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Galloway Fisheries Trust / Peatland Action annual water quality monitoring report 2024/2025 – Tannylaggie Flow & River Cree Catchment

For further information on this report please contact:

Name of GFT Project Manager – K Galt
Galloway Fisheries Trust
Fisheries House
Station Industrial Estate
Newton Stewart
DG8 6ND
Telephone: 01671 403011
E-mail: kenny@gallowayfisheriestrust.org

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Summary

Annual water quality monitoring report on behalf of Peatland Action – Tannylaggie Flow & River Cree Catchment

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Keywords

Peat; Peatland Restoration; EXO1 Sonde; Brown trout; Atlantic salmon; River Cree; High Cree; Water of Minnoch; Water Quality, pH; Acidification

Galloway Fisheries Trust (GFT) have been actively involved with encouraging and supporting peatland restoration in Southwest Scotland. GFT's main interest in this work is associated with the potential water quality benefits from peatland restoration, particularly to help address acidification impacts and restore degraded fish populations. Starting in November 2019, and continuing over subsequent years, Peatland Action (PA) has funded an annual water quality monitoring program within the Galloway region under the guidance of Emily Taylor, Galloway's local Peatland Action Peatland Officer.

Water quality monitoring during winter 2024/2025 was split into two related projects. The first was a continuation of the water quality monitoring in the Dargoal Burn as part of the Tannylaggie Flow peatland restoration. This aims to record the extent of the potential for improvements in water quality resulting from peatland restoration within an acidified watercourse. Tannylaggie Flow is an area of deep basin peat in the upper Bladnoch catchment (within the Polbae Burn sub-catchment). A large percentage of the Polbae Burn sub-catchment was historically drained and converted to commercial forestry, typically dominated by Sitka spruce, covering most of the Tannylaggie Flow peatland. The Dargoal Burn flows through Tannylaggie Flow and is the destination for many of the forestry drainage ditches within. The Dargoal Burn flows into the Polbae Burn, itself a major headwater tributary of the upper Bladnoch and forms part of the River Bladnoch SAC. As a result of historic acidic pollutants in the atmosphere, industrial scale drainage and dense conifer planting the Dargoal Burn has become one of the most acidified watercourses within Galloway and frequently experiences pH levels that are lethal to fish (regularly below pH 4 over winter as previously shown by GFT/PA water quality monitoring). The resulting degraded water quality extends downstream for a considerable distance impacting both the Polbae Burn and the River Bladnoch, and therefore the River Bladnoch SAC. As part of the latest plan for the management of Tannylaggie Forest areas of deep peat at Tannylaggie Flow and some surrounding areas have been highlighted for peatland restoration. As the felling of mature conifer plantations is staggered some areas are still covered in mature conifer's and will not be considered for restoration until the trees are removed. However, extensive areas have been felled and are ready for peatland restoration. Restoration commenced in a section of land adjacent to the Dargoal Burn in early 2023, with approximately 10% of the target area being restored as of winter 2023/2024. Restoration techniques included stump flipping, ground smoothing and ditch blocking. Water quality was recorded from the Dargoal Burn using EX01 Sondes which collect data at 15-minute intervals. Parameters recorded include pH, Dissolved Oxygen (DO), depth, conductivity and Fluorescent Dissolved Organic Matter

(fDOM), the latter two being a representative measure of peatland erosion. Water quality monitoring to date has picked up no obvious improvement within the Dargoal Burn. However, this is to be expected at this early stage due to the timescale since restoration took place, the area restored and due to no additional peatland being restored since recording the previous winter. Much of Tannylaggie Flow is still covered in commercial conifers. The latest update from Forestry and Land Scotland is that they plan to harvest most of the remaining trees during 2025. It is hoped peatland restoration can resume at scale thereafter.

The second part of the monitoring was a catchment wide review of water quality within the River Cree catchment. This included a review of the electrofishing data held by Galloway Fisheries Trust to identify where juvenile salmonid numbers were low or absent and a catchment scale water quality overview to record the extent of acidification within the river catchment and the contribution of degraded peatlands. Given the sensitivity of salmon and trout to low pH during sensitive periods of development the aim of the electrofishing review was to look at the current distribution and density of trout and salmon, to see if there were any areas where fish numbers showed signs of being impacted by poor water quality and to see if there were any changes in fish numbers over time that would indicate improving or declining conditions. The water quality overview focused primarily on pH and combined constant water quality monitoring (at 15 min intervals) from selected locations with catchment wide spot sampling (which involved collecting water samples from around the Cree catchment during low pH flushes and analysing the samples in the office). Again, EX01 Sondes were used to record water quality and the parameters recorded were pH, DO, depth, conductivity and fDOM.

The Cree catchment fish survey and water quality monitoring results match up well, with areas of poorest water quality (low pH) generally having the most depleted salmonid fish populations (with an almost complete absence of salmonids in some instances). In these areas pH levels can often be well below the threshold known to be damaging to salmonid egg development. In contrast many areas where pH appears to only occasionally reach levels damaging to salmonids, and only just creeps below the known threshold, show high densities of trout or salmon fry. The results showed the High Cree sub catchment of the River Cree to be heavily impacted by low water quality (low pH) with widespread damage to fish populations throughout much of the sub-catchment, although there were some variations between areas and some signs of recovery in headwater burns. The cause of the poor water quality (low pH) in the High Cree sub-catchment is degraded/afforested peatlands, with areas of degraded/afforested dystrophic blanket peat appearing to make the biggest contribution to the low pH levels recorded. This report has identified a section of land running from the middle reaches of the east bank of the High Cree to the middle reaches of the west bank of the Water of Minnoch as having the biggest contribution to water quality/low pH levels. It is advised that, wherever possible, peatland restoration should be undertaken on dystrophic blanket peat within this area. This will also address localised water quality issues within the Water of Minnoch (which is generally much less acidified due to only a small section of the identified area being within its catchment).

Main findings/recommendations

- There is no obvious recovery in water quality within the Dargoal Burn at the current stage of peatland restoration. This is not unexpected given the relatively modest amount of peatland restoration completed to date. As such long-term monitoring is required if potential benefits are to be recorded.

- The results from the peatland restoration monitoring, combined with the results from the Bladnoch water quality overview (from winter 2023/2024) provides data that can be fed into FLS Tannylaggie peatland restoration plans and GFT/Crichton Carbon Centre and SEPA should regularly meet with FLS to discuss the water quality monitoring results (currently achieved through a Tannylaggie peatland restoration group).

- Due to the timescale and level of data likely to recorded as part of the Tannylaggie Peatland Restoration project, and the time and resources required to fully analyse the data, a Masters or PhD project should be considered on completion of data collection to ensure the enough time can be given for the data can be properly analysed.

- The high flow pH readings from around the Cree catchment largely line up with the juvenile salmon and trout data recorded by Galloway Fisheries Trust. Unsurprisingly, the areas where low pH is recorded at levels that are likely to be damaging to salmonid egg development have very low levels or a complete absence of juvenile salmonids.

- As a result of less impacted water quality the Lower Cree, Water of Minnoch and Penkiln Burn appear to be the “backbone” of salmonid production within the Cree catchment. In contrast, acidification and the associated failure in salmonid egg development, has resulted in heavily depleted, or absent salmon and trout fry numbers from much of the main stem of the High Cree and many of its inflowing burns.

- The cause for the poor water quality (low pH) in the High Cree sub-catchment is degraded/afforested peatlands, with areas of degraded/afforested dystrophic blanket peat appearing to make the biggest contribution to the low pH levels recorded. This report has identified a section of land running from the middle reaches of the east bank of the High Cree to the middle reaches of the west bank of the Water of Minnoch as having the biggest contribution to water quality/low pH levels and it is advised that wherever possible peatland restoration should be undertaken on dystrophic blanket peat within this area. This will also address localised water quality issues within the Water of Minnoch (which is generally much less acidified).

- Much of the dystrophic blanket peat within the High Cree sub-catchment is surrounded by soils classed as peaty gleys within the NatureScot peat map. There are known to be areas of semi-confined peat within these peaty gleys which are also contributing towards degraded water quality that is impacting aquatic ecosystems (to a lesser extent than the blanket peat but still having a significant impact). More work is needed to locate the peatlands within these areas, identify their condition and assess their impact on water quality.

- There is a potential oxygen depletion within the waters flowing out of Loch Moan and more data is required to identify if this is the case.

- Water quality issues (low pH) were detected at the very top of the Palnure Burn (a burn flowing into the Cree estuary) and although data is limited it does appear to be impacting juvenile trout survival. In the case of the Palnure Burn the issues appear to be stemming from blanket peat and semi-confined peat on the boundary between the Palnure Burn headwaters and the Black Water of Dee catchment. The poor water quality stemming from this area appears to persist for a significant distance downstream but does not appear to be impacting salmon production (as salmon spawn further downstream) as much as trout production. Peatland restoration should be considered for this section of the Palnure catchment.

For further information on this project contact:
Name of Project Manager – K Galt
Telephone No. of Project Manager – 01671 403011

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1 INTRODUCTION

1.1 Acidification in Galloway and native fish species

The Galloway region of Southwest Scotland has been well documented in being subject to the effects of acidification. Atmospheric acid deposition from the burning of fossil fuels in areas of base-poor geology has resulted in soils exceeding their capacity to buffer against acid inputs, leading to artificially lowered pH within soils and waterbodies in these areas. Where large scale conifer plantations are present (in particular Sitka spruce) the impacts of acidification are often greater, with several authors finding a direct link between plantations and lowered pH (e.g. Harriman & Morrison, 1982) resulting from increased rates of wet and dry deposition of acidic pollutants. The Galloway region is one of the most afforested areas in the UK (Yang. A, 2020) with most plantations typically consisting of Sitka spruce (*Picea sitkensis*). Much of the planting was historically carried out in the "lower-value", base-poor upland areas that are more susceptible to acidification. Acidification resulted in widespread artificially lowered pH levels in many upland areas within the Galloway region, with many upland lochs being reported as fishless by the late 1980's (Maitland et al., 1987). In more recent times improvements in air quality resulting from reductions in the burning of fossil fuels has seen recovery form acidification in some areas, but others remain heavily impacted (Ferrier et al,. 2001; Helliwell et al., 2001).

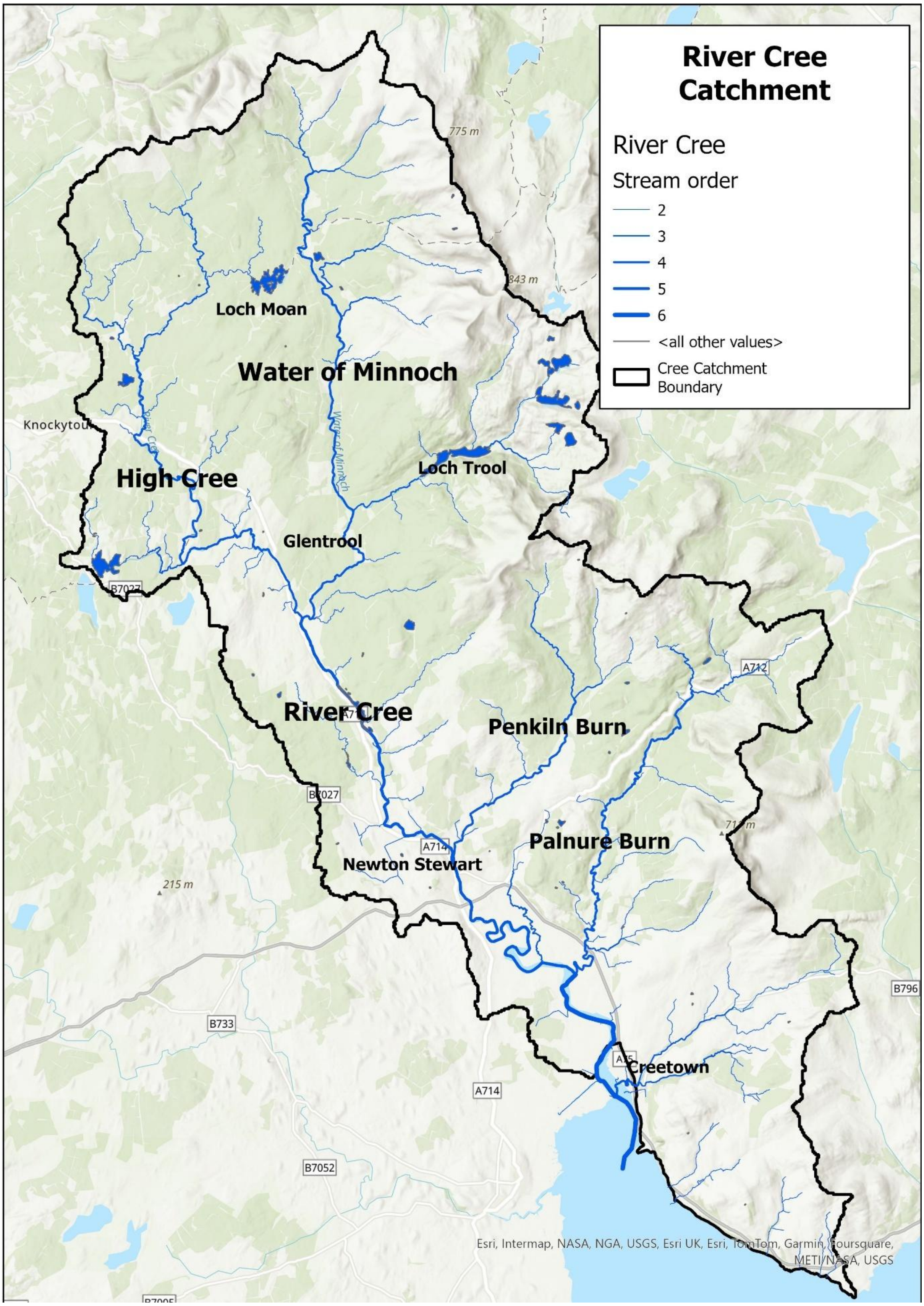
The two main native fish species within upland acidified areas in Galloway are typically Brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*). Low pH can have significant impacts to both trout and salmon at critical stages within their lifecycle. At the time of hatching pH below 4.5 can block the action of the hatching enzyme chorionase leading to mortalities in Atlantic salmon (Waiwood & Haya, 1983). One of the main impacts of lowered pH is the association with increased levels of labile Aluminium (Driscoll, 1985), which can be toxic to trout and salmon. Mobilised Aluminium in soils can form complexes with water molecules, enabling them to bind to fish gills at low pH levels resulting in both ionoregulatory and respiratory impacts (Gensemer & Playle, 1999), whilst the physiological transformations that Atlantic salmon smolts undergo to cope with changes in salinity levels makes them particularly sensitive to Aluminium levels and has been associated with mortalities (Kroglund et al., 2008). Due to the complex interactions between pH and the environment, and the subsequent impacts on fish Crisp (2000) summarises the general levels of concern of low pH for trout and salmon as being harmful at values below five and lethal at values below four. As a result of reduced pH levels within watercourses one of the major impacts within the Galloway region was the reduction, and in many cases complete loss, of Brown trout and Atlantic salmon populations. Maitland et al., in their 1987 publication *Acidification and Fish in Scottish Lochs* reported that in eleven lochs studied in the Galloway region that were known to once hold fish, six were now fishless whilst others showed impacts consistent with increased acidity. Since the late 1980's improvements in air quality, liming, forestry restructuring and changes in land use have resulted in some improvements to fish populations with recovery of trout populations in some areas. However, recovery appears slow in some areas where improvements have been made, whilst other areas remain at pH levels that severely impact fish populations (Ferrier et al., 2001, Battarbee et al., 2011, Brown et al., 1998, Shilland et al., 2009). Electrofishing surveys carried out by Galloway Fisheries Trust (GFT) still routinely record low or absent trout and salmon numbers from some areas that once held either or both.

Peatlands are common within many of the acidified areas within the Galloway region, with Dumfries and Galloway holding some of the largest areas of peat within Scotland (Chapman et al., 2009). The importance of Peatlands cannot be understated. Their role as a carbon store is gaining increasing exposure in the public eye given the importance being placed upon acting on climate change. However, they also carry out several other ecological services including water purification, improving climate resilience, flood control and act as unique habitats for flora and fauna (Harenda et al., 2018). Their occurrence on waterlogged, often nutrient poor "low value" uplands has resulted in the degradation of many peat bogs within Dumfries and Galloway, primarily from draining for agriculture and forestry (Peacock et al., 2018). Draining peatlands lowers the water table and exposes the peat to aerobic decomposition, resulting in the stored carbon being released into the atmosphere (Martin-Ortega et al., 2014). In addition to the release of carbon, drained peatlands can have impacts on waterbodies with increases in the quantity of Fine Particulate Organic Matter, metal concentrations, dissolved organic carbon (DOC), water turbidity and lowered pH (Martin-Ortega et al., 2014). In areas where conifer plantations have been planted on drained peat the resulting changes can be very damaging. Drainage and loss of vegetation, combined with the increased scavenging of atmospheric acidic pollutants associated with conifers, can result in the amplification of acidification issues within watercourses beyond that experienced within degraded peatlands or conifer plantations alone. Conifer plantations planted on peat can result in an additional lowering of pH, an increase in toxic metals, an increase in ammonia, an increase in DOC and an increase in turbidity (Harrison et al., 2014; Puhr et al., 2000). This has clearly been shown on the Cardoon Burn in the headwaters of the Water of Fleet where Peatland Action sponsored water quality monitoring carried out by Galloway Fisheries trust showed significantly different pH levels between afforested and restored sections of the same deep peat unit (Galt, 2022).

The identification of areas where acidification impacts fish populations, and working to address, mitigate or inform land management practice, forms a large part of the work carried out by GFT. Within this the identification of areas of degraded peatlands (and areas where conifers are planted on deep peat) that are causing significant water quality issues forms a key component. Where land use results in degraded peatlands that are impacting fish populations there may be the opportunity for multiparty work towards peatland restoration that fulfils several environmental and climatic goals such as carbon storage, repopulating unique peatland flora and fauna and improved water quality with resulting benefits for fish populations. For that purpose, GFT has been working in partnership with Peatland Action (PA) and the Crichton Carbon Centre (CCC) since 2019 to monitor water quality in sections of Galloway rivers that are impacted by acidification because of damaged/degraded peatlands. The project/partnership aims to monitor the impacts of peatland restoration on water quality (particularly in relation to salmonids), assess water quality across upland sections of rivers where degraded peat is present and to use the information gathered to raise awareness, prioritise areas where peatland restoration will result in the biggest improvements to water quality and to provide data to feed into land management plans. The collaboration between GFT, CCC and PA is funded by NatureScot (NS) with funding being secured in the autumn of 2024 to monitor water quality during winter 2024/25 and winter 2025/26 (winter being the period when rainfall is typically highest resulting in more frequent acid flushes into watercourses).

1.2 River Cree catchment summary

The River Cree is a medium sized river located in Western Galloway. It is over 50 km long, has over 390 km of channel length and has a catchment of roughly 500 km^2. The upper reaches of the river consist of two major tributaries, the High Cree and the Water of Minnoch, which converge to form the River Cree just South the village of Glentrool. Both tributaries originate in South Ayrshire, the High Cree forming in the Craigenreoch and Polmaddie Hills above Loch Moan and the Minnoch forming in the Eldrick and Craiganheather Hills. The Cree flows into the Solway Firth through a large estuary South of the town of Newton Stewart. From its source the river runs roughly South, Southeast. Like it's neighbouring rivers the Bladnoch and the Water of Fleet, the Cree has a relatively uncrowded catchment with a low human population density. Newton Stewart and its neighbour Minnigaff are the only large settlements within the catchment, both being located either side of the river just above the tidal influence. The population of Newton Stewart is just over 4,000.



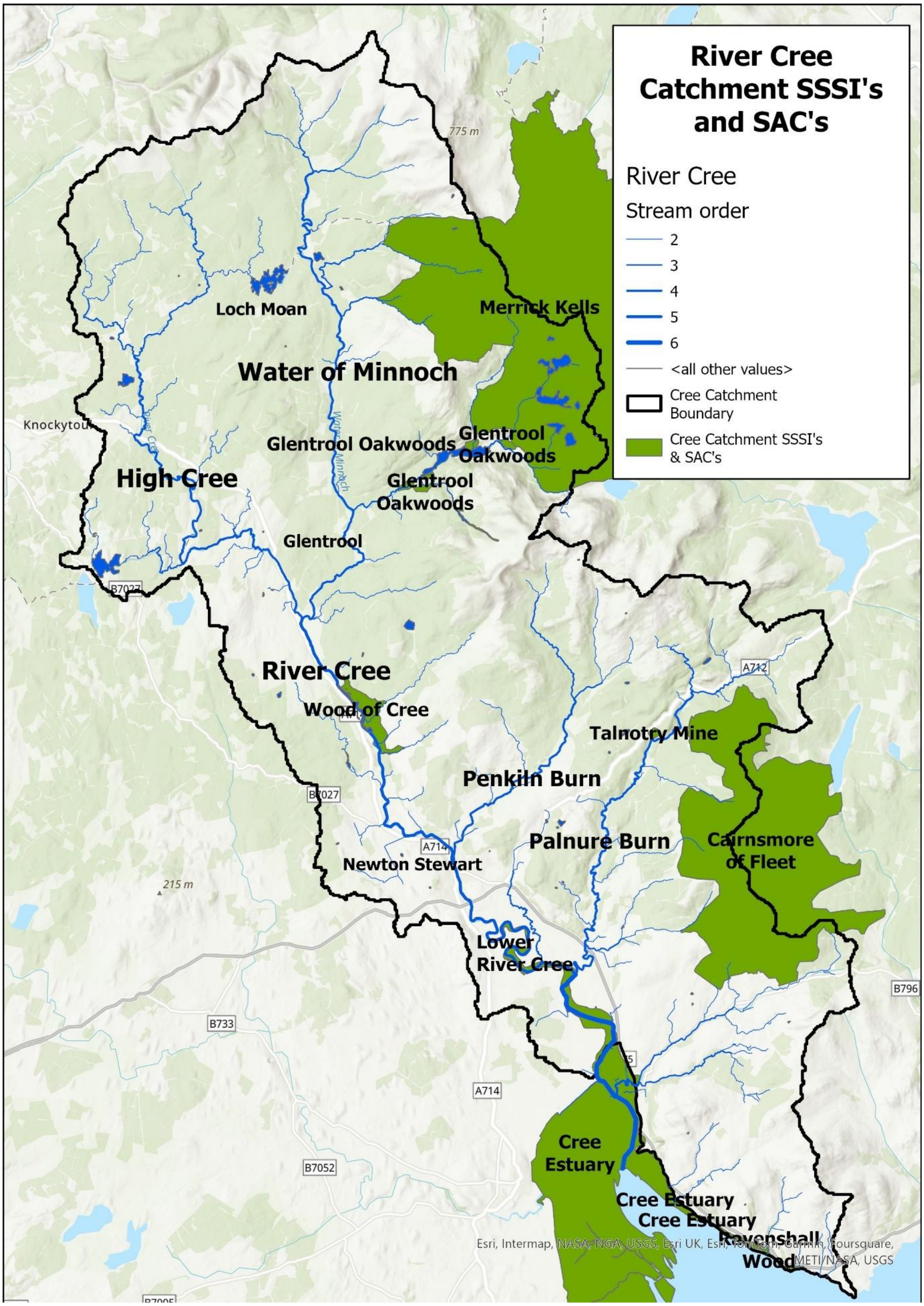
Map 1: Catchment map for the River Cree

Picture 1 – the lower Water of Minnoch near Glentrool

Picture 2 – the High Cree downstream from Loch Moan with water quality monitoring sonde support frame in the foreground

