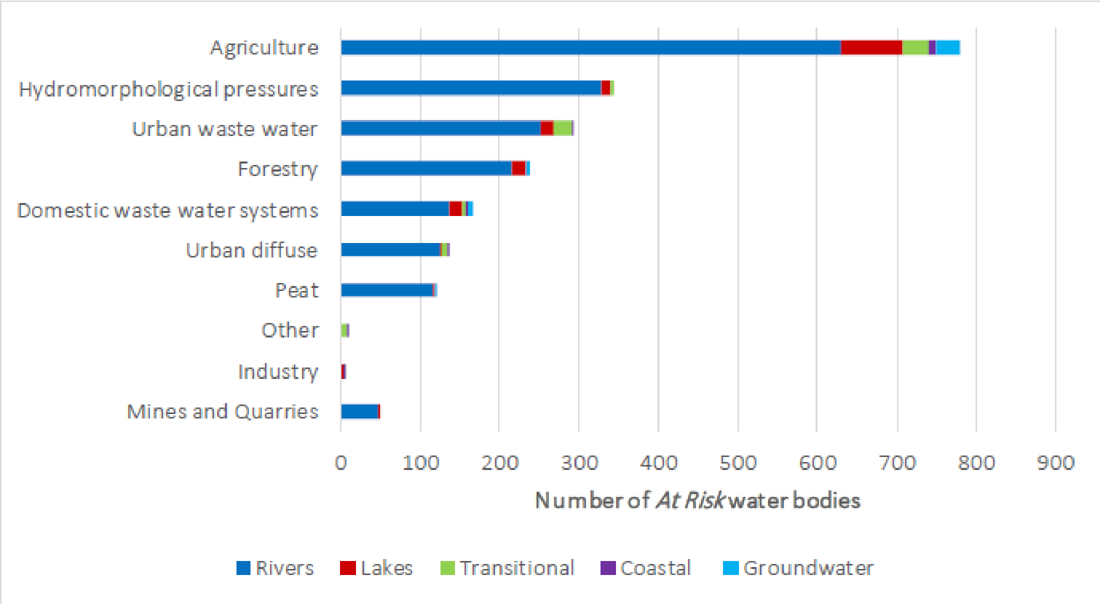


Figure 31: Overview of Significant Pressures in All Water Bodies Nationally in 2015 (Figure 2-1 LCA Guidance, Volume 1)

This data is based on both rural and urban settings. Hydromorphological pressures are likely to occur in higher densities in urban than in rural catchments. Thus, hydromorphological pressures will be one of the most frequently identified significant pressures in urban catchment walks. As discussed in Section 9 of this guidance, this is being addressed by the National Hydromorphology Working Group. Implementing measures for such pressures is a long and complex process relative to the other pressures. Where hydromorphological pressures are identified as significant, assessors should determine if a relationship exists between hydromorphological pressures and the other significant pressure(s). For example, there can exist a relationship between urban runoff and hydromorphological pressures. This may occur where a stream that has been artificially narrowed receives large volumes of urban runoff that contains a high suspended solids (sediment) load. The narrowing of the stream will result in an increase in water velocity as the same volume of water is forced through a narrower area. This velocity will be greater with the addition of rain. Where urban runoff enters the stream, through either diffuse or point sources, it is possible that much of the fine sediment load contributed by the runoff will be washed downstream due to the increased velocity. This fine sediment will eventually be dropped from the water column when there is a decrease in water velocity. In this case, the hydromorphological alteration results urban runoff not having an effect in the modified stretch of river. Though the volume of urban runoff entering the stream may be large and point to this being a significant pressure, the hydromorphological alteration may negate the impact of this pressure. Conversely, say the opposite situation occurs, i.e. a stream is widened in an urban catchment (for flood protection or by road culverts for example). This will result in a decrease in the water velocity. This may result in sedimentation from the water column of fine sediments transported from upstream in the catchment and may also result in immediate deposition of fine sediments from urban runoff; thus, exacerbating the effect of the urban runoff. See section *3.3.1 Sedimentation of the Stream Bed*, and refer to *LAWPRO Sediment Visual Assessment Methodology* (available from Autumn 2019) for discussion and methodology on sediment as an indicator.

Appendix 6.1: Reference Material

First Misconnection Notification

Dublin City Council
Comhairle Cathrach Bhaile Átha Cliath

Environment and Transportation Department
Drainage Division
Floor 4, Block 1
Civic Offices
Fishamble Street
Dublin 8
Tel: 353-1-2224838
Fax: 353-1-2222300
Website: www.dublincity.ie

Local Government (Water Pollution) Acts, 1977 & 1990

NAME: The Householder

ADDRESS:

RE: INSPECTION OF DRAINAGE SYSTEM.