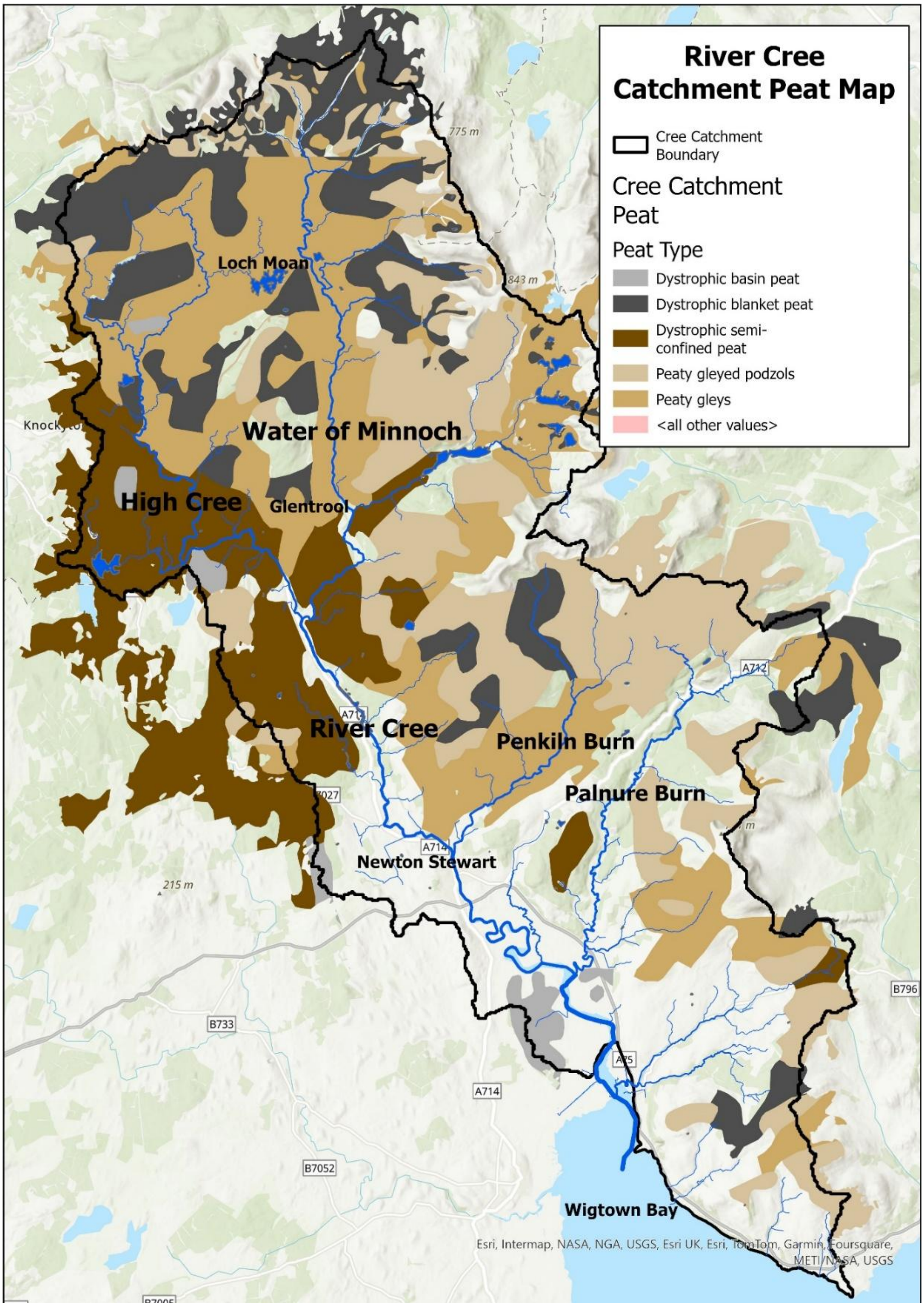
Picture 3 – the River Cree at its tidal limit at Newton Stewart

The river catchment contains several important areas classed as Sites of Special Scientific Interest (SSSI) or as Special Areas of Conservation (SAC). The Merrick Kells SSSI and SAC is an example upland habitat in SW Scotland. It is noted for its water body, bog, heath, alpine grassland and sub alpine grassland habitats and for its geology. The Cairnsmore of Fleet SSSI is another example of upland habitats and was chosen for similar reasons. Both the Wood of Cree and Glentrool Woodlands are noted as examples of ancient native woodland. The Talnotry mine which lies beside the Penkiln Burn is noted for its important geology. The whole estuary of the River Cree, which extends for over 20km due to the low gradient of the land, has protected status as a SSSI. It is classed as important esturine habitat due to its mud flat and salt marsh habitats (amongst other qualifying features). The Cree catchment SSSI and SAC are shown on Map 2.



Map 2: Catchment map for the River Cree showing the location of SSSI's and SAC's

Like many of the rivers in Southwest Scotland, much of the upper Cree catchments consist of nutrient poor moorland and heathland with significant areas of deep and shallow peat present. Map 3 shows the peat map for the Cree catchment.



Map 3: Catchment map for the River Cree showing peat distribution and type, map provided by the Crichton Carbon Centre

Whilst the exact locations, areas and depths of all peat within the Cree catchment have not been accurately recorded, Map 3 clearly shows there are significant areas of blanket and basin peat (which typically describe deep peat) and semi-confined peat (which typically contains a significant proportion of deep peat). Analysis of the National Soil Map of Scotland[1] shows that peatlands make up a significant proportion of the soils in the catchment (Table 1).

Table 1: Peatland soils in the Cree catchment[1]

Soil Type	*Area (Ha)*	*% of Catchment*
Dystrophic basin peat	*737.6*	*1.4*
Dystrophic blanket peat	*4125.2*	*7.8*
Dystrophic blanket peat with peaty gleys	*2272.9*	*4.3*
Dystrophic semi-confined peat with brown earths	*2146.2*	*4.0*
Dystrophic semi-confined peat with peaty gleyed podzols with peaty gleys	*390.8*	*0.7*
Dystrophic semi-confined peat with peaty rankers	*3251.4*	*6.1*
Peaty gleys with dystrophic blanket peat	*1019.6*	*1.9*
Peaty gleys with dystrophic semi-confined peat	*2940.7*	*5.5*
Peaty gleys with dystrophic semi-confined peat with brown earths with peaty gleyed podzols	*6087.8*	*11.5*
Peaty gleys with peaty gleyed podzols with dystrophic blanket peat	*2280.9*	*4.3*
Total	*25253.3*	*47.5*

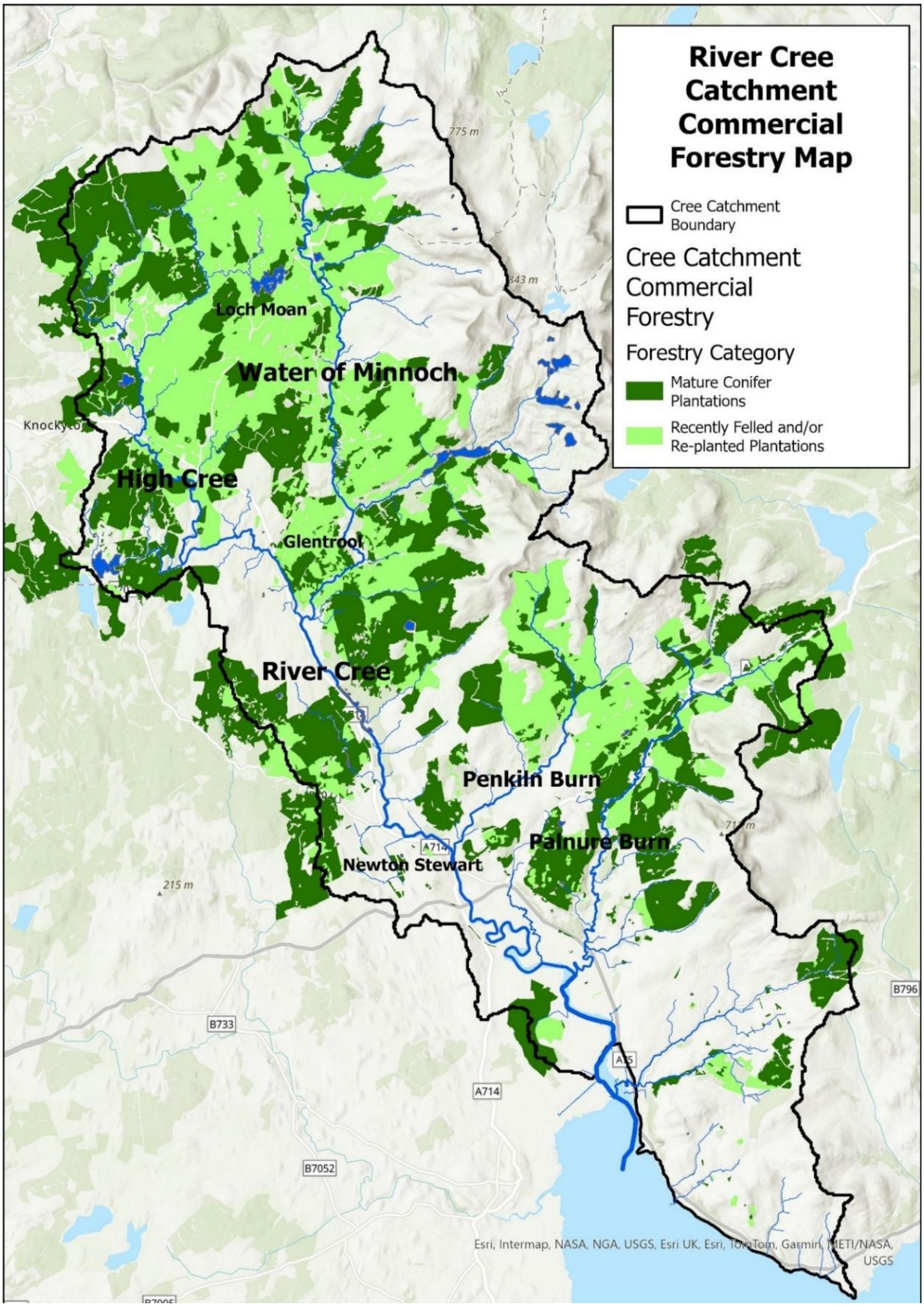
It is also interesting to note that Ordnance Survey maps highlight several areas within the Cree catchment that are named as Moss or Flow, old names for waterlogged peatlands. These include Moss of Cree, Shinvally Moss, Chlachrom Moss, Blackquarter Moss, Drumatier Moss, Fergie's Moss, Calnavie Moss, Mulmein Moss, Minniwick Moss, Knocknamoon Moss, Kenmure Moss, Kenmuir Flow, Spirns Moss and Bog of the Gairy. Most of these named mosses and flows are in the lower and middle reaches of the catchment and were most likely named due to their proximity to historic settlements, with areas of deep peat in the upper catchments generally being un-named.

Unlike its neighbouring catchment, the River Bladnoch, the Cree catchment has no protected peatlands, despite both catchments containing large areas of deep peat. This, in part, may be down to the Cree catchment having a slightly lower proportion of deep peat, but may also reflect the extent to which the peatlands have been altered/damaged (although this is also the case for much of the Bladnoch, but possibly to a lesser degree in protected areas). However, the Cree does have the Moss of Cree peatland restoration project, which is located within the lower, tidal catchment. Restored in the late 2010's it is one of the few examples of peatland restoration within the catchment. There has also been some restoration undertaken by Forestry and Land Scotland within the upper Water of Minnoch catchment. Details of this are scarce but aerial photography would suggest that extensive ditch blocking has taken place on Eldrick hill between the Pilnyark Burn and the very top of the Water of Minnoch. Despite the large section of peatland restoration both sub-catchments still have commercial forestry covering a significant percentage of their catchments. As such, it is difficult to say if the restoration has resulted in improved water quality, but it is likely that it will have had some impact.

Due to the low cost and low productivity of the land, a large proportion of the uplands within the Cree catchment were historically bought up and converted to commercial forestry (typically between the late 1940's and the 1970's), with this land use continuing to the present day. Map

[1] Soil Survey of Scotland Staff (1981). Soil maps of Scotland at a scale of 1:250 000. Macaulay Institute for Soil Research, Aberdeen. DOI: 10.5281/zenodo.4646891'

4 shows the extent of the commercial forestry (majority Sitka spruce) within the Cree catchment, with many areas of deep peat being drained and afforested. Where deep peat was historically prepared for commercial forestry extensive, deep drainage networks were often required to drain the land for planting, resulting in considerable damage to the peatland. Whilst little information is available regarding the nature and extent of commercial forestry drainage of deep peat within the Cree catchment, it is likely that a significant proportion of afforested peatlands have been drained to this extent.



Map 4: Catchment map for the River Cree showing commercial forestry distribution

1.3 SEPA water hub Cree catchment water quality data

Given the known water quality issues within the Cree and their impacts on fish populations some information on current River Cree water quality and ecological status is available through the Scottish Environment Protection Agency (SEPA) water hub (https://www.sepa.org.uk/data-visualisation/water-classification-hub/), which summarises their own monitoring data. The hub splits the Cree catchment into several sub-catchments. All parameters are scored on a “High” (Blue), “Good” (Green), “Moderate” (Yellow), “Poor” (Amber) and “Bad” (Red) scoring system. Screenshots from the SEPA hub for Overall status, Overall ecology, Water quality, pH, Dissolved oxygen, Fish ecology, Macroinvertebrates (acid) and Macroinvertebrates (RICT/WHTP) are shown below. These parameters have been selected from the large number of parameters available due their link (either direct or indirect) to water quality (specifically pH) and its potential impacts on fish and invertebrates.