Please be advised that during the abovementioned inspection, staff of the Drainage Division noted the following misconnections:

A <insert identified misconnection(s)> is/are connected to the surface water drains.
In order to avoid pollution of the local rivers and streams, you are requested to carry out the following work within **six weeks** of the date of this notice:

Please connect these appliances to your foul drains.

Should you have any queries please contact:

Ms. xxxx xxxxx Tel: xxx xxxxxxx

Yours Sincerely,

________________ **Date**__________________
X. xxxxxxx
Senior Engineer

Dún Laoghaire-Rathdown
County Council Comhairle Contae
Dhún Laoghaire-Ráth an Dúin

County Hall, Dún Laoghaire, Co. Dublin, Ireland
Halla an Chontae, Dún Laoghaire, Co. Átha Cliath, Éire
Tel: 01 205 4700 Fax: 01 280 6969 corp@dlrcoco.ie www.dlrcoco.ie

Water Services
Water Pollution Control Department
Ballyogan Services Depot
Ballyogan Road
Co. Dublin
Direct Tel:+353 1 2904800

<<Letter Date>>

First Non-Compliance Letter regarding misconnected household drainage

Dear <<Addressee>>,

During a recent drainage survey it was discovered that the foul drainage from your premises is wrongly connected with the Council's surface water system. The Drainage official <<Inspector>> who visited your property on the <<Misconnected Date>> brought this to your attention.

It is important that all foul water is diverted to the Irish Water's Wastewater Treatment Plants, to ensure that surface water systems are kept pollution free. A large variety of wildlife animals including fish and birds, are dependent on oxygen rich pollution free water.

It is the Council's policy to seek co-operation and give any advice necessary to the public where water pollution is of concern. For this reason I would be grateful if you can connect this drainage to the foul sewer and indicate when the above matter has been rectified. It is also the policy of the County Council to enforce the Water Pollution Act, through a prosecution where continued failure to cease pollution exists.

Thanking you for your co-operation in this important work to help keep our river ways clean. If you have further queries regarding the pollution work that the Council is undertaking, please contact either of the DLRCC representatives identified below, during Council Offices' opening hours, which are between 9am until 4.30pm, Mon to Fri.

Yours sincerely,

Xxxx Xxxxx - Authorized Water Pollution Officer
Emails xxxxxxx@dlrcoco.ie
Tel 01 2955124, Mobile – xxx xxxxxxx

Second Misconnection Notification

Dún Laoghaire-Rathdown
County Council Comhairle Contae
Dhún Laoghaire-Ráth an Dúin

County Hall, Dún Laoghaire, Co. Dublin, Ireland
Halla an Chontae, Dún Laoghaire, Co. Átha Cliath, Éire
Tel: 01 205 4700 Fax: 01 280 6969 corp@dlrcoco.ie www.dlrcoco.ie

Water Services
Water Pollution Control Department
Ballyogan Services Depot
Ballyogan Road
Co. Dublin
Direct Tel:+353 1 2904800

«strTitle» «strChristianName» «strSurname»
«AddressNo»«AddressNoSuffix» «strAddress1»
«strAddress2»
«strAddress3»

«FirstNCletterdate»

Second Non-Compliance Letter regarding misconnected household drainage

Dear «strTitle» «strSurname»,

Our records indicate that household drainage originating from the above address is still misconnected into DLRCC's public surface water drainage network. A "First Non-Compliance Letter" was issued to the above address on «FirstNCletterdate» to which no response has as yet been received by DLRCC. We would strongly urge at this time for a responsible representative of the above property, to arrange rectification of the misconnected drains as soon as possible, informing DLRCC personnel of their proposals via a formal response to this letter.

Under the Local Government (Water Pollution) Act, 1977, amended 1990, you are legally obliged to ensure that all household originating drains connect into the public foul sewer and not the surface water system. Section 3 of the Act indicates that it is a prosecutable offence to allow polluting matter to enter into waters.

As public citizens it is our civic duty to ensure that all public amenities including watercourses are preserved ecologically to the highest environmental standards, ensuring safer and more environmentally friendly habitats for humans and wildlife. Household drains pollute open watercourses indirectly via misconnections into the public surface water system.

If the misconnection has been rectified, you are obliged to contact the Council and arrange for a Water Pollution Officer (xxxxxxxx xxxx) to call out and confirm connection.

Failure to respond to this letter will be noted, and could lead to the issuing of a more legally prescribed Section 12 notice, under the Water Pollution Act.

We look forward to your co-operation in trying to keep our public waterways clean for current and future generations. If you have any queries regarding the above, please contact either of the representatives indicated below.