Figure 1: SEPA Condition Classification Scores

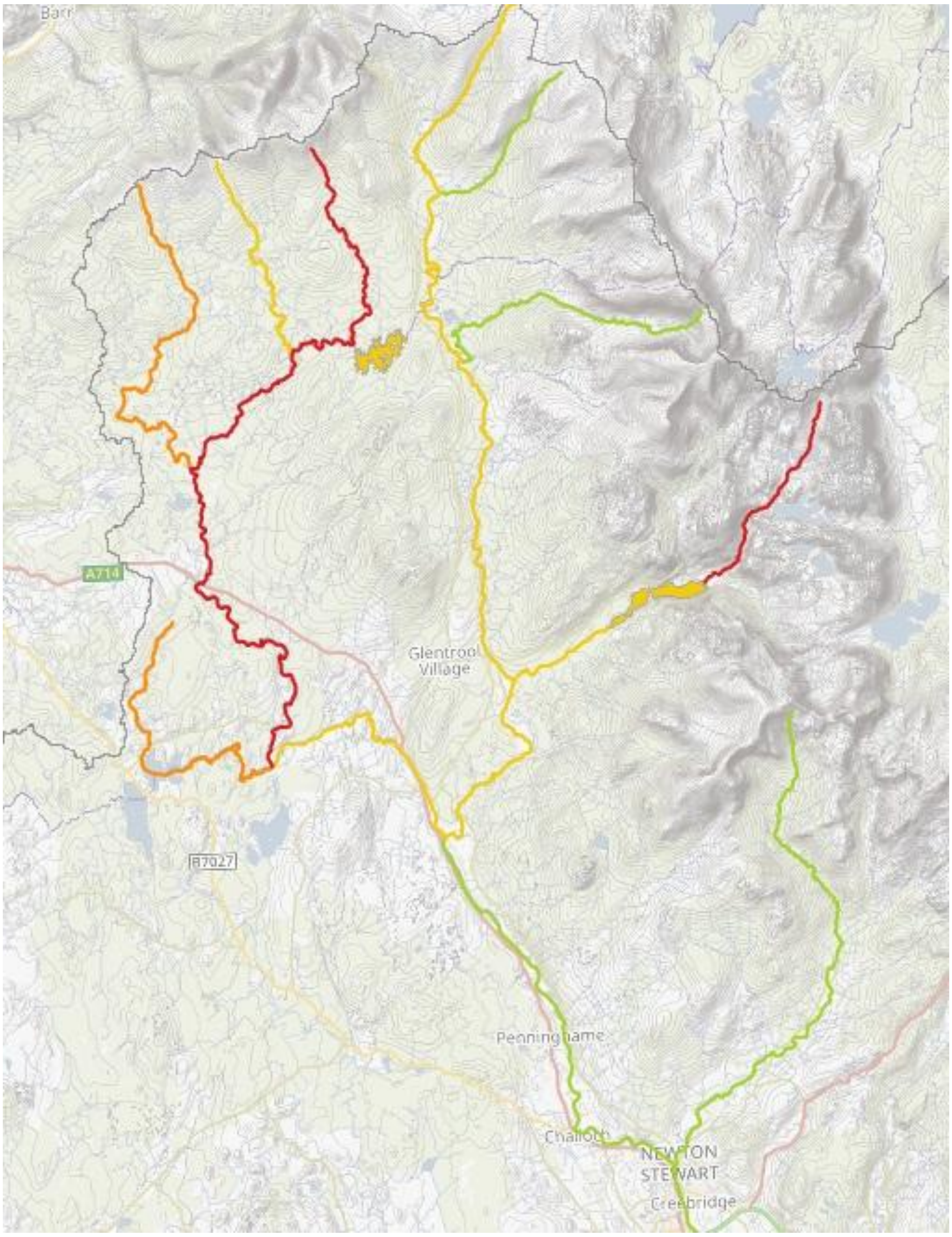


Figure 2: SEPA water hub River Cree classification: Overall Status

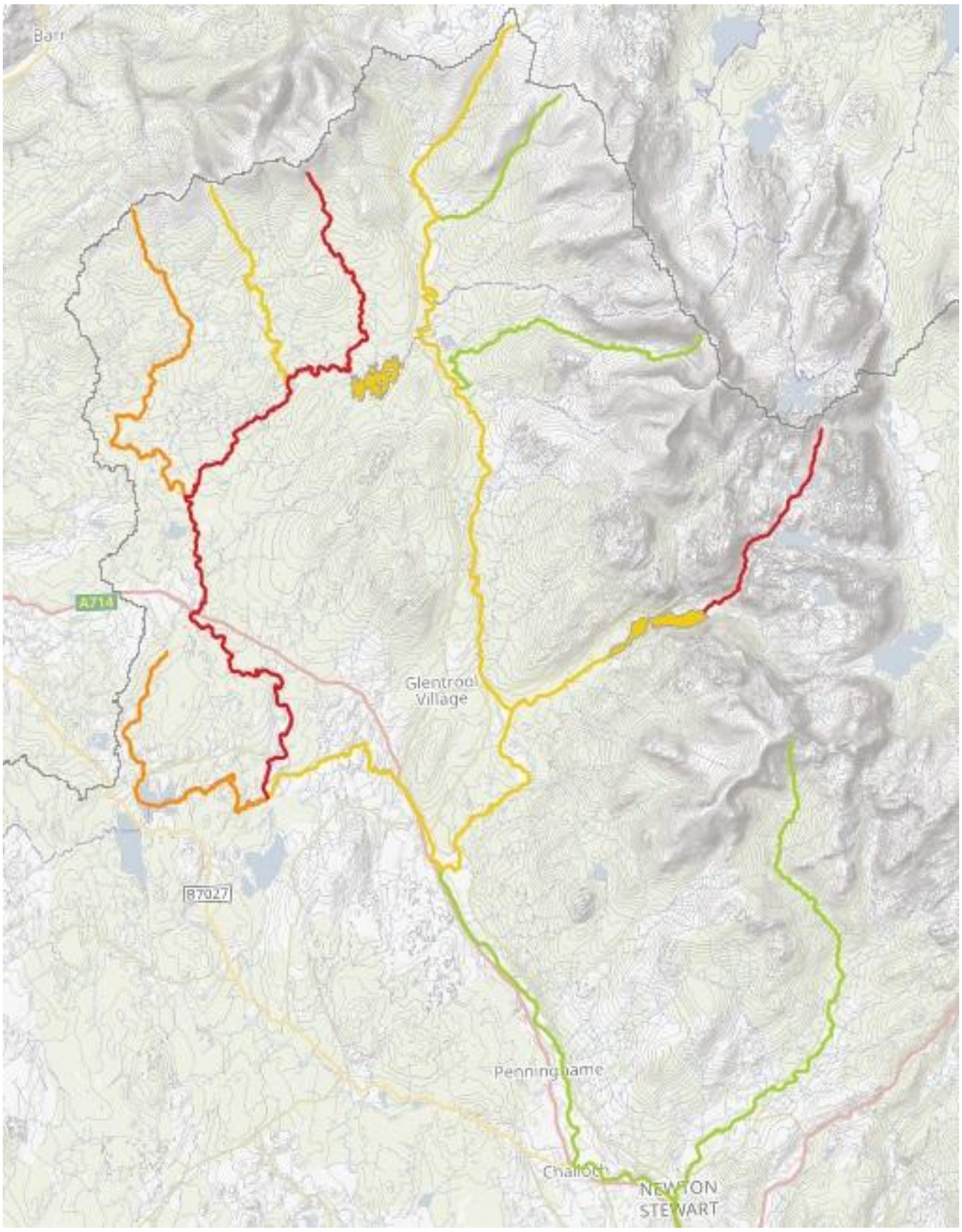


Figure 3: SEPA water hub River Cree classification: Overall Ecology

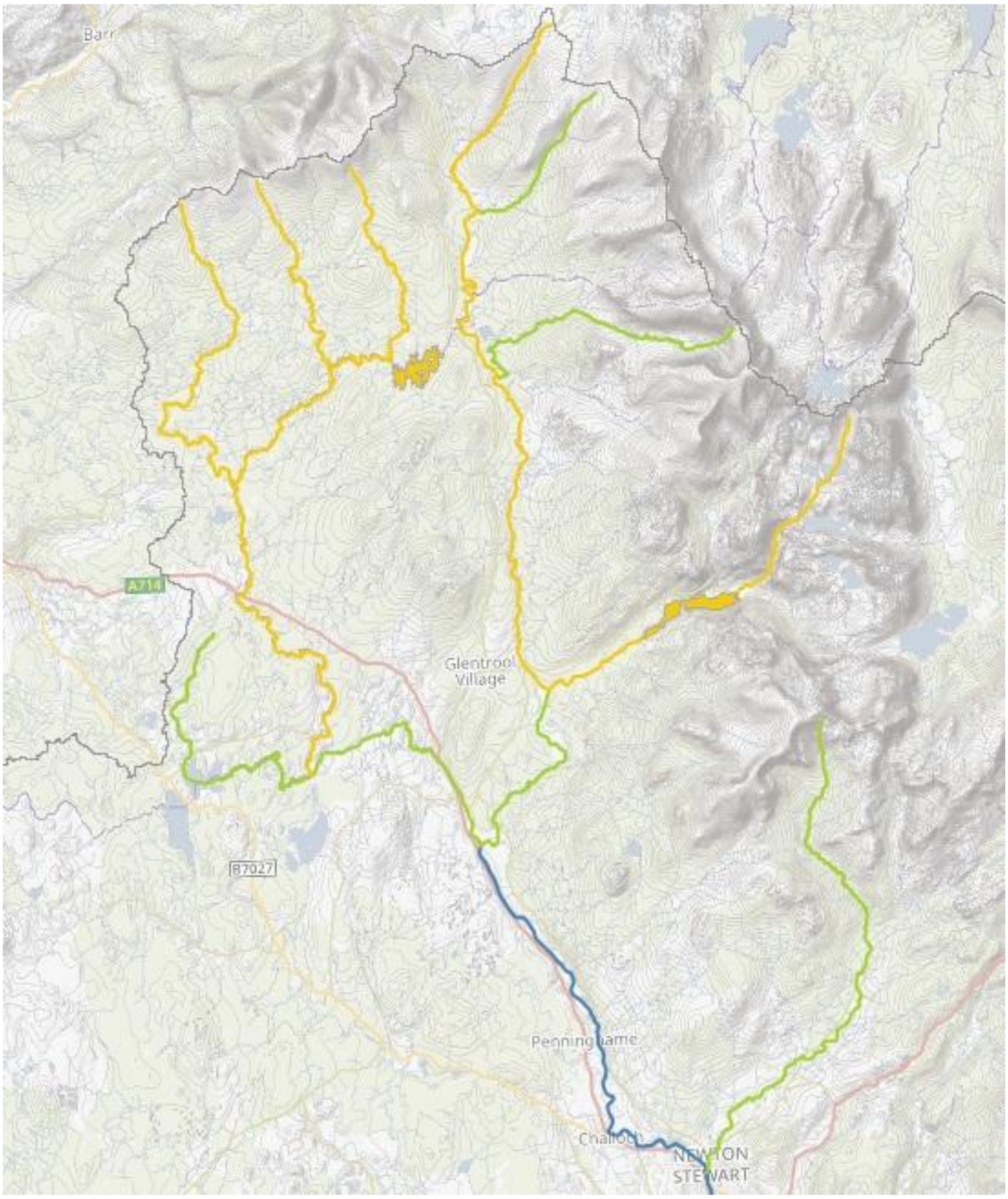


Figure 4: SEPA water hub River Cree classification: Water Quality

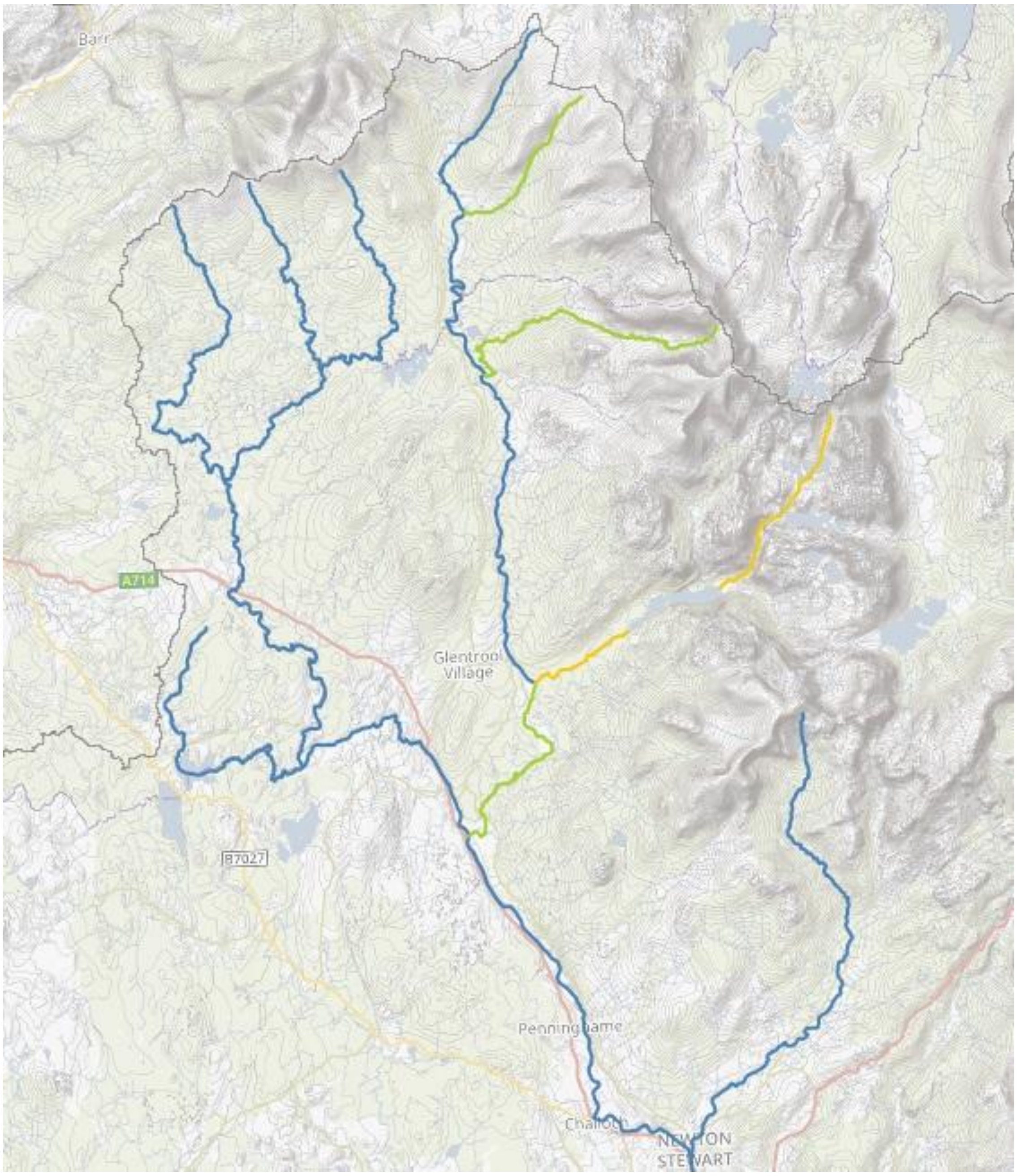


Figure 5: SEPA water hub River Cree classification: pH

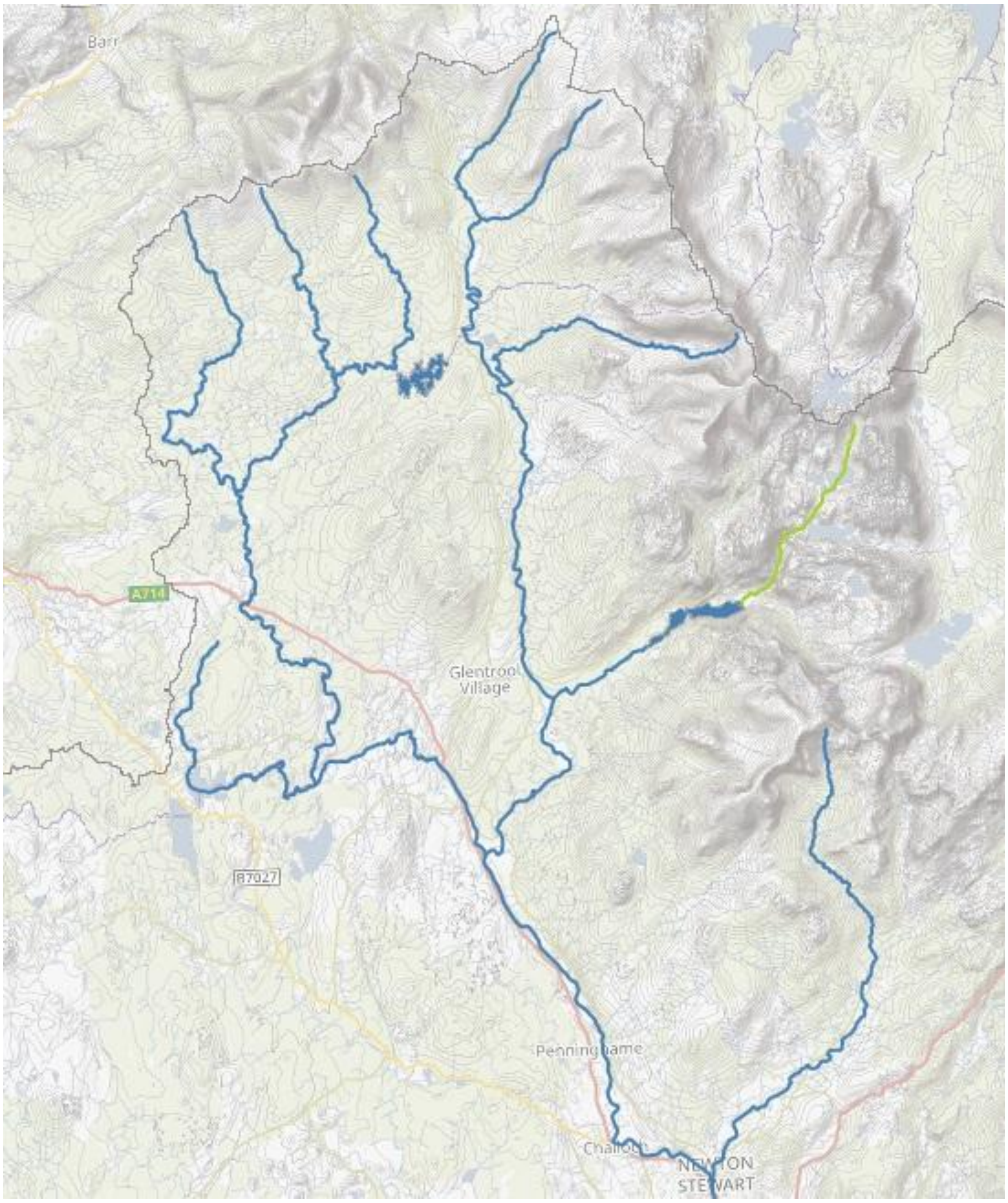


Figure 6: SEPA water hub River Cree classification: Dissolved Oxygen

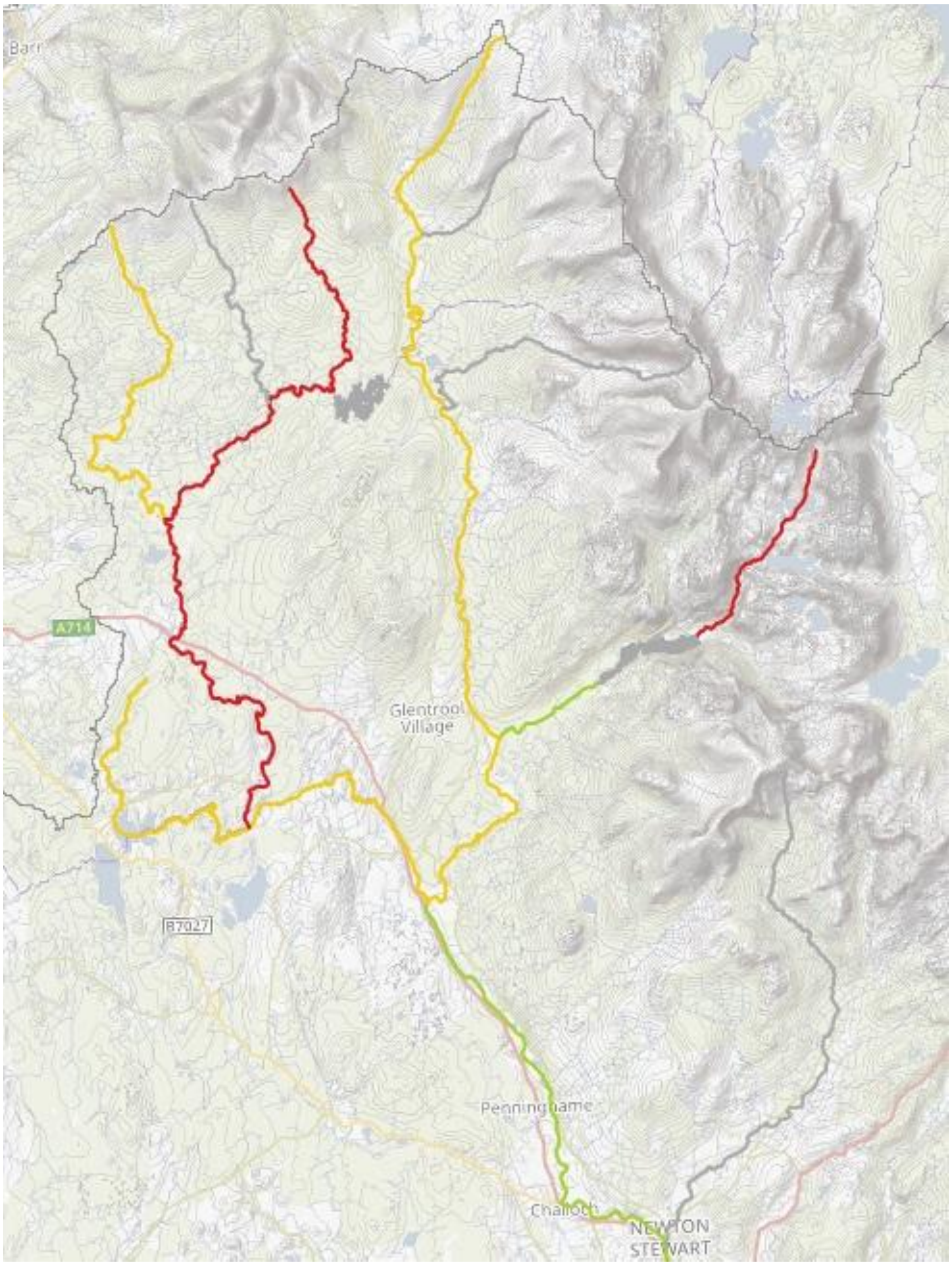


Figure 7: SEPA water hub River Cree classification: Fish Ecology

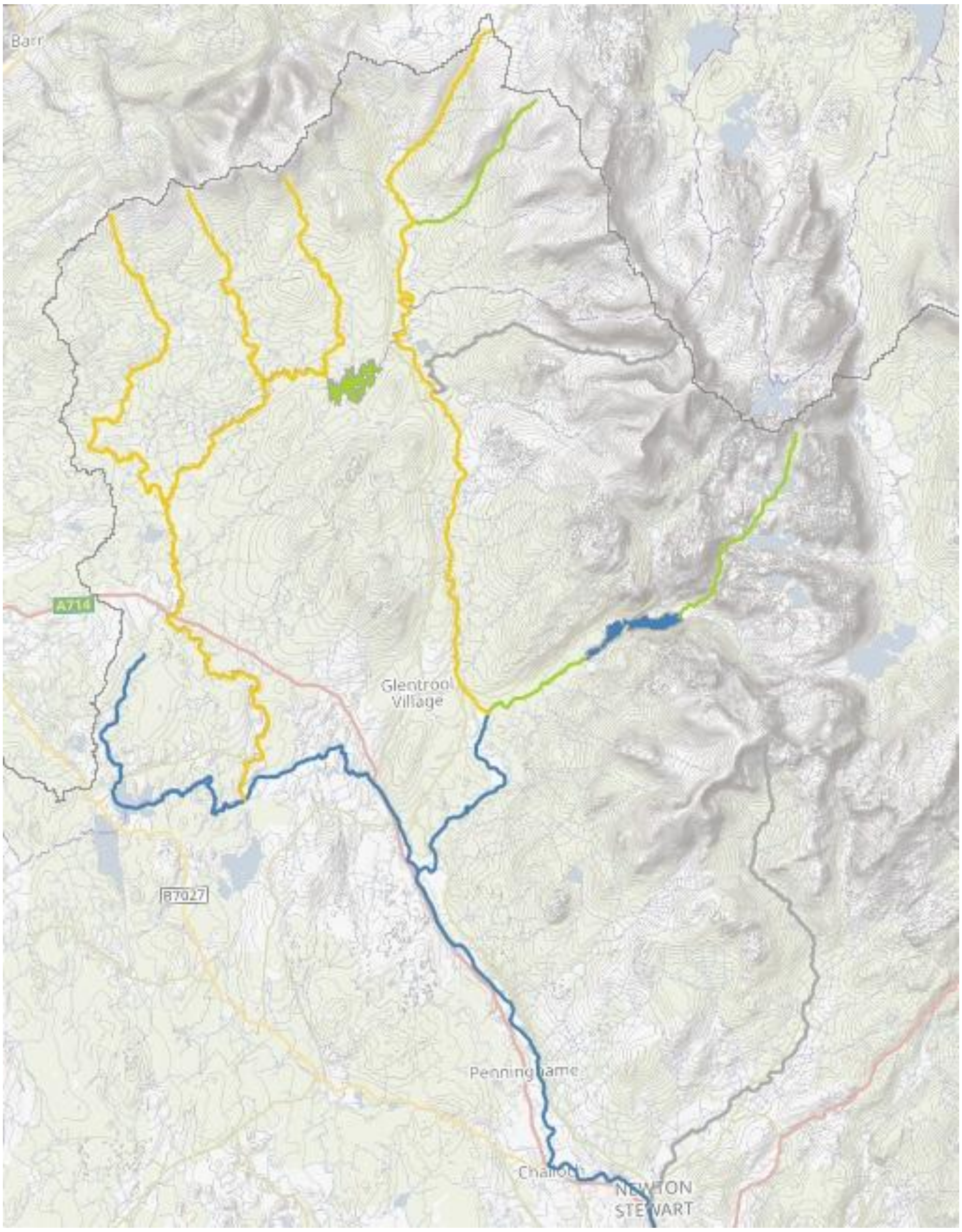


Figure 8: SEPA water hub River Cree classification: Macroinvertebrates (Acid)

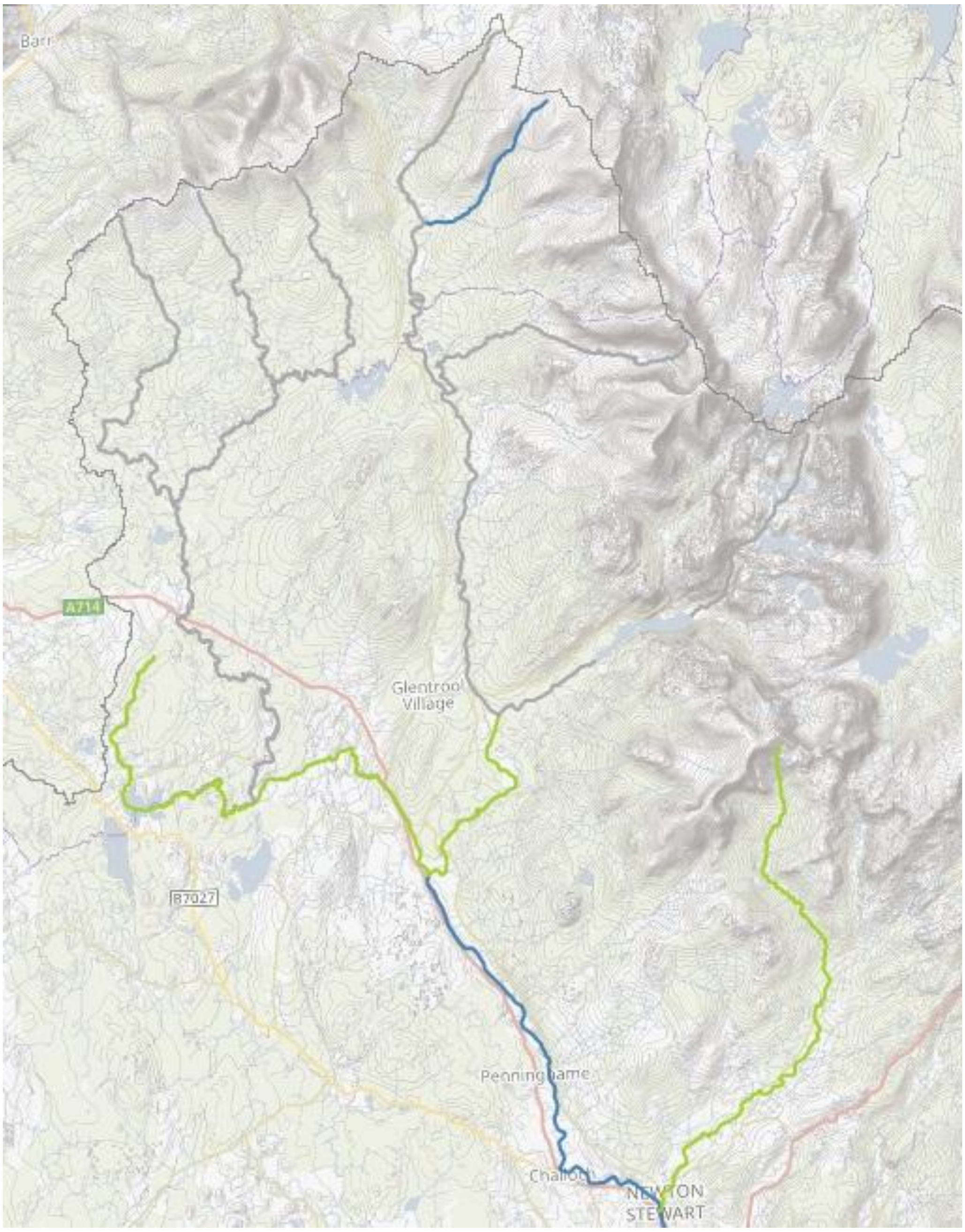
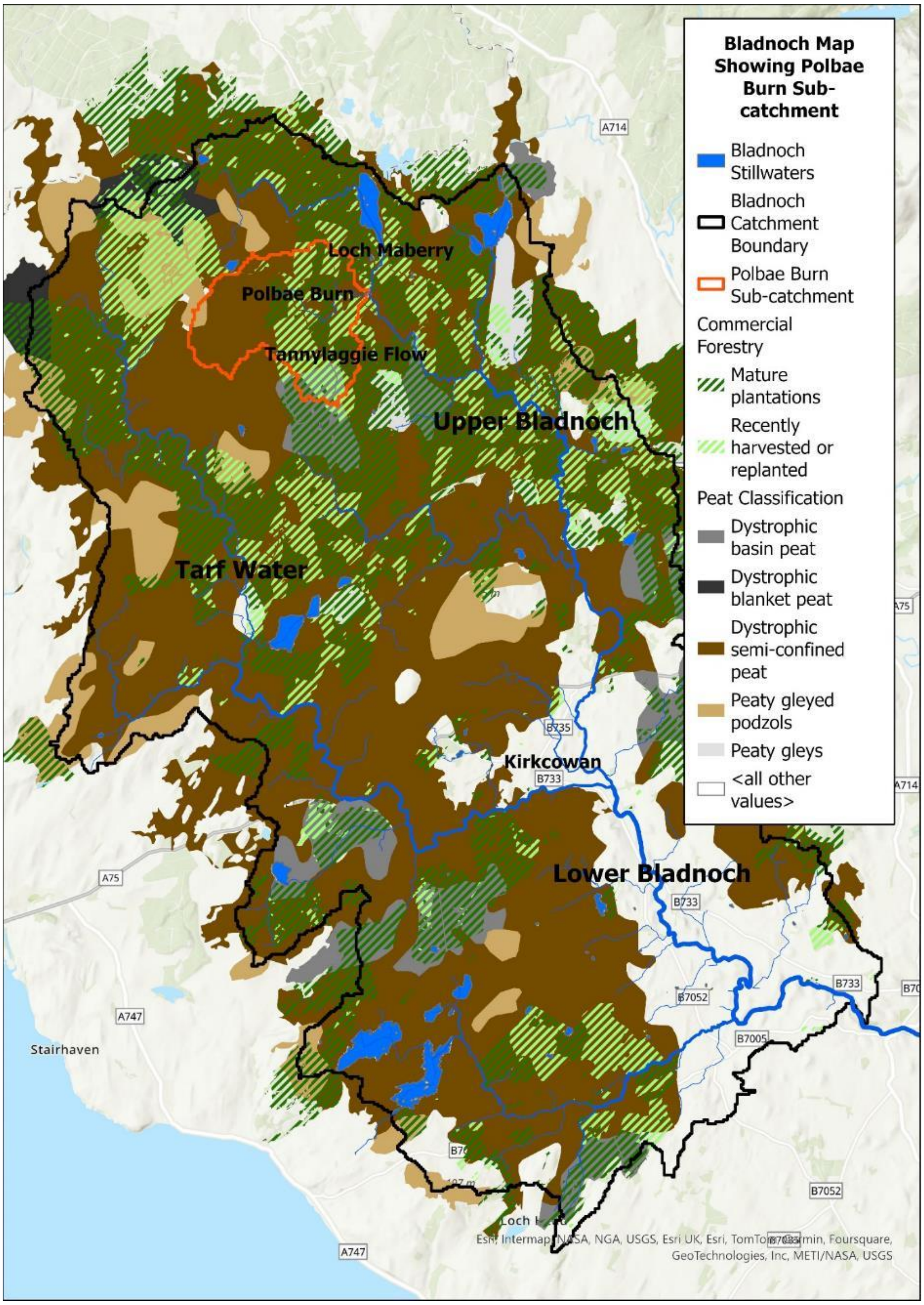


Figure 9: SEPA water hub River Cree classification: Macroinvertebrates (RICT/WHTP)

As can be seen from the SEPA classifications, the results for some parameters vary between maps, and often vary from the results shown later in this report. This may be because of limited SEPA sampling within a section of river, or from results from a small number of locations being considered representative of a much larger area with localised impacts being missed as a result. The results for overall status and overall ecology are generally representative of the water quality and fish data shown later in this report. However, the SEPA classification for pH, which classes as “Good” or “High” throughout most of the catchment, seems to be unrepresentative of the poor water quality and ecological damage recorded within parts of the Cree catchment.

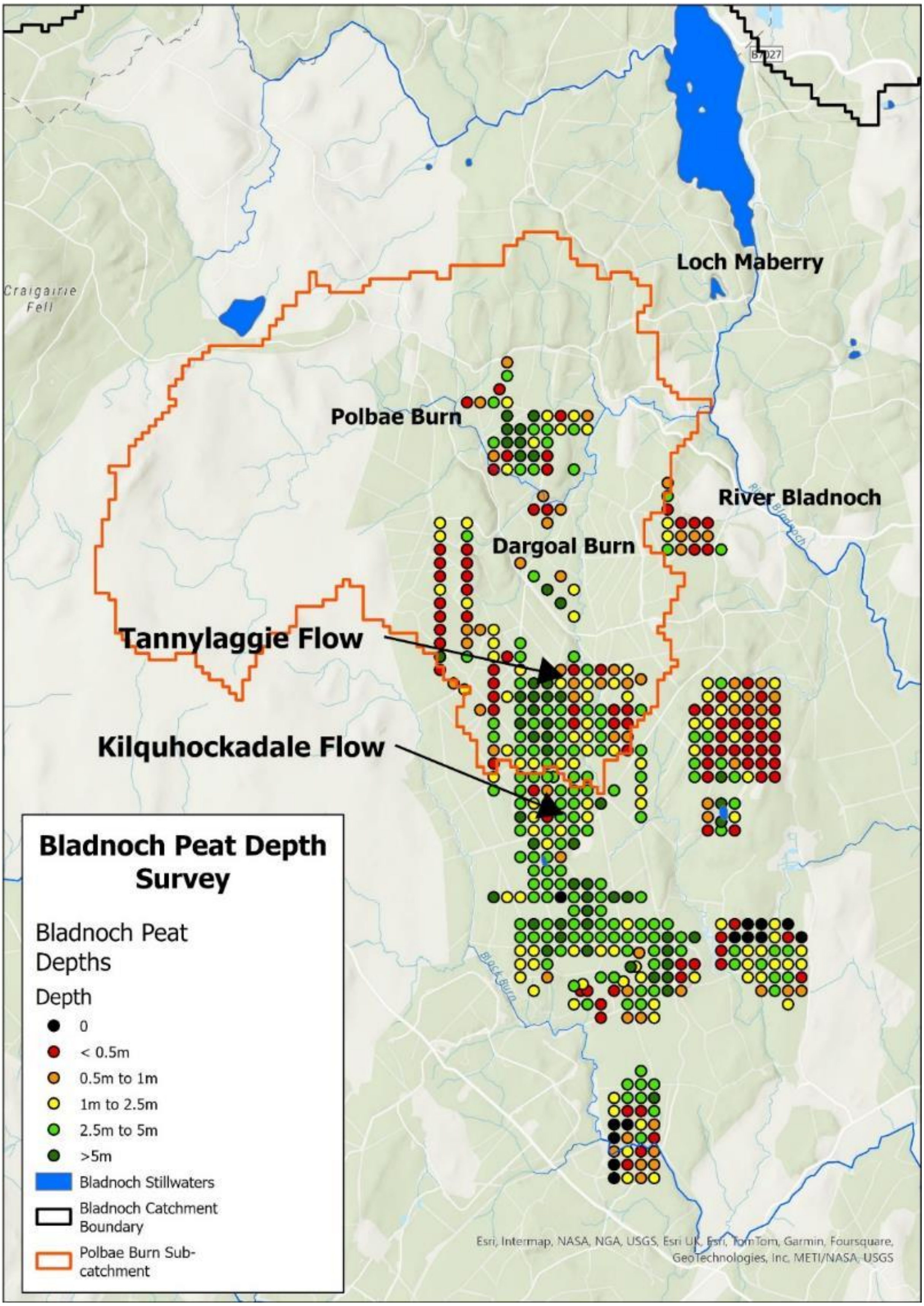
1.4 GFT Peatland Action water quality monitoring winter 2024/2025

Tannylaggie Flow is an area of deep basin peat within the upper Bladnoch catchment. It lies within the Polbae Burn sub-catchment near waterside as shown on Map 5.

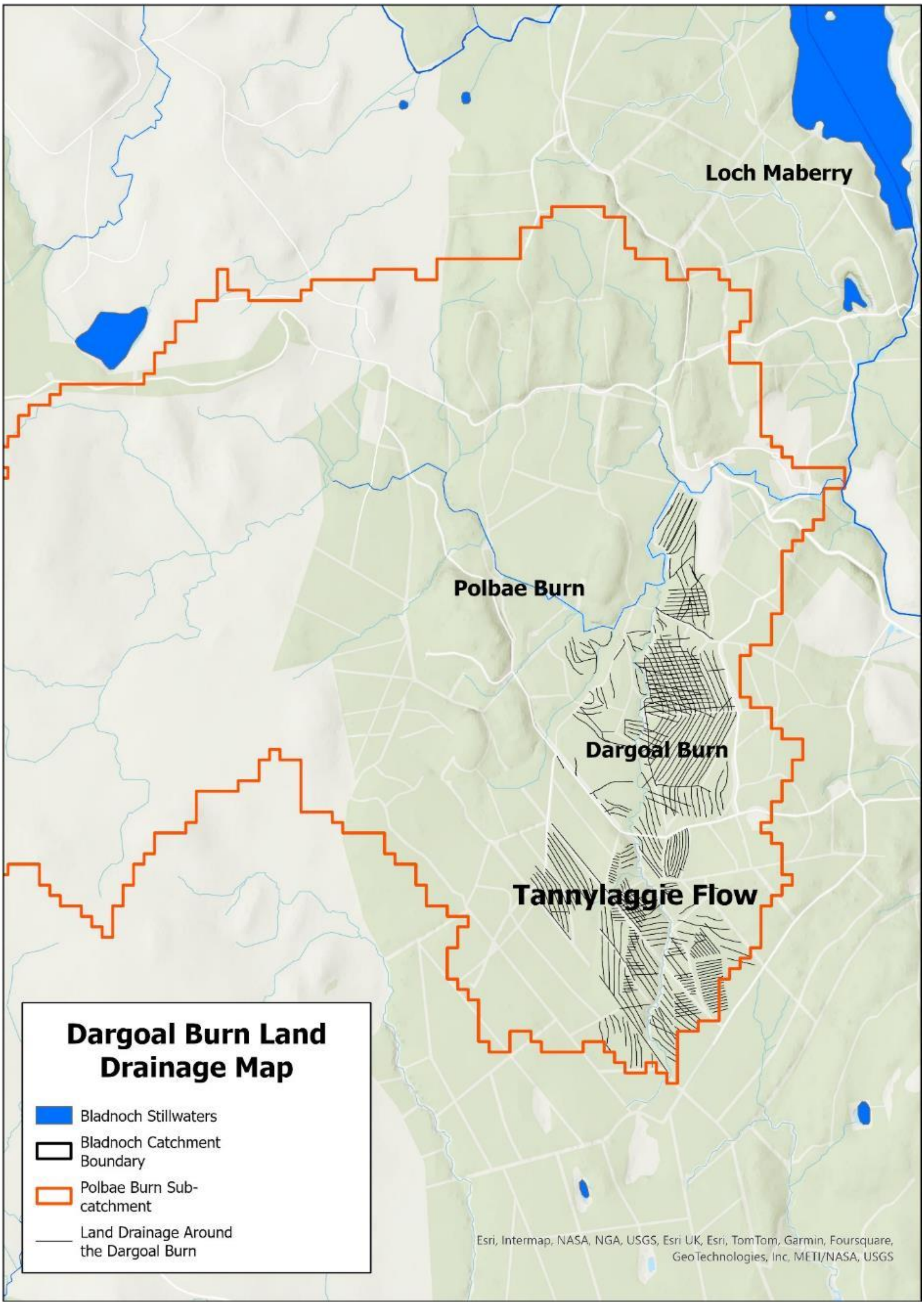


Map 5: Catchment map for the River Bladnoch showing the location of the Polbae Burn sub-catchment, peat type and forestry cover

A large percentage (well over half) of the Polbae Burn sub-catchment was purchased by the UK government post Second World War and converted to commercial forestry, typically dominated by Sitka spruce. This area covered almost the entirety of the Tannylaggie Flow area of deep basin peatland. To allow for the growth of commercial trees the peatland was extensively drained to prepare the land for planting. The combination of drainage and planting caused considerable damage to the peatland. Map 6 shows peat depths recorded by GFT in and around Tannylaggie Flow showing he extent of peat depths whilst Map 7 shows a sub-section of the drainage channels along the Dargoal Burn as mapped by the Crichton Carbon Centre. This gives an indication of the extent of the drainage network.

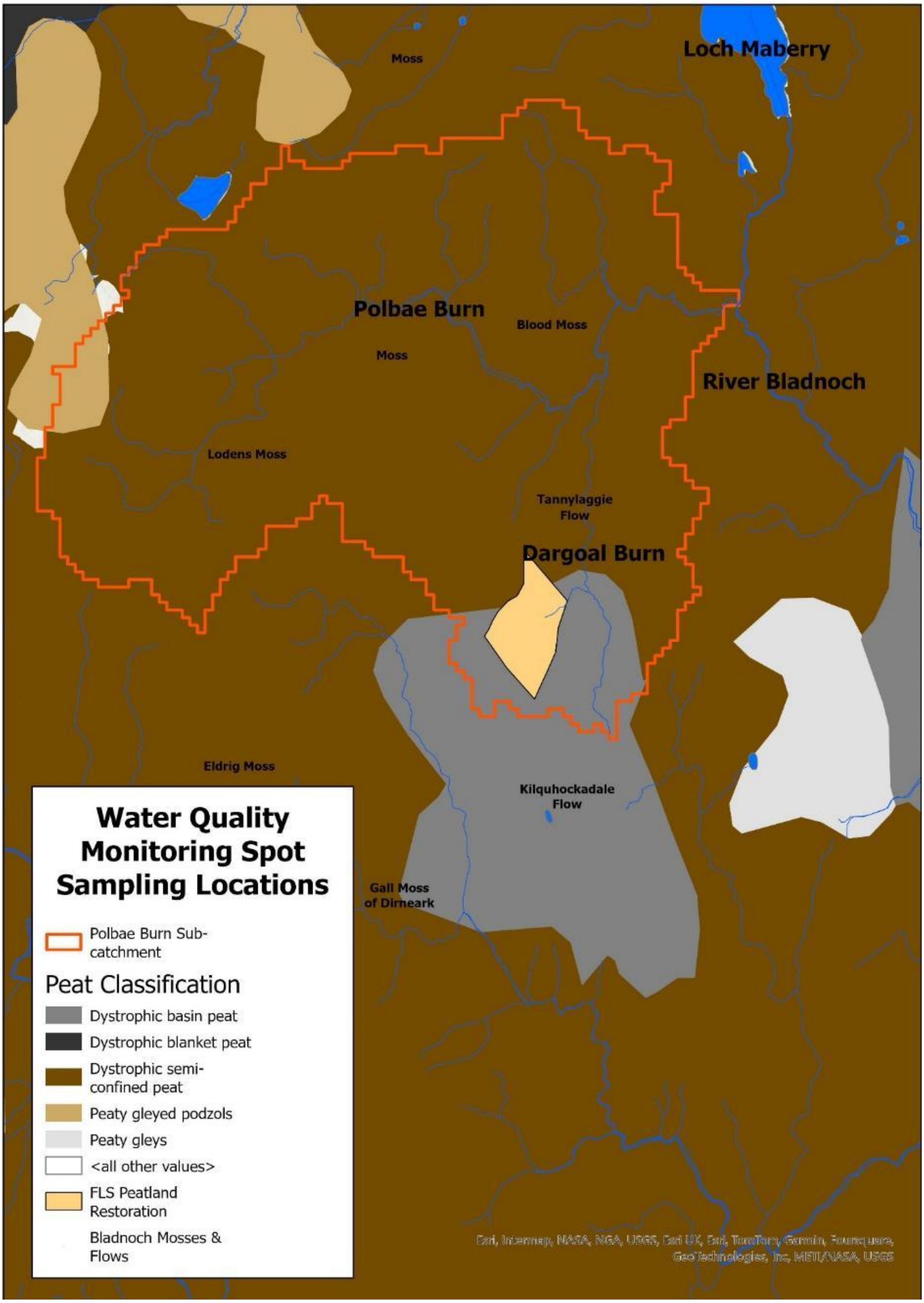


Map 6: Peat depths recorded around Tannylaggie and Kilquhockadale Flow (deep peat is classed as peat at a depth of 0.5m or over)



Map 7: Some of the forestry drainage network around the Dargoal Burn as mapped by the Crichton Carbon Centre. It is assumed that the drains mapped in this area represent the drainage intensity throughout the planted deep peat areas in the catchment.

The Dargoal Burn flows through Tannylaggie Flow and is the destination for much of the drainage network. Given the extent of the drainage and the size of the burn it is unclear just how natural it is in its current form. The author has observed that the banks are eroding bare peat in many sections of the burn, which appears to have artificially widened the channel width in many areas. This is likely because of artificially high flows following periods of prolonged heavy rainfall (resulting from the extent of the drainage). The Dargoal Burn flows into the Polbae Burn, itself a major headwater tributary of the upper Bladnoch and part of the River Bladnoch SAC. As a result of historic acidic pollutants in the atmosphere, industrial scale drainage and dense conifer planting the Dargoal Burn has become one of the most acidified watercourses within Galloway and frequently experiences pH levels that are lethal to fish (regularly below pH 4 during winter flows as previously shown by GFT/PA water quality monitoring). As a result of low pH levels within the Dargoal Burn, and in the general area surrounding the upper Polbae Burn, water quality (low pH) is impacted in the middle and lower Polbae Burn, with impacts persisting downstream into the River Bladnoch as well. The knock-on effect is that the acidification from the Dargoal Burn and greater Polbae Burn sub-catchment is significantly impacting the River Bladnoch SAC. The commercial forestry within the Dargoal Burn and greater Polbae Burn sub-catchment is primarily owned/managed by Forestry and Land Scotland, the government agency responsible for managing state owned forestry. As part of the latest plan for the management of Tannylaggie Forest (the name for the large section of commercial forestry surrounding the section of the upper Bladnoch catchment containing the Dargoal and Polbae Burns) large areas of deep peat at Tannylaggie Flow and Kilquhockadale Flow (both are part of the same peat unit) have been highlighted for peatland restoration. As the felling of mature conifer plantations is staggered over multiple years large sections of Tannylaggie Flow are still covered in mature conifers and will not be considered for restoration until the trees are removed. However, other areas have been felled and are ready for peatland restoration. After a delay resulting from FLS being unable to find a contractor to carry out the work peatland restoration commenced in a section of land adjacent to the Dargoal Burn in early 2023. Restoration techniques included stump flipping, ground smoothing and ditch blocking following best practice as described in the Peatland Action Technical Compendium. Map 8 shows an estimation of the area that has been restored to date. As a result of the restoration only beginning in early 2023 water quality monitoring up to that date was pre-restoration data collection, with monitoring over winter 2023/2024 and 2024/2025 recording data during the early stages of restoration. The restoration to date (estimated at roughly 20-25 hectares) represents a relatively modest percentage of the total area intended for peatland restoration, and of the Dargoal Burn sub-catchment. However, GFT understands that FLS intends to remove a large percentage of the remaining trees during summer 2025 and it is hoped that peatland restoration can progress from there.



Map 8: Approximate area of FLS peatland restoration at Tannylaggie Flow

The FLS Tannylaggie Forest Land Management Plan 2016 – 2026 is available from the link below.

https://forestryandland.gov.scot/images/corporate/design-plans/galloway/tannylaggie-land-management-plan-2016-26.pdf

In addition to the Tannylaggie Flow peatland restoration monitoring the 2024/2025 water quality monitoring also included a catchment wide review of water quality within the River Cree catchment. The first part of the this was analysis of electrofishing data held by GFT to assess the current impacts of water quality on fish populations across the Cree catchment and to ascertain any long-term trends. Given the sensitivity of salmon and trout to low pH during some periods of development the aim of the review was to look at the current distribution and density of trout and salmon, to see if there were any areas where fish numbers showed signs of being impacted by poor water quality and to see if there were any changes in fish numbers over time that would indicate improving or declining conditions. GFT has been carrying out electrofishing surveys to record juvenile salmonid densities in the Cree river system since the late 1990's and has amassed a significant amount of data from over 200 separate survey sites. However, sampling was undertaken for a wide variety of reasons and in a wide variety of locations so the amount of long-term data from individual sampling sites is limited.

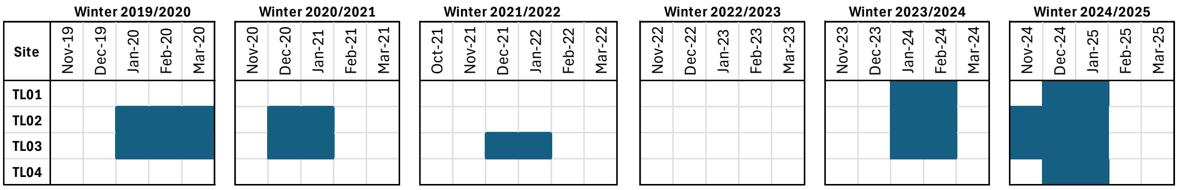
The final part of the winter 2024/2025 monitoring was to collect a record of catchment wide water quality across the Cree river catchment. The aim was to look at variation in water quality (primarily pH) across the whole river system and to highlight areas of poorer water quality for targeted restoration and/or further gathering of information. It is hoped that once the areas with the poorest water quality have been identified more data can be collected and that this can be directly linked to the current land use land use and/or the current state of any peatlands present.

2 METHOD

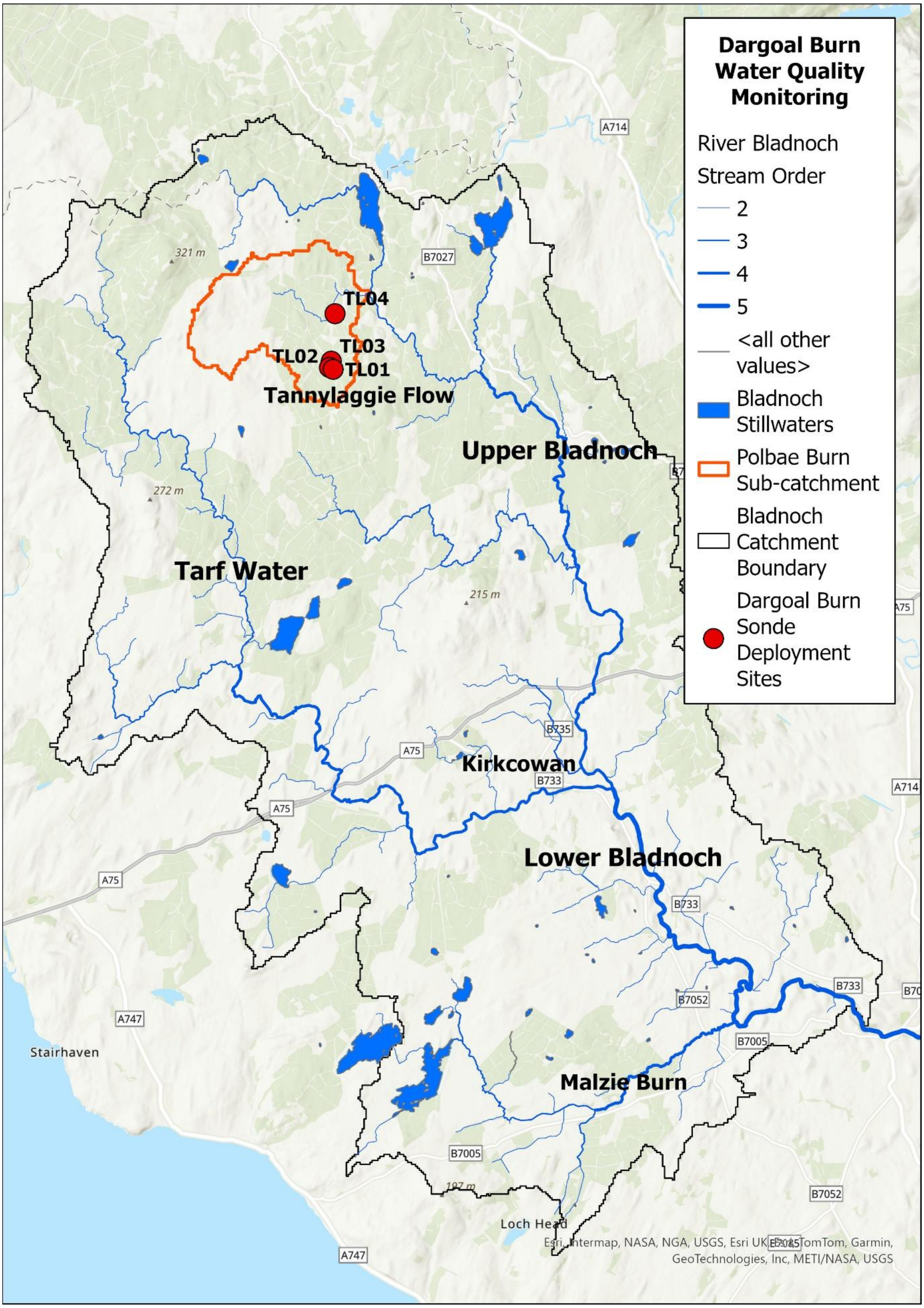
2.1 Tannylaggie peatland restoration water quality data collection

Tannylaggie peatland pre-restoration recording began in winter 2019/2020, with additional pre-restoration data being collected during winter 2020/2021 and winter 2021/2022. No monitoring took place during winter 2022/2023 as the upper Water of Luce was monitored instead because of the possibility of peatland restoration taking place, but monitoring re-commenced in winter 2023/2024 and continued during winter 2024/2025. The long-term monitoring sites in the Dargoal Burn centre around a small tributary/large drain within Tannylaggie Flow which appears to drain the area where the first section of peatland restoration took place and into which several large forestry ditches drain. Sites are located above the tributary (TL01), within the tributary itself (TL02) and below the tributary (TL03). An additional site at the bottom of the Dargoal Burn just upstream of its confluence with the Polbae Burn was added in winter 2024/2025 because of an additional sonde being available. The peatland restoration carried out to date lies upstream of the monitored tributary, but it is unclear exactly how much of the area drains into it.