Yours sincerely,

Xxxxx Xxxxx - Authorised Water Pollution Officer
Emails xxxxx@dlrcoco.ie
Tel 01 2955124, Mobiles – xxx xxxxxx

Third Notification of Misconnection

Dún Laoghaire-Rathdown
County Council Comhairle Contae
Dhún Laoghaire-Ráth an Dúin

County Hall, Dún Laoghaire, Co. Dublin, Ireland
Halla an Chontae, Dún Laoghaire, Co. Átha Cliath, Éire
Tel: 01 205 4700 Fax: 01 280 6969 corp@dlrcoco.ie www.dlrcoco.ie

Water Services
Water Pollution Control Department
Ballyogan Services Depot
Ballyogan Road
Co. Dublin
Direct Tel:+353 1 2904800

<<LetterDate>>

Final Letter of non-Compliance regarding misconnected household drainage

Dear <<Addressee>>,

To date our records indicate that as yet we have not received a response indicating if the misconnected drainage at the above address has been rectified.

You will be aware from recent correspondence sent to your address (sent on <<First NC Letter>> and <<Second NC Letter>> respectively), and visits from Pollution Control personnel, that the Council is carrying out a drainage survey in your area to determine if pollution matter from domestic households is being discharged to the surface water drainage system. During this survey your property was found to have defective drainage.

The Council is endeavouring to seek your assistance in removing pollution from local streams and rivers.

For this reason the Council is again seeking your assistance in this matter. In the event that you refuse to remove or correct the defective drainage within 15 days of the date of this letter the Council will have no alternative but to issue a statutory notice **Under the Local Government (Water Pollution) Act.**

Section 16/7 of the Local Government (Water Pollution) Act:

> **A person shall not permit or cause the entry of any pollution matter, including sewage, to any drain or sewer provided solely for the reception or disposal of storm water.**

Section 3/1:

> A person shall not cause or permit any pollution matter to enter waters.

If you require any further clarification or information in relation to this letter please contact the undersigned.

Yours sincerely,

Xxxx Xxxxxx - Authorised Water Pollution Officer
Emails xxxxxxx@dlrcoco.ie
Tel 01 2955124, Mobiles – xxx xxxxxxx

Confirmation of Compliance

Dún Laoghaire-Rathdown
County Council Comhairle Contae
Dhún Laoghaire-Ráth an Dúin

County Hall, Dún Laoghaire, Co. Dublin, Ireland
Halla an Chontae, Dún Laoghaire, Co. Átha Cliath, Éire
Tel: 01 205 4700 Fax: 01 280 6969 corp@dlrcoco.ie www.dlrcoco.ie

Water Services
Gerry Cullen Pollution Officer
Ballyogan Operations Depot
Ballyogan Road,
Carrickmines,
Dublin 18.
Main No.01 2904800
Direct Tel:+353 1 2904851
07/11/18

Mr Cxxxx O' Bxxx
29 xxxx Way
Blackrock
Co Dublin

Re: Misconnected Drainage

Dear Mr O' Bxxx,
This is to confirm that the misconnection above discovered on the(03/02/18) was the subject of a follow up inspection on the (07/04/18) and was found to be corrected. Our records have been amended accordingly. Thank you for your assistance with this issue.

Yours sincerely,

____
Xxxx Xxxxxx
Water Pollution Officer
086 xxxxxx

Xxxx Xxxx/ - Authorized Water Pollution Officer.

Email- Xxxxxxxx@dlrcoco.ie ,

Mobile– G. Xxxx 086 xxxxxx.

Water pollution destroys life, so make a difference by helping to make our rivers and streams more pleasant habitable environments for all natural life forms

Appendix 6.2: Analysis Suites for further Laboratory Investigation

Pollutant Categories and Specific Pollutants	Recommended Analytical Suite	Leaking Sewers	Contaminated Land – Unlined Landfills	Treated Effluent	Urban Runoff – Catch basins	Manufacturing Sites	Sewage Discharge (Domestic Misconnections, SWOs)	Illegal Industrial Discharge (and Trade Misconnections)	Urban Runoff - Roads	Contaminated Land or Trade Misconnection - Petrol Stations	Contaminated Land- Gas Works	Trade Misconnection, Urban Runoff- Accidental Spills	Contaminated Land -Railway Yards
Metals	**I2, I3, I4**	**(Metals in reduced oxidation states tend to be mobile in groundwater)**											
Iron	I2, I3												
Arsenic	I4												
Aluminium	I2												
Lead	I4												
Mercury	I4												
Silver	I2												
Zinc	I2												
Copper	I2												
Chromium	I2												
Cadmium	I2												
Cyanide	I4												
Other metals	I4												
Standard cations and anions	**I2**												
Chloride	I2												
Sulphate + Sulphite	I2												
Bicarbonate (alkalinity)	I2												
Sodium	I2												
Calcium	I2												
Manganese	I2												
Magnesium	I2												
Potassium	I2												
Nutrients and other related parameter	**I2**												
Nitrate	I2												
Nitrite	I2												
Ammonium	I2												
Total Organic Nitrogen (TON)	I2												
Total Kjeldahl Nitrogen (TKN)	I2												
Orthophosphate	I2												
Total Phosphate (TP)	I2												
Pathogens and other microbiological indicators (MBIO)	**M1**												
Faecal coliform	M1												
Total coliforms	M1												
E. coli	M1												
Viruses (enterococci, streptococci, etc)	M1												
Disinfection by – products (trihalomethanes)	M1												
Field or probe- measured parameters (field)	**I1**												
pH	I1												
Specific conductivity (SC or EC)	I1												
eH (redox potential)	I1												
Temperature	I1												
Dissolved oxygen (DO)	I1												