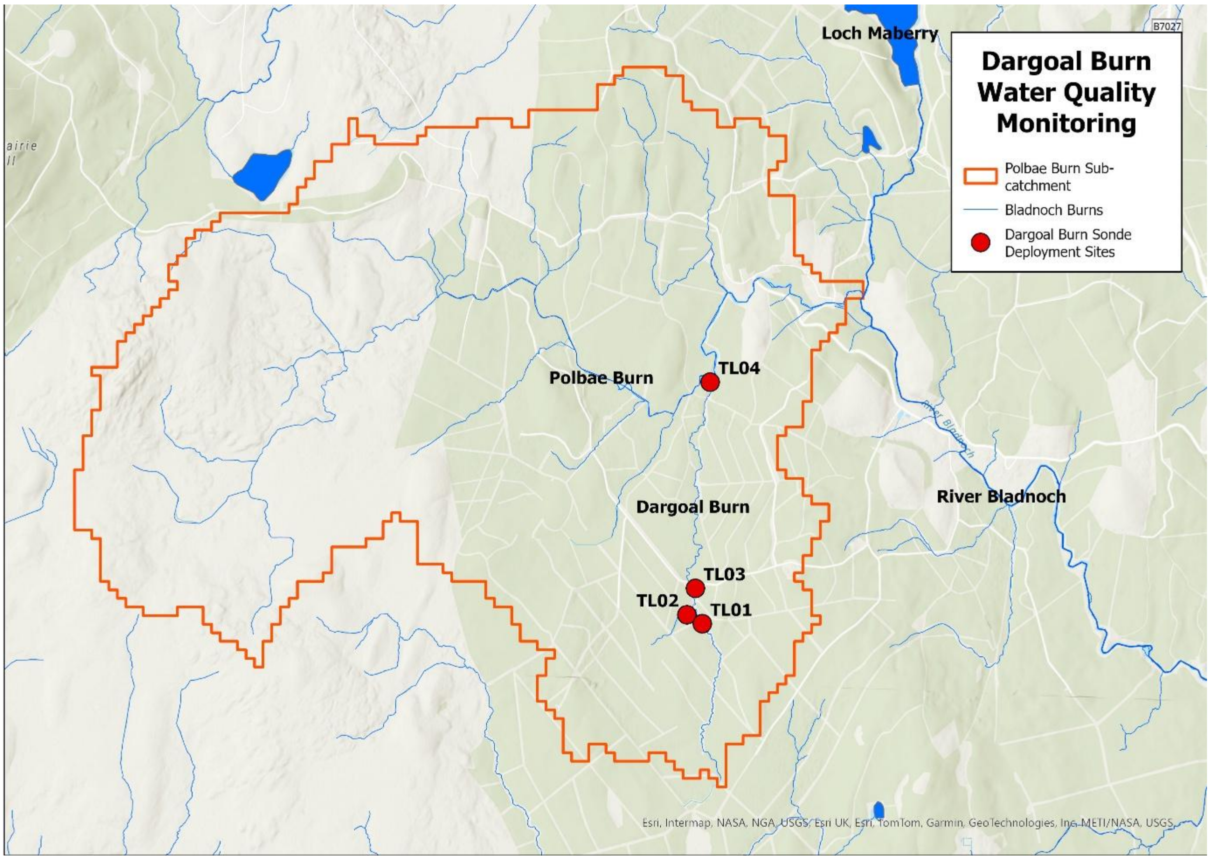
Chart 1: Tannylaggie Peatland Restoration Water Quality Monitoring Approximate Timeline



The sites were chosen to show the overall condition of the Dargoal Burn, localised variations coming from the tributary and to show if the water from the tributary is having any significant impact on water quality. Map 9 shows the locations of the sample sites within the greater Bladnoch catchment whilst Map 10 shows the sites at a local level. Tree felling within the Tannylaggie Flow restoration area was well underway by the time the pre-restoration monitoring began, although there has been significant regeneration of Sitka since the felling took place (author, personal observation). There have also been issues with calibrations and sensor faults during deployment which explains any gaps seen within the recorded data in the results section of this report.



Map 9: Tannylaggie peatland restoration water quality monitoring Sonde deployment sites within the greater Bladnoch catchment



Map 10: Tannylaggie peatland restoration water quality monitoring Sonde deployment sites within the Polbae Burn sub-catchment

The first phase/section of peatland restoration was completed during early 2023 and data was collected from all three sites during January/February 2024 (but with the TL01 sonde moved upstream approximately 10 m as previously stated). Monitoring in Winter 2024/2024 commenced in mid-November 2024 and finished in mid-January 2025. Due to issues with equipment servicing and the availability of calibration chemicals only two sondes were deployed at sites TL02 and TL03 (the most important sites in terms of data collection). However, four sondes were available for the second month of recording, and all three sites were monitored along with a new site at the bottom of the Dargoal Burn (shown in maps 9 and 10). As with all previous GFT water quality monitoring data was collected using EXO1 Sondes. The first two sondes (TL02 and TL03) were deployed on 15/11/2024 and taken out on 11/12/2024. They were redeployed along with the two additional sondes (TL01 and TL04) on 13/01/2025.12.2024.

EXO1 Sondes recorded water quality parameters at 15-minute intervals after deployment. At each site pH, Dissolved Organic Matter (DOM), Dissolved Oxygen (DO), conductivity, and depth were recorded. Of the sensors available from the manufacturer each parameter was chosen for the following reason:

- pH – acidification of upland waterbodies on base-poor geology is a significant problem within the Galloway region. Several scientific papers have linked degraded peat with increased acidification in watercourses.
- Dissolved Organic Matter – as extensive drainage is often the primary cause of damage to Peatlands and as the drainage results in the peat eroding around the drains and entering watercourses DOM represents a direct measure of the levels of suspended solids within watercourses.

- Dissolved Oxygen – as peat is partly decomposed organic matter decomposition is likely to continue (but at a faster oxidised rate) when it enters rivers/burns through bacterial action. The increase in bacteria associated with increased volumes of organic matter increases Biological Oxygen Demand and can lead to reduced oxygen levels within watercourses.
- Conductivity – the ease at which an electric current can pass through water is directly related to the level of particulate matter in the watercourse. As such conductivity represents another method of recording the volume of suspended solids resulting from Peatland erosion.
- Depth – to give an indication of flow so it can be used to assess impacts of changes in flow/rainfall.

All Sondes were calibrated before being deployed. The Sondes were held in place submerged within monitoring sites using frames constructed out of drainpipe and supported by wooden stobs as shown in Picture 4.

Picture 4: Example of GFT frame designed for the support of EXO1 Sondes

The Sondes are located within the lower, submerged sections of pipe, which are perforated to allow water to pass through.

The parameters measured, the calibration interval (approximately one month) and the method of deployment are standard for all GFT PA funded continual water quality monitoring.

2.2 River Cree electrofishing data review

GFT has been carrying out electrofishing surveys to assess juvenile salmonid populations on the River Cree since the late 1990's, with sites having been visited on and off between 1997 and 2024. Cree electrofishing sites have been chosen/visited for several purposes. These include general monitoring of fish populations, assessing spatial distribution, directly monitoring habitat works, consultancy work and investigative work (e.g. investigating the impacts of barriers or acidification on fish populations). The period within which each site was visited, and the number of times each site has been repeated, varies greatly between electrofishing sites. As the purpose of this electrofishing review is to look at the areas impacted, or potentially impacted, by acidification, the review focuses on sites within areas of base-poor geology. However, all main stem sites and some lowland burns have also been included to see how far downstream populations are potentially impacted by poor water quality and to highlight the overall picture of fish populations within the river.

The electrofishing sampling methodology adopted for the electrofishing sites included within the review is one to three run area delineated sampling following the Scottish Fisheries Co-ordination Centre (SFCC) methodology (Scottish Fisheries Co-ordination Centre, 2021). This gives quantitative or semi-quantitative results based on the number of runs completed and gives, at the very least, a minimum estimate of fish density per 100 m^2 for each site (based on a single run). This allows, at the very least, for the first run fish density to be compared between sites, with electrofishing efficiency likely to be similar between different sites. Due to the practical limitations of electrofishing the fish habitat sampled is typically shallow riffle and run habitat which is typically dominated by juvenile salmon and trout, with salmon and trout being both the target species and the main native fish species present within watercourses. Sites are normally visited during July, August, or September, and to a lesser extent, early October. This is when fry (juveniles in the first year of their life) have grown large enough to be influenced by the electrofishing process and to be easily identified. In all cases within this review, to allow direct comparison between sites, the results are given as a minimum density per 100 m^2 based on a single electrofishing run. Whilst this does not give the actual density and underrepresents the fish numbers present, it does allow a comparison between equal sampling effort for all sites regardless of the numbers of runs completed. The results given in this report are primarily for the fry (0-year-old “young-of-the-year”), however parr (one year old and over juveniles) are also shown in some cases. Fry are primarily chosen as their movements from the areas in which they were spawned are more limited than older life stages (Hesthagen, 1988) and therefore give the most accurate indication of whether the eggs of salmon and trout can develop and hatch (the stage most susceptible to the impacts of acidification). As such, fry give the best indication of any potential impacts on fish populations caused by acidification. Where electrofishing sites have been visited on six or more occasions the results for these sites are shown individually to show long term trends in numbers. Only a relatively small number of sites have enough data to show this. Therefore, for the remaining data, to allow some sort of comparison that can be used to assess whether there have been changes over time, the results have been assigned into three roughly equal time periods – 1997 to 2006; 2007 to 2015 and 2016 to 2024. Where a site has had more than one visit during a given period the results have been averaged. It should also be noted that salmon and trout tend to segregate at spawning time with salmon spawning in larger, wider channels (rivers) and trout in smaller, narrower channels (burns). The exact channel width at which salmon spawning changes to trout spawning varies from location to location and both can overlap but, for the most part, shallow riffles and runs within burns under 2 - 3 m average width should typically be dominated by trout fry (with salmon fry often absent), with larger channels dominated by salmon fry. This has been considered within the data analysis with salmon fry results shown for larger channels, trout fry results shown for burns and both shown where salmon and trout fry overlap or would be expected to do so. To aid with data analysis a scoring/rating system for salmon and trout fry densities was developed by Godfrey (2006) using data collected from 1,638 Scottish electrofishing survey sites covering the period 1997 to 2002. From this, regional figures were created to allow more accurate local ‘density ranges’ with the Solway region scorings/ratings shown in Table 2. Colour coding has been added to help visualize results shown on maps.

Table 2: Minimum density per 100 m^2 ranges for juvenile trout and salmon fry based on one-run electrofishing events, calculated on densities > 0 over 291 sites in the Solway Statistical Region

Fry Density Rating	Salmon Fry Density Range	Trout Fry Density Range
Absent	0	0
Very Low	0.01 to 5.20	0.01 to 4.13
Low	5.21 to 12.67	4.14 to 12.08
Moderate	12.68 to 25.27	12.09 to 26.62
High	25.28 to 46.52	26.63 to 56.48
Very High	46.53 +	56.49 +

One additional point of note from the Cree electrofishing data is the impact of stocking with juvenile salmon to counter the impacts of acidification. Stocking, where eggs from adult salmon are reared in a hatchery before being released back into watercourses as fry, has been widespread within some reaches of the Cree system during the period in which electrofishing surveys have taken place. Whilst a valid method of countering the impacts of acidification on fish populations, it does mean that any area that has been stocked can not be used to monitor the impacts of acidification on fish populations. As a result, a significant amount of juvenile salmon electrofishing sites have been discounted from the review due to historic stocking with salmon fry.

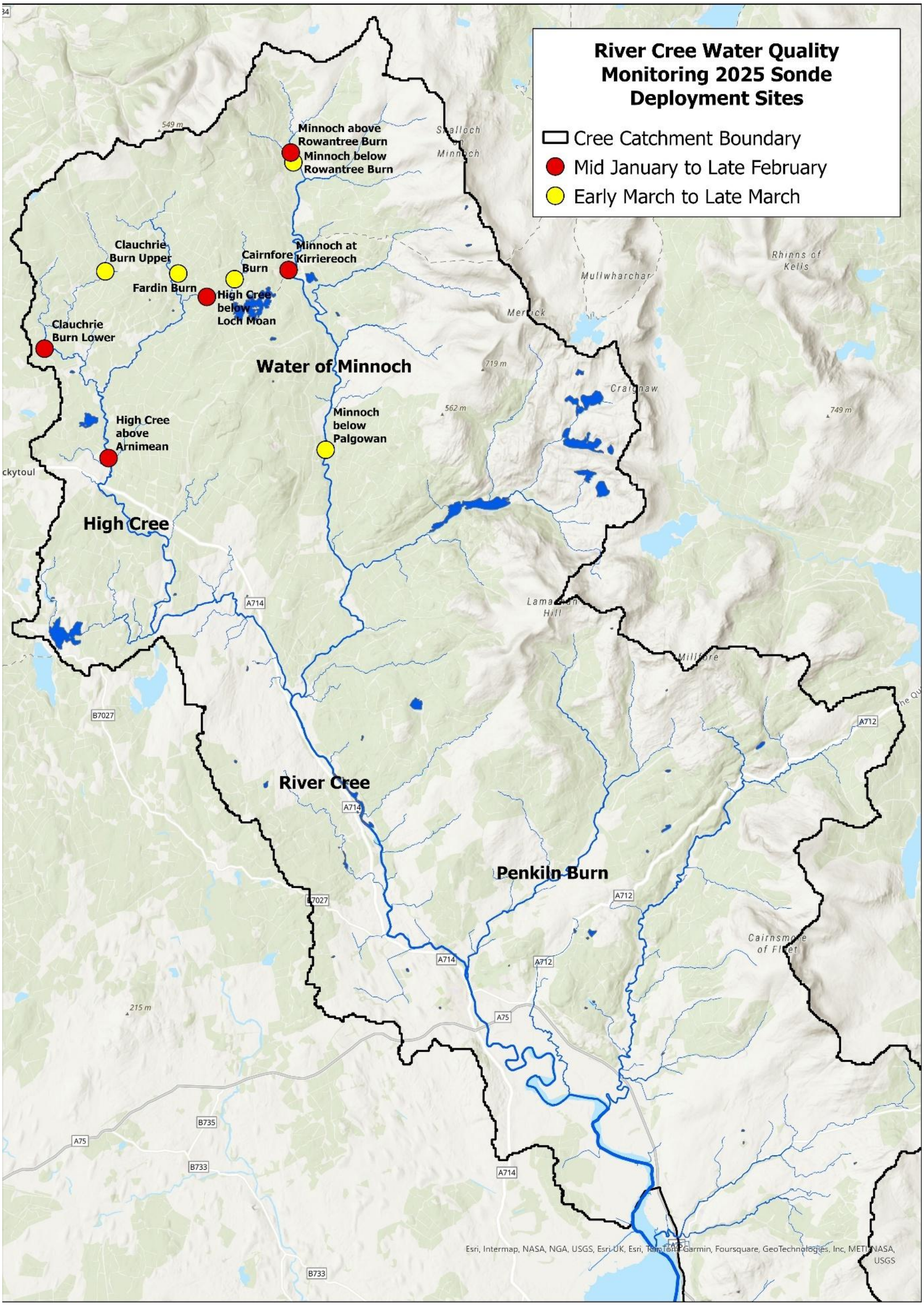
2.3 River Cree water quality overview

To gain an overview of water quality across the River Cree catchment EXO1 Sondes were deployed at 10 locations on the High Cree and Water of Minnoch to gather data at 15-minute intervals. Due to limitations on the number of sondes available (five in total) the sondes were deployed between mid-January and February before being retrieved, calibrated and redeployed between early March and late March. Table 3 provides a summary of the deployment details whilst Map 11 shows the deployment locations. Sites were chosen to monitor heavily impacted areas (based on unpublished Galloway Fisheries Trust water quality and fish survey data) to give coverage of the High Cree and Water of Minnoch catchments. The water quality parameters recorded are the same as those for the Tannylaggie peatland restoration monitoring, for the same reasons.

Table 3: River Cree Water Quality Monitoring Sonde deployment summary

ID	Easting	Northing	Watercourse	Location	Deployment
Cr01	230515	581312	High Cree	Upstream of Arnimean Bridge	15.01.2025 to 27.02.2025
Cr02	228638	584520	Clauchrie Burn (High Cree)	Lower Clauchrie Burn	15.01.2025 to 27.02.2025
Cr03*	233398	586038	High Cree	Below Loch Moan	15.01.2025 to 23.02.2025
Cr04	235794	586829	Water of Minnoch	At Kirriereoch	15.01.2025 to 26.02.2025
Cr05	235858	590268	Water of Minnoch	Above Rowantree Burn inflow	15.01.2025 to 26.02.2025
Cr06	230420	586789	Clauchrie Burn (High Cree)	Upper Clauchrie Burn	06.03.2025 to 28.03.2025
Cr07	234210	586556	Cairnfore Burn (High Cree)	Lower Cairnfore Burn	06.03.2025 to 28.03.2025
Cr08	232559	586726	Fardin Burn (High Cree)	Lower Fardin Burn	06.03.2025 to 28.03.2025
Cr09	236882	581557	Water of Minnoch	Below Palgowan	06.03.2025 to 28.03.2025
Cr10	235935	590180	Water of Minnoch	Below Rowantree Burn inflow	06.03.2025 to 29.03.2025

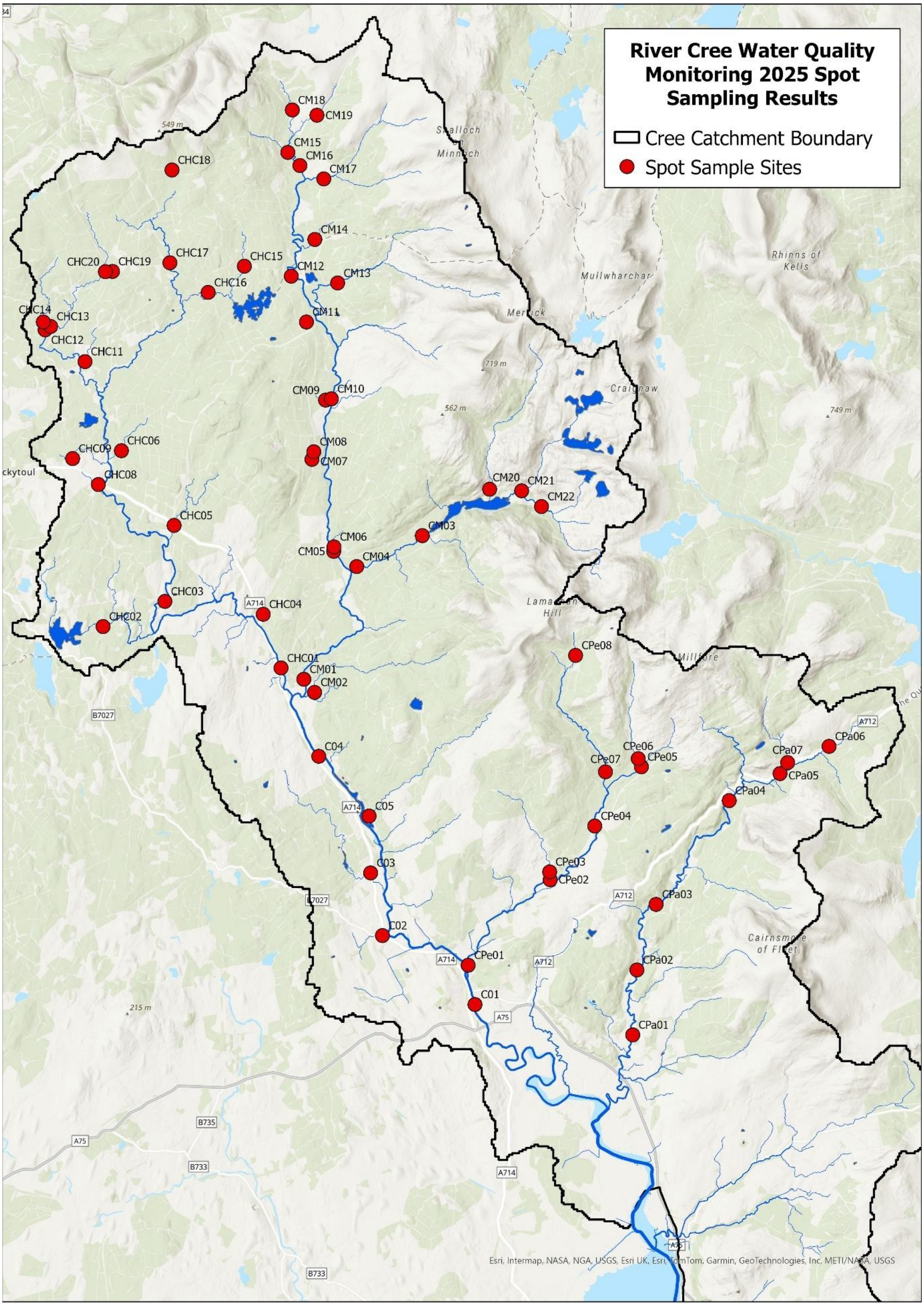
* Recording at Site Cr03 ended prematurely because of an unexpected battery drain within the sonde.



Map 11: Water quality monitoring locations on the High Cree and Water of Minnoch

In addition to the deployment of the EXO1 Sondes spot sampling was carried out across the whole Cree catchment. Spot sampling involves collecting water samples from chosen locations within watercourses after periods of high flows. This is to catch pH at, or near, its most acidic level. Once collected water samples are taken back to the GFT office and water quality is measured using an EXO1 Sonde retained within the office. The same parameters are recorded as with the sondes that are deployed in the field. Spot sampling sites were spread across the whole catchment to assist in gaining a water quality overview for the whole river system. Whilst sondes deployed in the field provide detailed information on trends in water quality their cost limits the number of locations from which data can be collected at any one time. Although only one reading is collected from a single point in time, spot sampling allows data to be collected from many sites in a relatively short period of time allowing spatial relationships to be investigated in more detail and allowing areas to be highlighted for more detailed investigation.

Map 12 shows the spot sampling sites within the Cree catchment. In addition to the original site locations several additional sites were added during the monitoring to provide additional coverage. Spot sampling was carried out on 28/01/2025, 31/01/2025, 21/02/2025, 24/02/2025, 07/03/2025 and 21/03/2025, although it was not possible to cover all sites within a single day and some days targeted only some sub-sections within the Cree catchment. Most sampling took place after (variable) periods of rainfall; however, some sampling was conducted at relatively low flows (for the time of year) to give an indication of how persistent/variable pH levels are within watercourses.



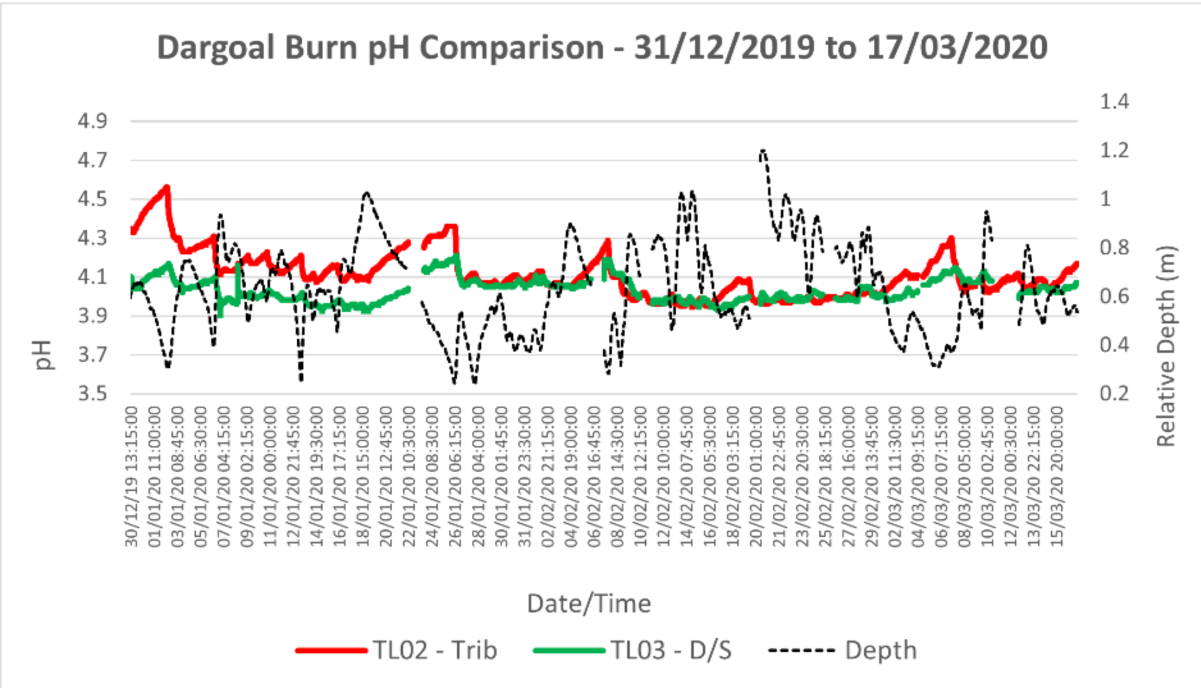
Map 12: Water quality monitoring spot sampling sites within the Cree catchment

3 RESULTS

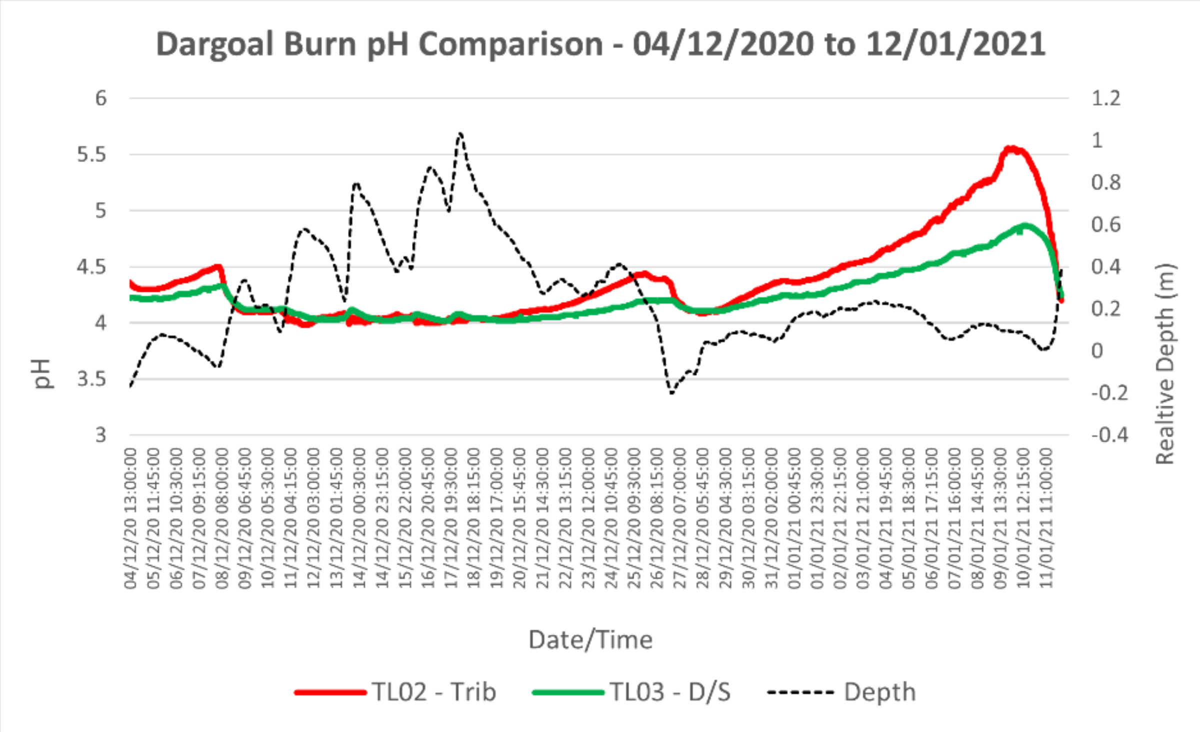
3.1 Tannylaggie peatland restoration water quality data collection

The water quality monitoring results from the Dargoal Burn during winters 2019/2020, 2020/2021, 2021/2022 and 2023/2024 are shown below in Graphs 1 to 18. The results for pH, fDOM and Dissolved Oxygen are shown. Conductivity was also recorded but fDOM is thought to be a better indication of suspended peat resulting from peatland erosion. The averages from each period are also listed in Tables 4 to 6. The monitoring site above the tributary (TL01) has proven problematic during monitoring and readings were thought to have been impacted by periodic exposure to air during low flows. As a result, and due to only two water quality monitoring sondes being available at the time, this site was not monitored during winter 2020/2021. It was redeployed during winter 2021/2022 with the sonde placed in deeper water. However, the issues persisted revealing that water stagnating at the monitoring site was the factor impacting results. The site was moved upstream approximately 10 m into an area of swifter flow during winter 2023/2024 which appears to have solved the issue. As such, the only reliable data for this site is from winter 2023/2024 onwards and all other data from this site has been disregarded. Therefore, the data from site TL01 (upstream) for 2019/2020, 2020/2021 and 2021/2022 has, for the most part, been left out of the results. However, the pH results from winter 2020/2021 have been included to highlight the issues experienced with the data. The data gaps clearly seen in some graphs are the periods when the sondes were taken out for re-calibration. These are present in graphs where the sondes are deployed at a single site for well over one month (as the recommended re-calibration period for the pH sensors is one month).

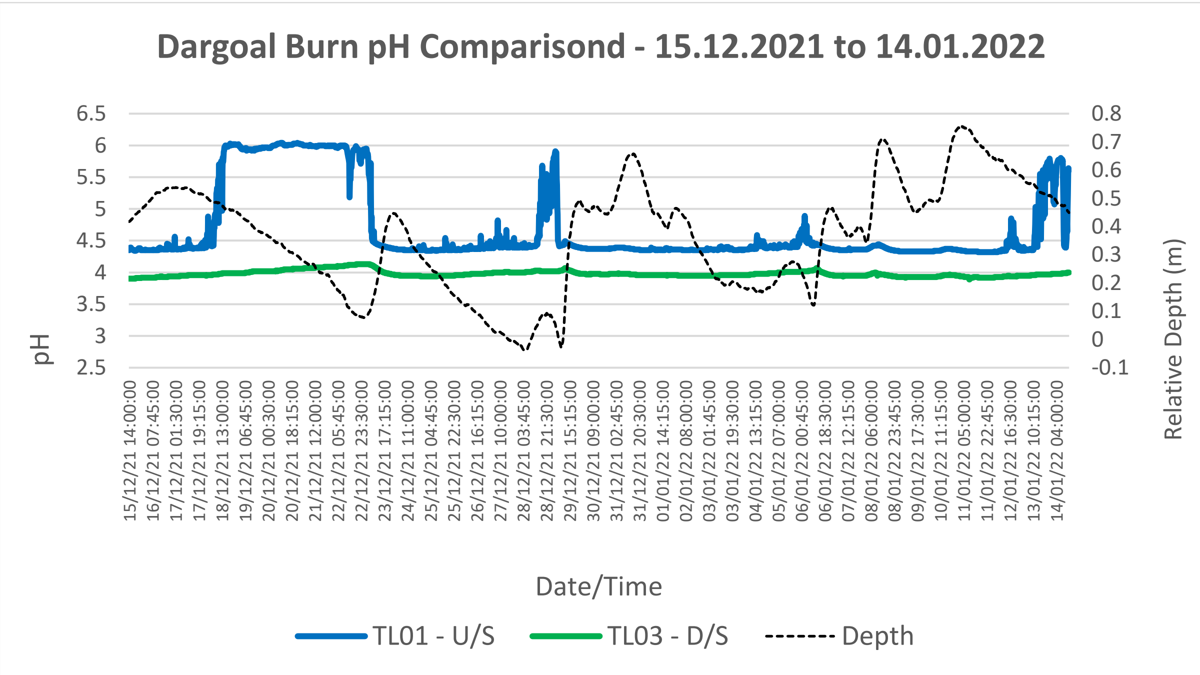
As FLS peatland restoration at Tannylaggie will be ongoing over the next few years the data prior to 2023 should be considered “pre-restoration” data whilst the winter 2023/2024 data should be considered as “during restoration” data. Even though the first stage of restoration has been completed a significant area of additional restoration is still in planning.



Graph 1: Comparison between pH and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2019/2020

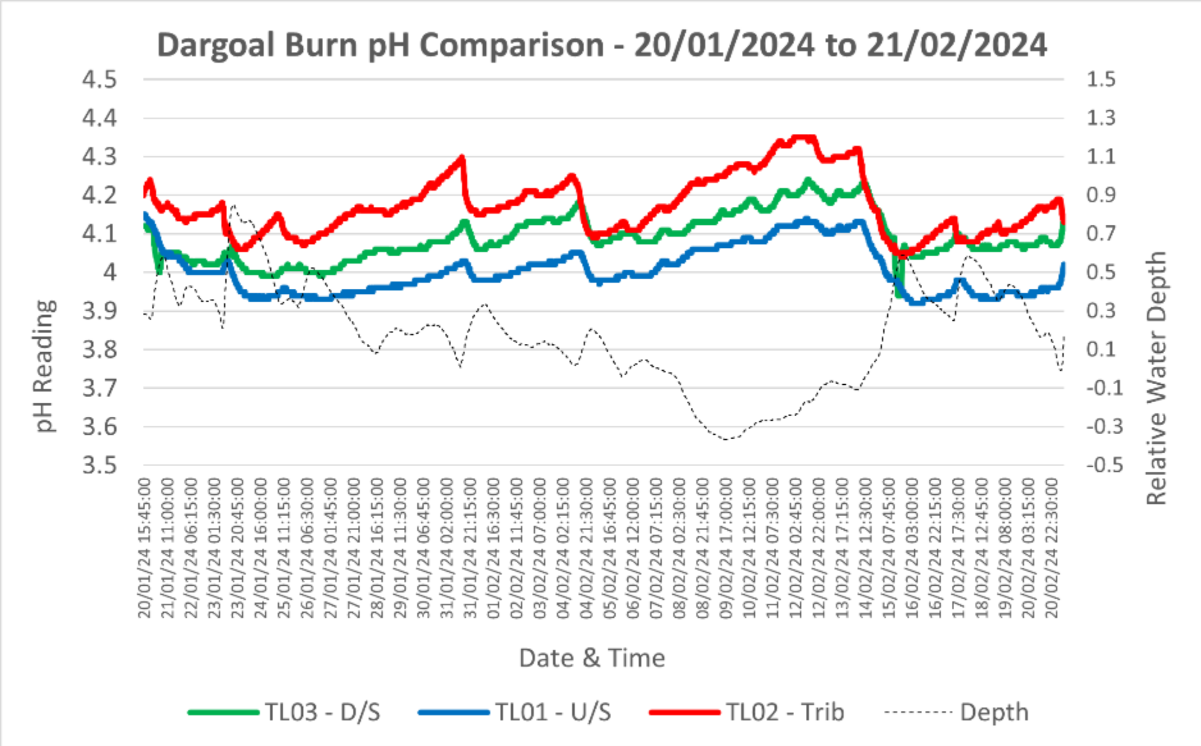


Graph 2: Comparison between pH and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2020/2021

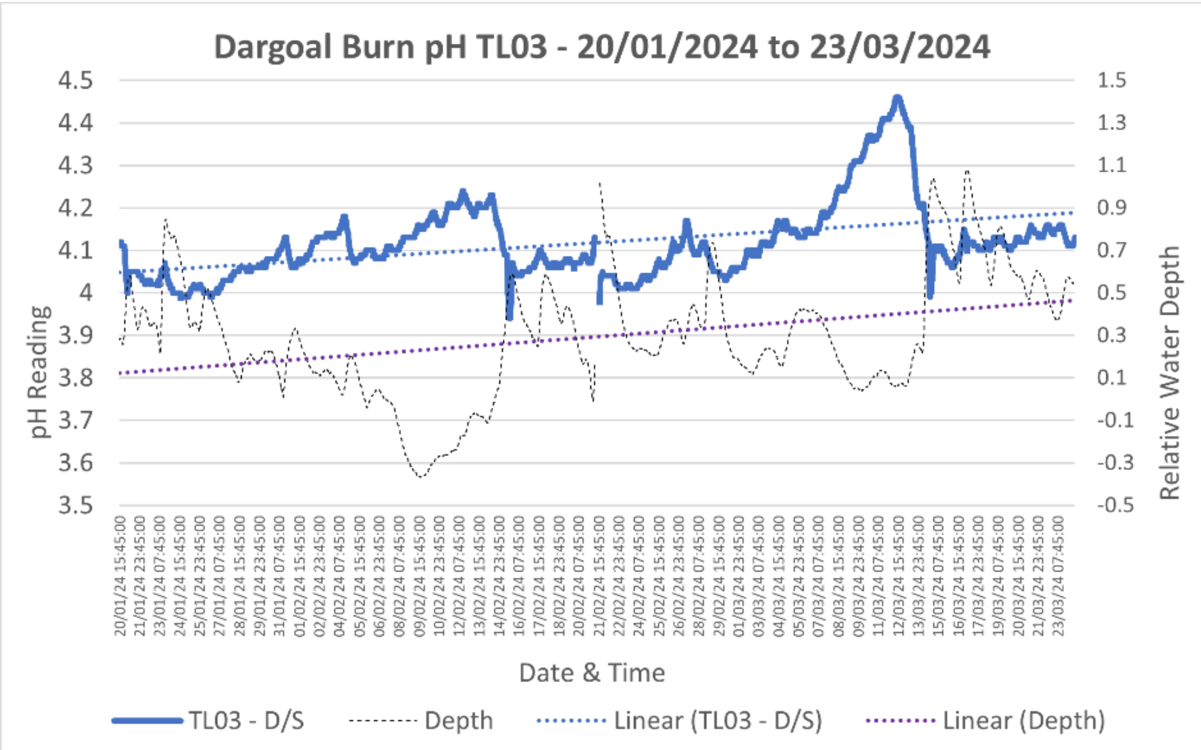


Graph 3: Comparison between pH and relative water depth (m) at TL01 (upstream) and TL03 (downstream) on the Dargoal Burn during winter 2021/2022

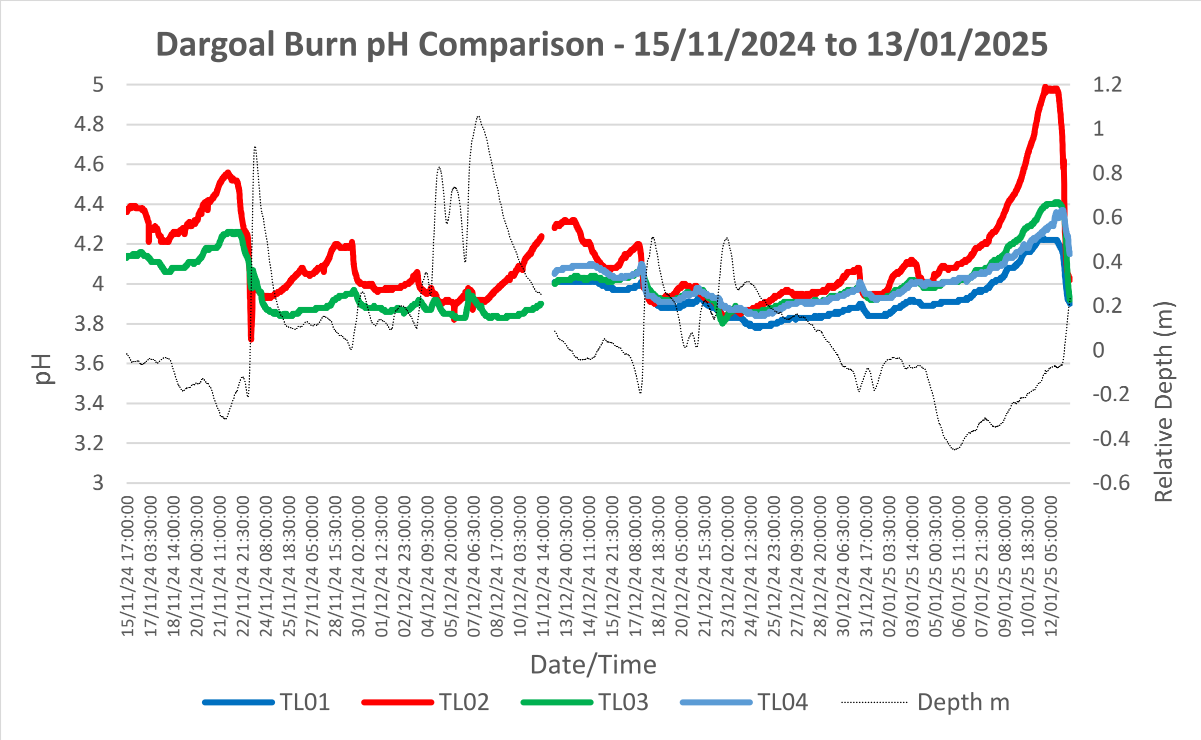
Graph 3 highlights the stagnation issues at site TL01 (before being re-sited) and the impact on pH readings.



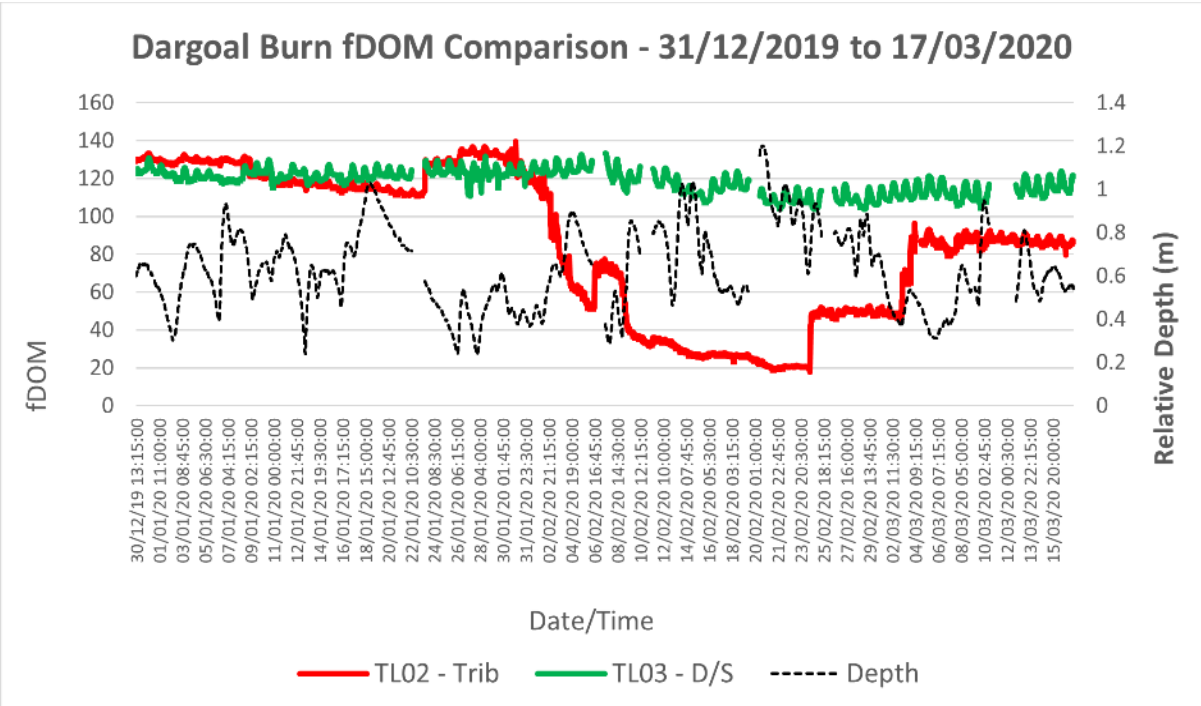
Graph 4: Comparison between pH and relative water depth (m) at TL01 (upstream), TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2023/2024



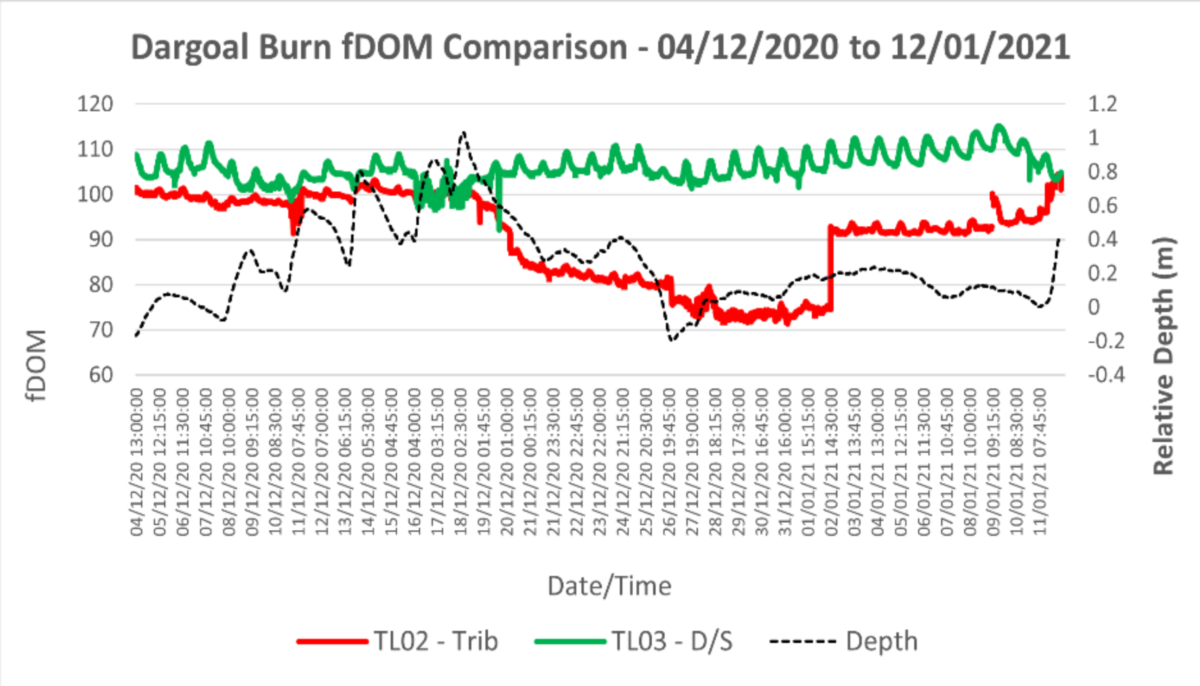
Graph 5: pH readings against relative depth for extended monitoring of Site TL03 (downstream) during winter 2023/2024