Pollutant Categories and Specific Pollutants	**Recommended Analytical Suite**	**Leaking Sewers**	**Contaminated Land – Unlined Landfills**	**Treated Effluent**	**Urban Runoff – Catch basins**	**Manufacturing Sites**	**Sewage Discharge (Domestic Misconnections, SWOs)**	**Illegal Industrial Discharge (and Trade Misconnections)**	**Urban Runoff - Roads**	**Contaminated Land or Trade Misconnection - Petrol Stations**	**Contaminated Land- Gas Works**	**Trade Misconnection, Urban Runoff- Accidental Spills**	**Contaminated Land -Railway Yards**
Composite measures													
Total dissolved solids (TDS)													
Total organic carbon (TOC)													
Dissolved organic carbon (DOC)													
Chemical oxygen demand (COD)													
Biological oxygen demand (BOD)													
PCBs and dioxins (PCB/DIOX)	**O2**												
Tracers and markers													
Boron	I2												
Fluoride	I4												
Gadolinium													
Fluorescing dyes (Brighteners/ MBAS)													
Caffeine													
Pharmaceuticals and personal care products (PPCP)													
Carbamazepine													
Primidone													
Bezafigrate													
Clofibric acid													
Dicolfenac													
Propyphenazone													
Oxybenzone													
Polycyclic aromatic hydrocarbons (PAH)	**O7**	**(Typically, very limited mobility in the subsurface and groundwater)**											
Anthracene	O7												
Pyrene	O7												
Benzodifuran	O7												
Napthalene	O7												
Other PAHs	O7												
Note, analysis of the VOCs, CVOC and SVOC listed below will generally be more expensive than analysis of the above listed parameters.													
Volatile organic compounds (VOCs)	O6	**(Chlorinated solvents, volatile petroleum hydrocarbons)**											
Chlorinated VOCs (CVOCs)	O6												
Tetrachloroethene (PCE)	O6												
Trichloroethene (TCE)	O6												
cis -1,2- Dichloroethene (cis -1,2-DCE)	O6												
trans – 1,2 -Dichloroethene (trans -1,2 -DCE)	O6												
Vinyl Chloride	O6												
1,1,1,2 – Tetrachloroethane (1,1,1,2 -PCA)	O6												
1,1,2,2 – Tetrachloroethane (1,1,2,2 -PCA)	O6												
1,1,1 - Trichloroethane (1,1,1 -TCA)	O6												
1,1,2 – Trichloroethane (1,1,2,2 -TCA)	O6												
1,1 - Dichloroethane (1,1,2 -DCA)	O6												
1,1 – Dichloroethene (1,1 -DCE)	O6												

Pollutant Categories and Specific Pollutants	**Recommended Analytical Suite**	**Leaking Sewers**	**Contaminated Land – Unlined Landfills**	**Treated Effluent**	**Urban Runoff – Catch basins**	**Manufacturing Sites**	**Sewage Discharge (Domestic Misconnections, SWOs)**	**Illegal Industrial Discharge (and Trade Misconnections)**	**Urban Runoff - Roads**	**Contaminated Land or Trade Misconnection - Petrol Stations**	**Contaminated Land- Gas Works**	**Trade Misconnection, Urban Runoff-Accidental Spills**	**Contaminated Land -Railway Yards**
Petroleum Hydrocarbons (PHC)	O6												
Benzene	O6												
Toluene	O6												
Ethylbenzene	O6												
Xylenes	O6												
Total Petroleum Hydrocarbons (TPH)	O6												
MTBE	O6												
Other VOCs	O6												
Semi -volatile organic chemicals (SVOC)	**O5**	**(Generally, these chemicals are industry -specific and need to be identified on case – by – case basis)**											
Phenols	O5												
Creosote	O5												
Coal tars	O5												
Other SVOCs	O5												