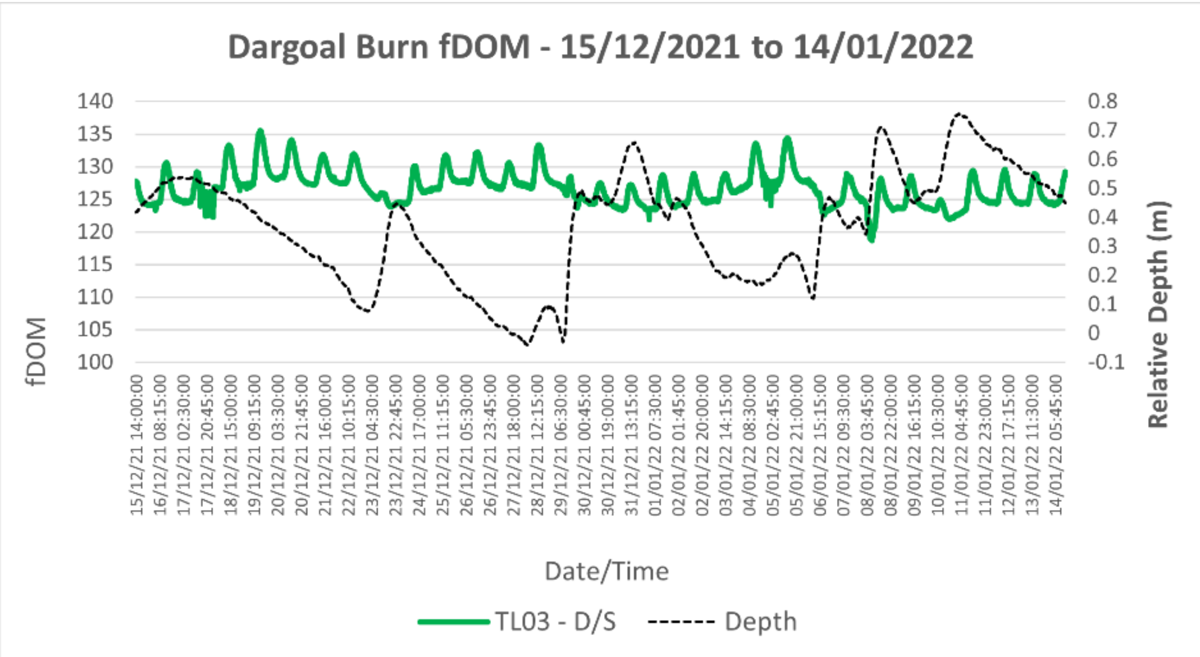
Graph 6: Comparison between pH and relative water depth (m) at TL01 (upstream), TL02 (tributary) and TL03 (downstream) and TL04 (Lower Burn) on the Dargoal Burn during winter 2024/2025



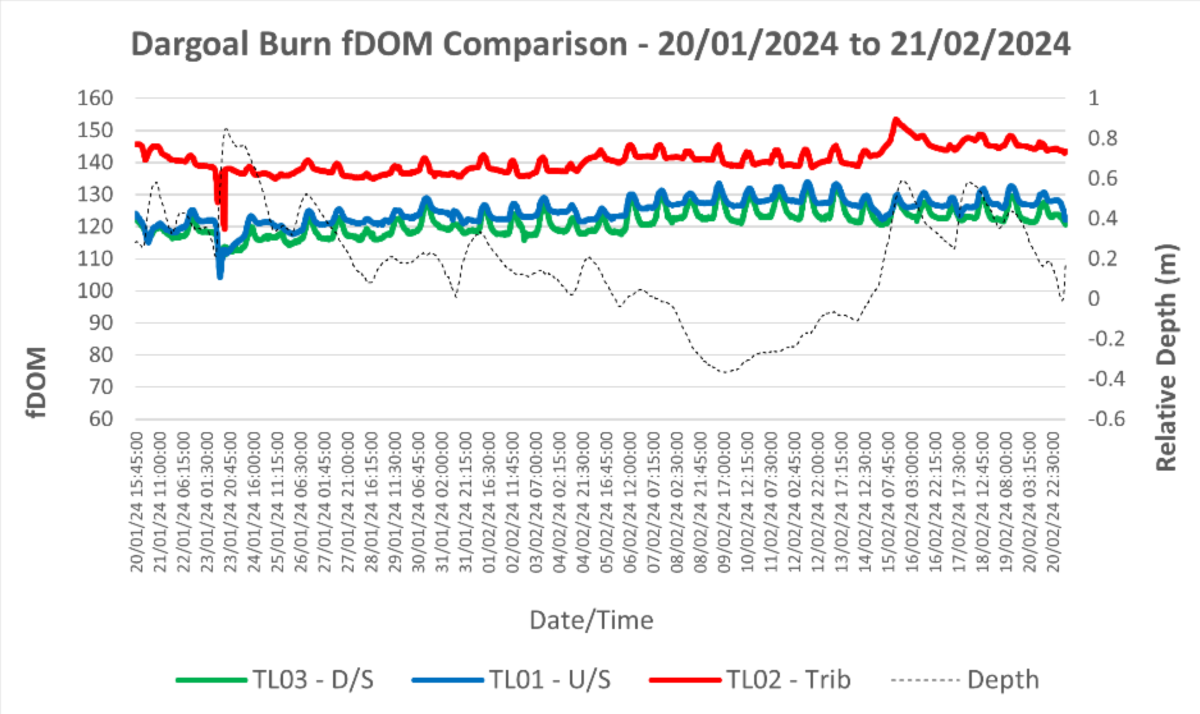
Graph 7: Comparison between fDOM and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2019/2020



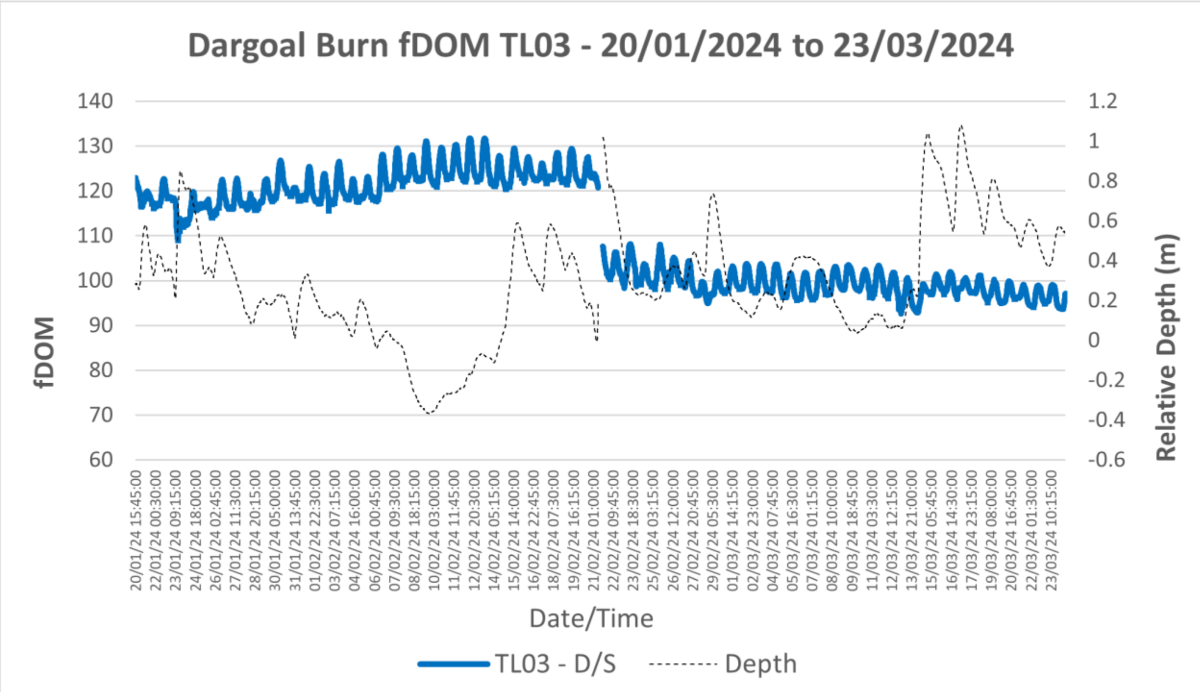
Graph 8: Comparison between fDOM and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2020/2021



Graph 9: Comparison between fDOM and relative water depth (m) at TL03 (downstream) on the Dargoal Burn during winter 2021/2022

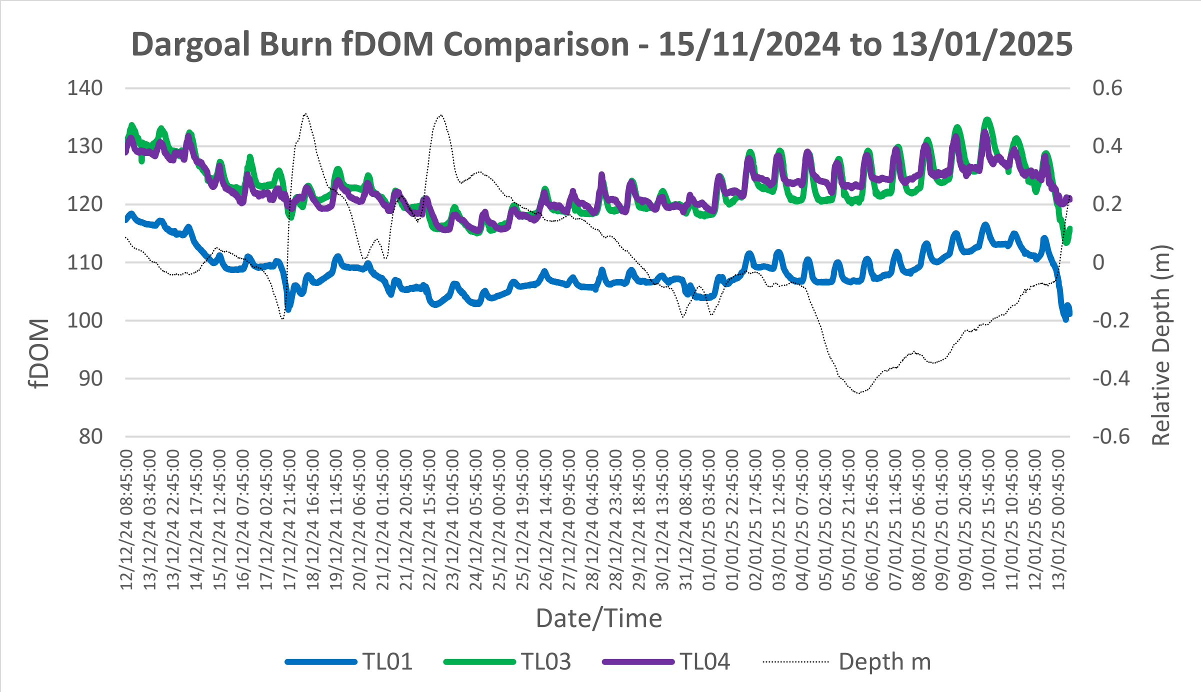


Graph 10: Comparison between fDOM and relative water depth (m) at TL01 (upstream), TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2023/2024

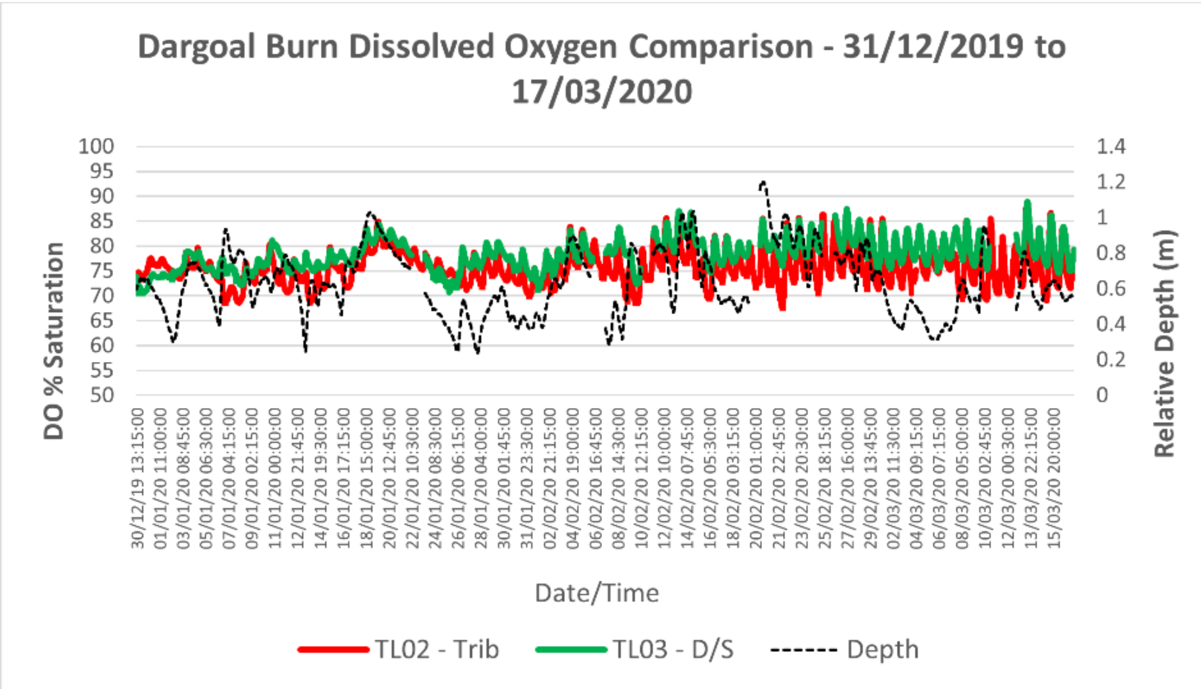


Graph 11: fDOM readings against relative depth for extended monitoring of Site TL03 (downstream) during winter 2023/2024

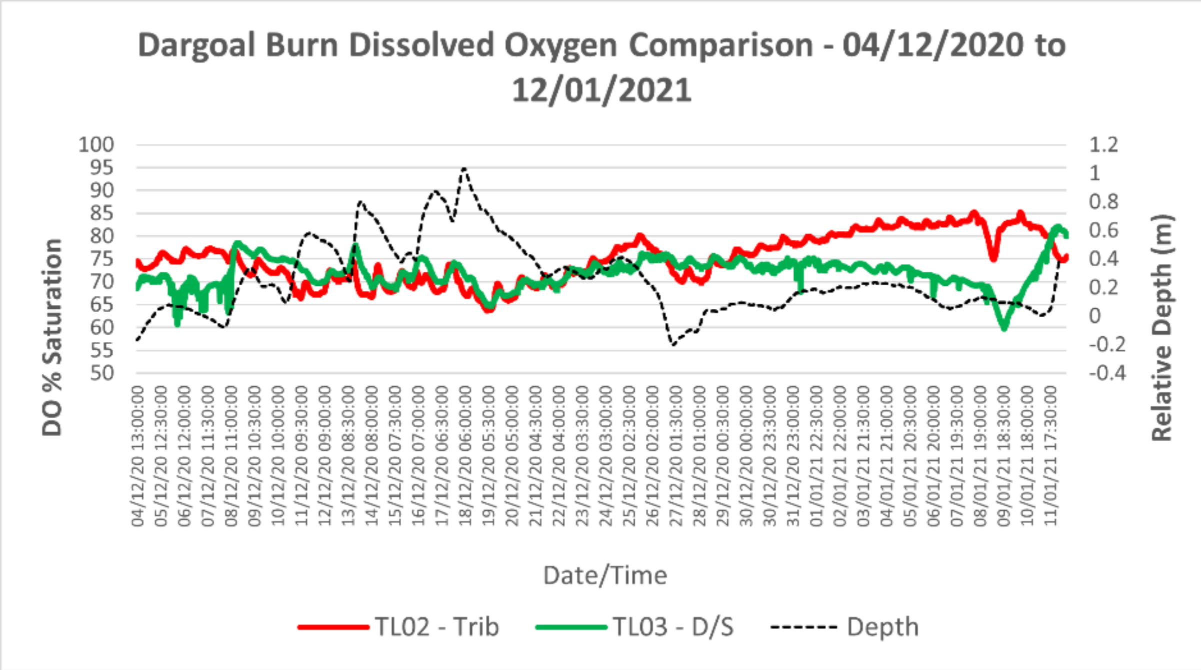
The drop in fDOM readings in Graph 11 during the latter recording period appears to be the result of a fDOM calibration issue as the data is inconsistent with all data recorded before or after this point.



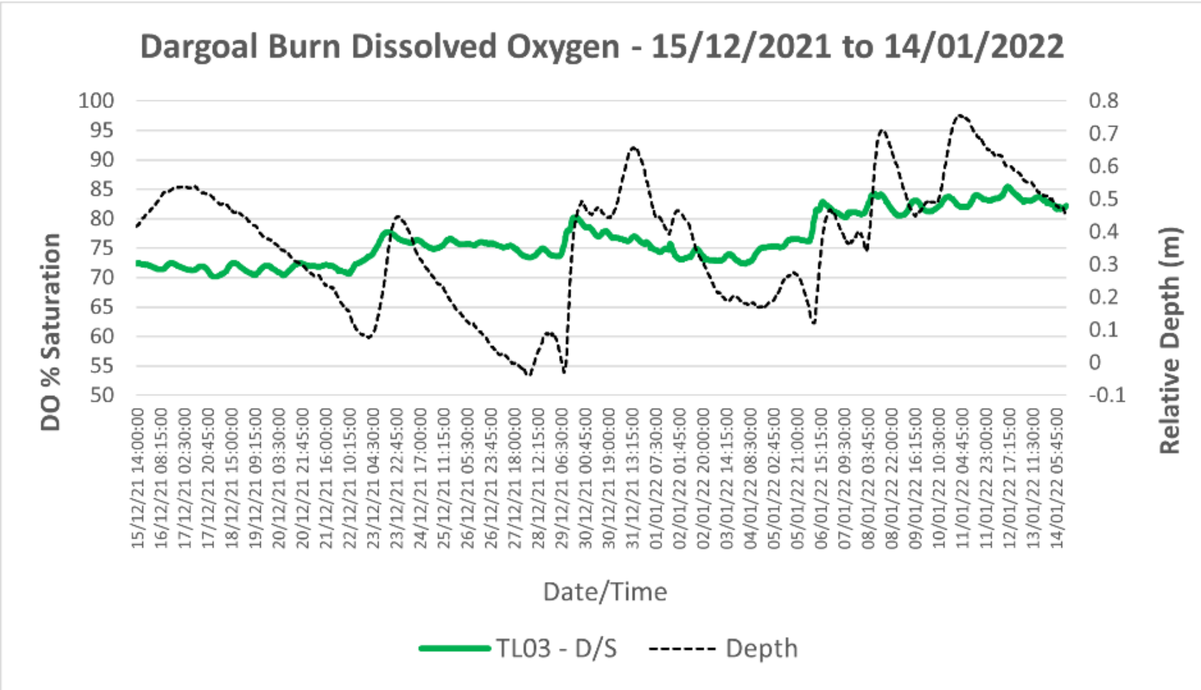
Graph 12: Comparison between fDOM and relative water depth (m) at TL01 (upstream), TL02 (tributary), TL03 (downstream) and TL04 (Lower Burn) on the Dargoal Burn during winter 2024/2025



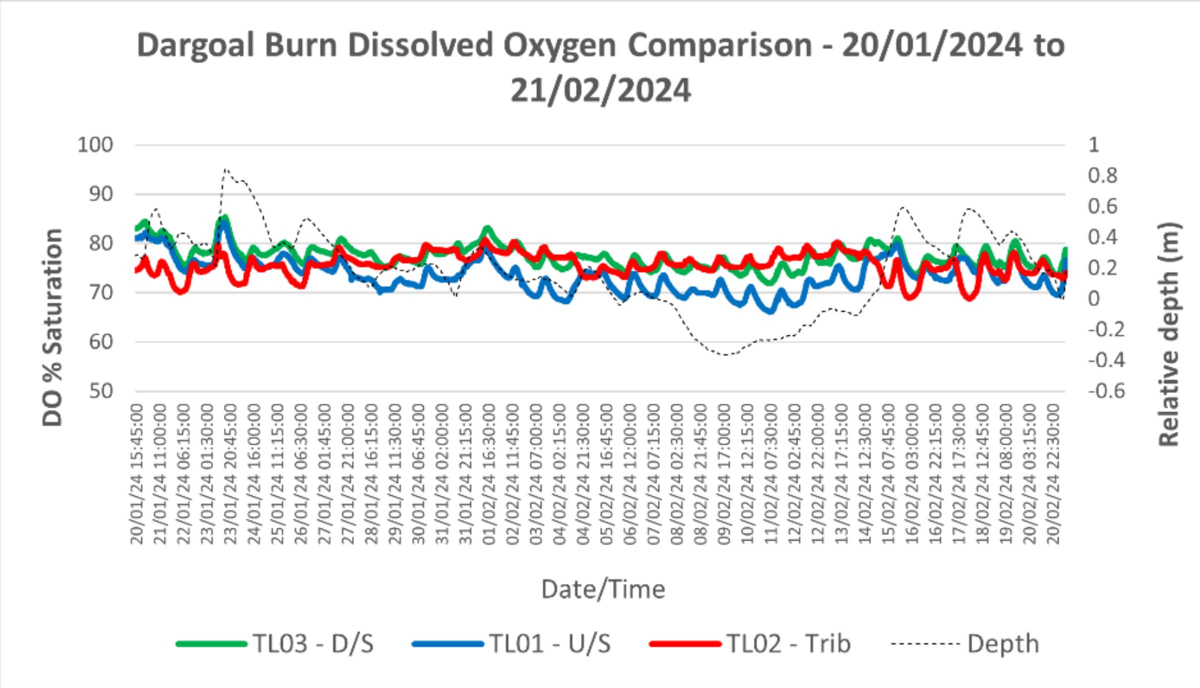
Graph 13: Comparison between Dissolved Oxygen and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2019/2020



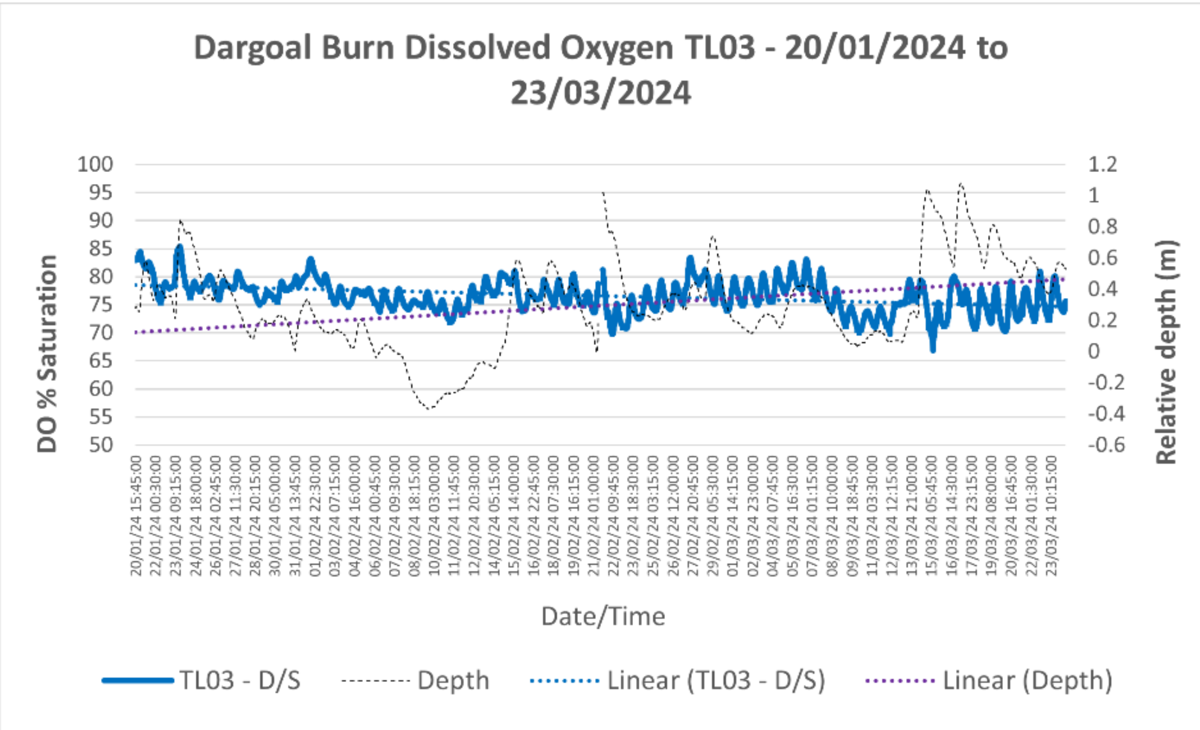
Graph 14: Comparison between Dissolved Oxygen and relative water depth (m) at TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2020/2021



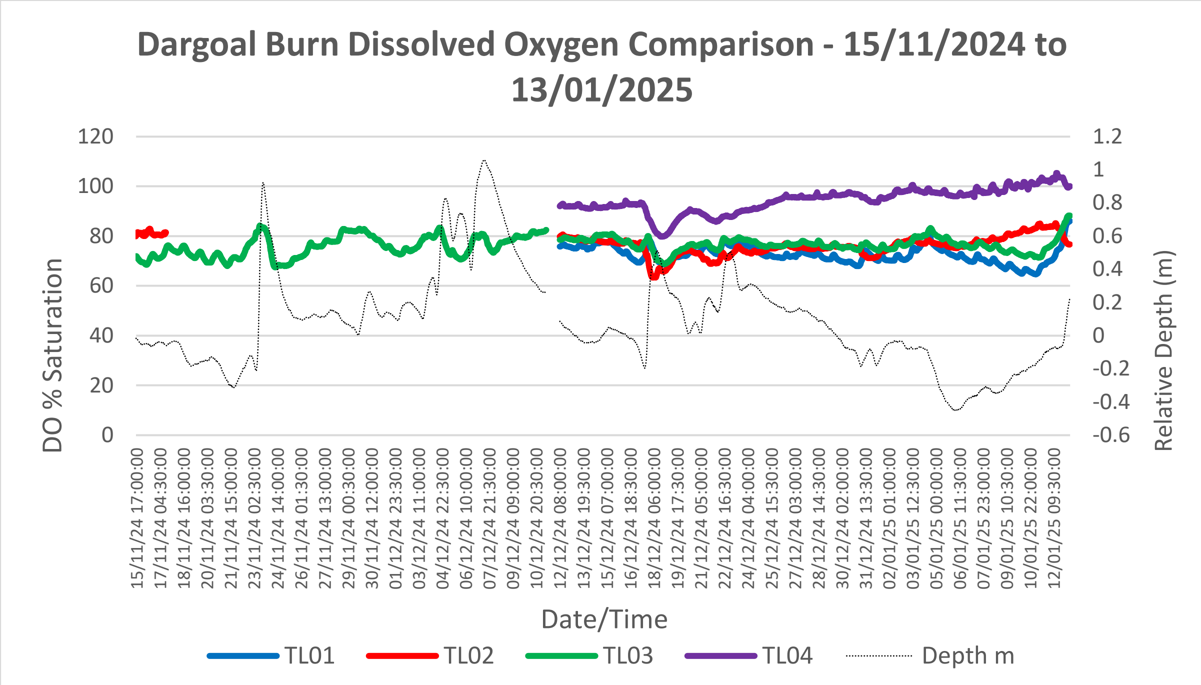
Graph 15: Comparison between Dissolved Oxygen and relative water depth (m) at TL03 (downstream) on the Dargoal Burn during winter 2021/2022



Graph 16: Comparison between Dissolved Oxygen and relative water depth (m) at TL01 (upstream), TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2023/2024



Graph 17: DO readings against relative depth for extended monitoring for Site TL03 (downstream) during winter 2023/2024



Graph 18: Comparison between Dissolved Oxygen and relative water depth (m) at TL01 (upstream), TL02 (tributary) and TL03 (downstream) on the Dargoal Burn during winter 2023/2024

Table 4: Dargoal Burn pH averages for each monitoring period

Site	Winter 2019/2020	Winter 2020/2021	Winter 2021/2022	Winter 2023/2024	Winter 2024/2025
TL01	-	-	-	4.00	3.93
TL02	4.11	4.37	-	4.17	4.11
TL03	4.03	4.24	3.98	4.09	3.99
TL04	-	-	-	-	4.00

Table 5: Dargoal Burn fDOM averages for each monitoring period

Site	Winter 2019/2020	Winter 2020/2021	Winter 2021/2022	Winter 2023/2024	Winter 2024/2025
TL01	-	-	-	124.9	108.6
TL02	86.1	90.54	-	140.7	
TL03	118.6	106.2	126.28	121.4	122.8
TL04	-	-	-	-	122.8

Table 6: Dargoal Burn Dissolved Oxygen (% saturation) averages for each monitoring period

Site	Winter 2019/2020	Winter 2020/2021	Winter 2021/2022	Winter 2023/2024	Winter 2024/2025
TL01	-	-	-	73.5	72.6
TL02	75.8	75.1	-	75.7	76.3
TL03	78.4	71.9	76.4	77.4	76.2
TL04	-	-	-	-	94.3

During the winter 2024/2025 (most recent) recording sites TL02 and TL03 were monitored between 15/11/2024 to 11/12/2024. They were then redeployed, along with sites TL01 and TL04 between 12/12/2024 and 13/01/2025. During the first recording there was a failure of the Dissolved Oxygen sensor after a couple of days deployment. This data has been omitted from the results. There was also an issue with fDOM reading from TL02 throughout both deployments, resulting in large variations in fDOM levels beyond anything recorded before. No definitive answer has been found for the issue as the sensor appears to be working. However, small lumps of peat were found within the sensor guard on the sonde and is possible that local scale gravel movements within the burn have resulted in changing flows depositing eroding peat into the sensor guard and impacting the sensor laser. As a result, the fDOM data from site TL02 has been omitted from the 2024/2025 monitoring.

A consistent pattern appears evident within the data. Whilst acidified, the pH in the Dargoal tributary (TL02) is typically less acidic than the pH in the Dargoal Burn, although only by a relatively small amount. This appears to have a minor diluting effect with the site above the tributary (TL01) being slightly more acidic that the downstream site (TL03). There also appears to be only very minor improvements in pH between the monitoring sites at TL01 and TL03 and the lower Dargoal Burn (TL04). Despite peatland restoration being underway at the current point in data collection the pH averages show no obvious sign of change with flow levels still being the most likely driver of the relatively small variations seen between years.

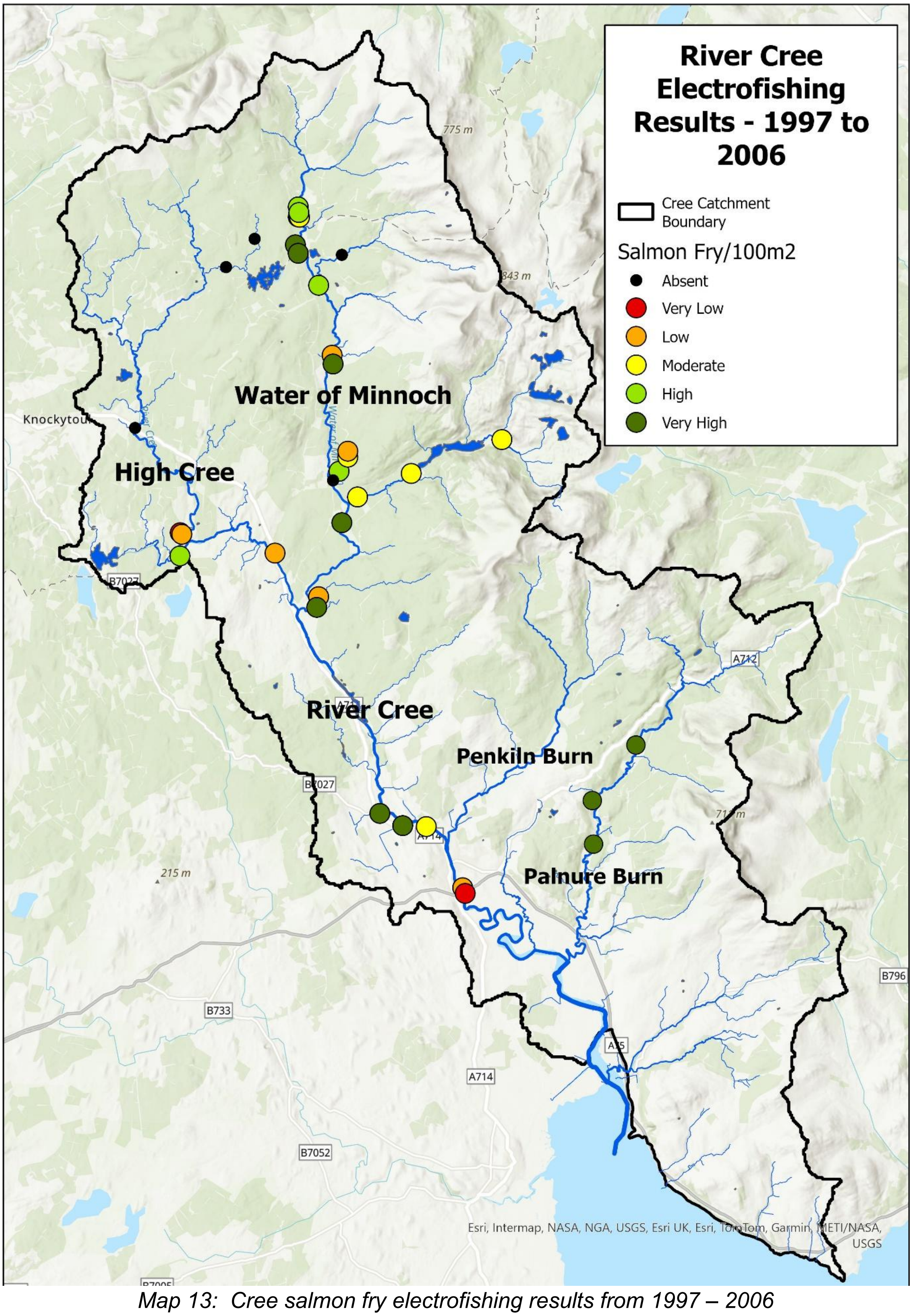
In contrast to the pH results the fDOM results show more variability between winters. It should also be noted that there are periods of recorded data from TL02 (tributary) during winter 2019/2020 and 2020/2021 where the results suddenly drop in a manner that is inconsistent with the other sites and years, suggesting a possible issue with the sensor at these points or insufficient depth. As such the fDOM averages for 2019/2020 and 2021/2022 should be taken with a “pinch of salt”, as should the results from the extended monitoring from early 2024 (Graph 11) for the same reasons. Looking at the Graphs, when considering the periods of reliable recording the fDOM results show no large-scale changes between years, except in the case of site TL02 (tributary) which recorded higher levels in 2024. This may be because of disturbance from the recently restored section of peatland (as that point in time). If this is the case, then levels should improve as the peatland settles, repairs and bog vegetation becomes re-established.

As has been described in previous reports, the relatively low Dissolved Oxygen levels in the Dargoal Burn remain a cause for concern for aquatic life, with the 2025 results continuing the trend of low levels being recorded. However, the results from TL04 show a significant oxygen re-saturation in the lower burn. This is likely because of the lower burn being shallower, steeper and faster flowing allowing for a significant level of re-oxygenation to take place. This means that the low oxygen levels are not directly impacting the Polbae Burn at the point at which the Dargoal Burn flows into it, at the time of year that recording took place.

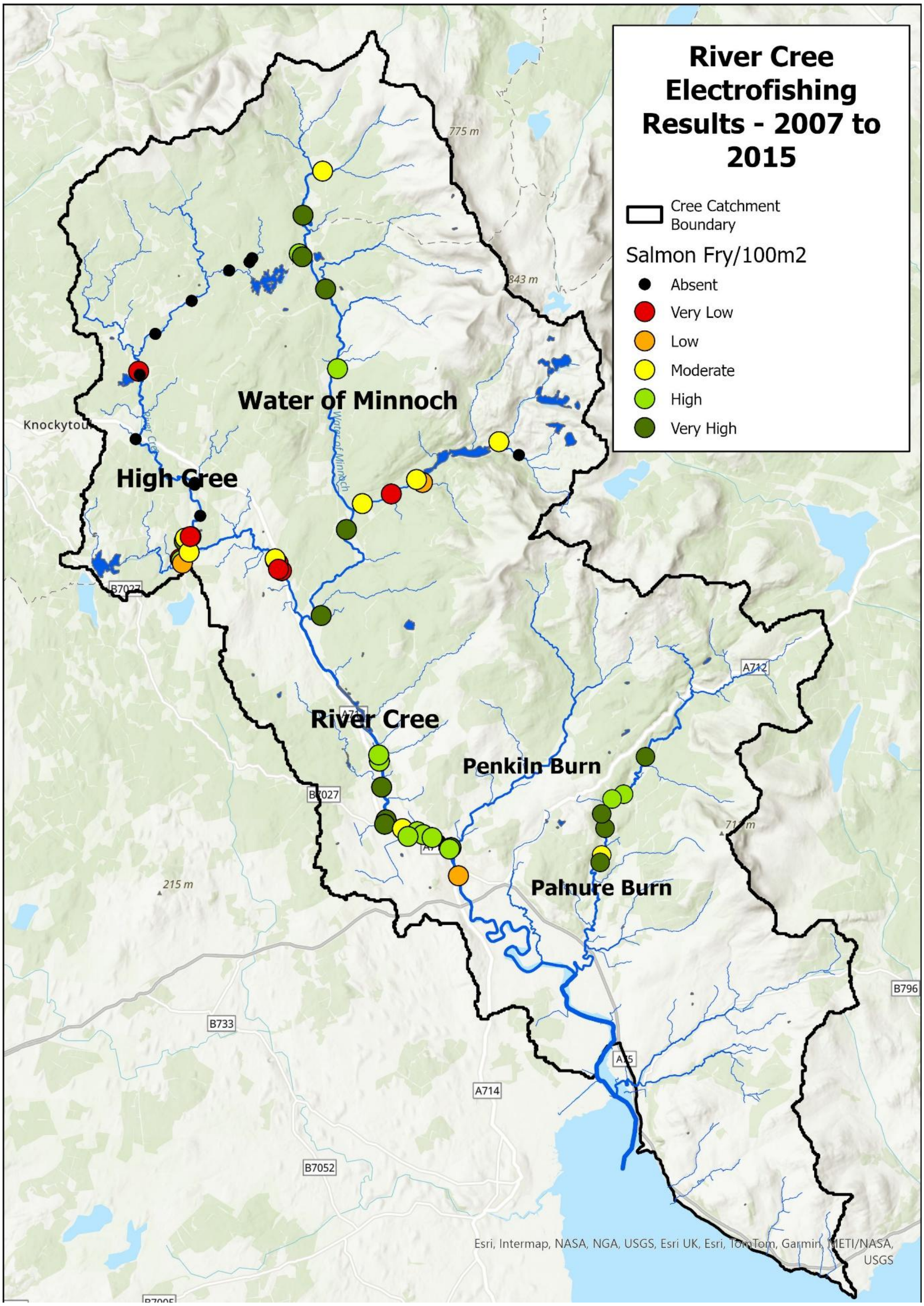
Although not having a significant impact on overall results daily fluctuations can be seen in several of the graphs. Whilst the exact reason for these fluctuations is unexplained at present, the day/night rhythm of the fluctuations would suggest the variations are related to temperature and/or biological activity.

3.2 River Cree electrofishing data review

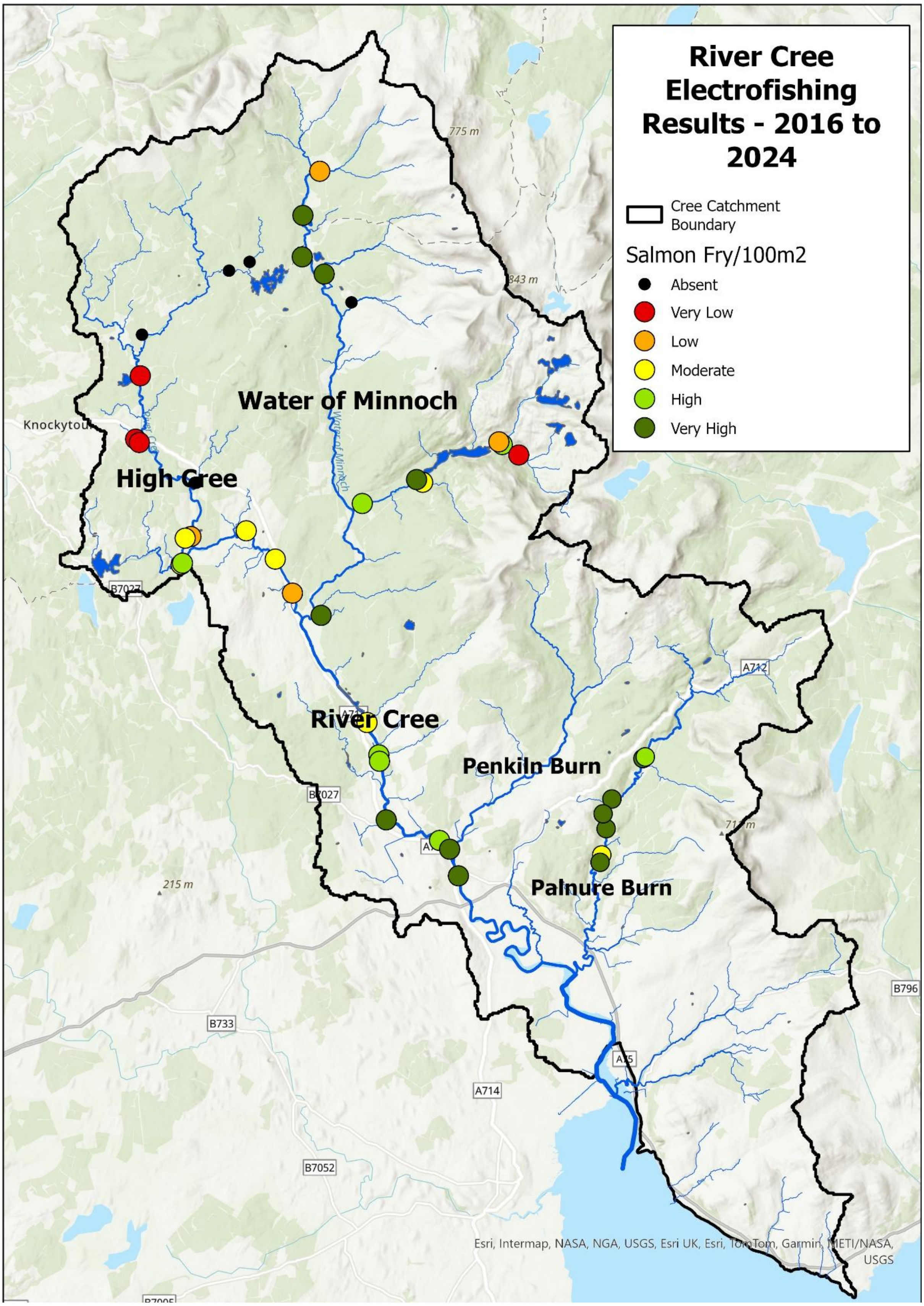
The salmon fry electrofishing results for the River Cree from the 1997 – 2006, 2007 – 2015 and 2016 - 2024 time periods are shown on Maps 13 to 15. Within the maps the electrofishing results have been displayed using the colour coding described in Section 2.2.



Map 13: Cree salmon fry electrofishing results from 1997 – 2006



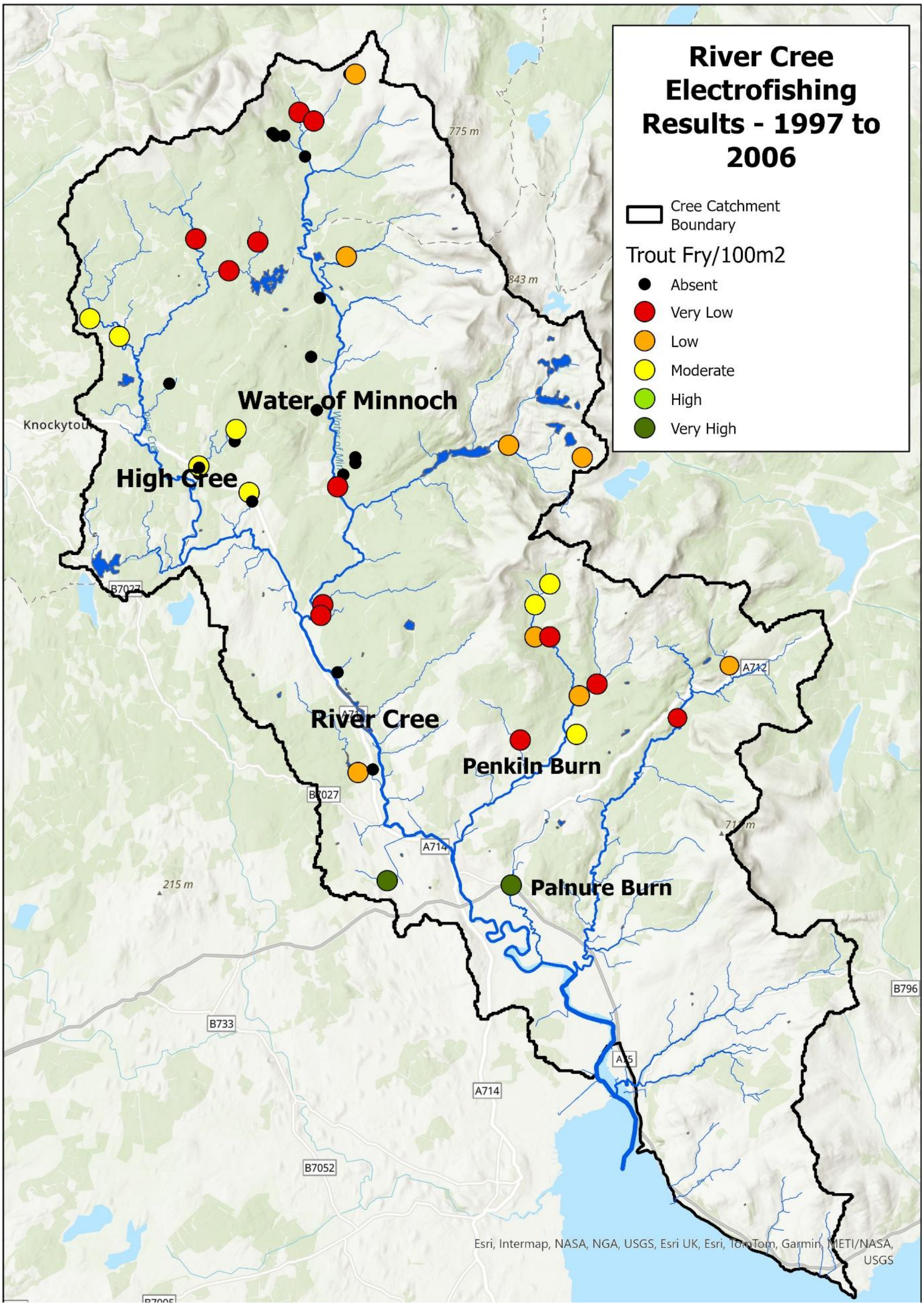
Map 14: Cree salmon fry electrofishing results from 2007 – 2015



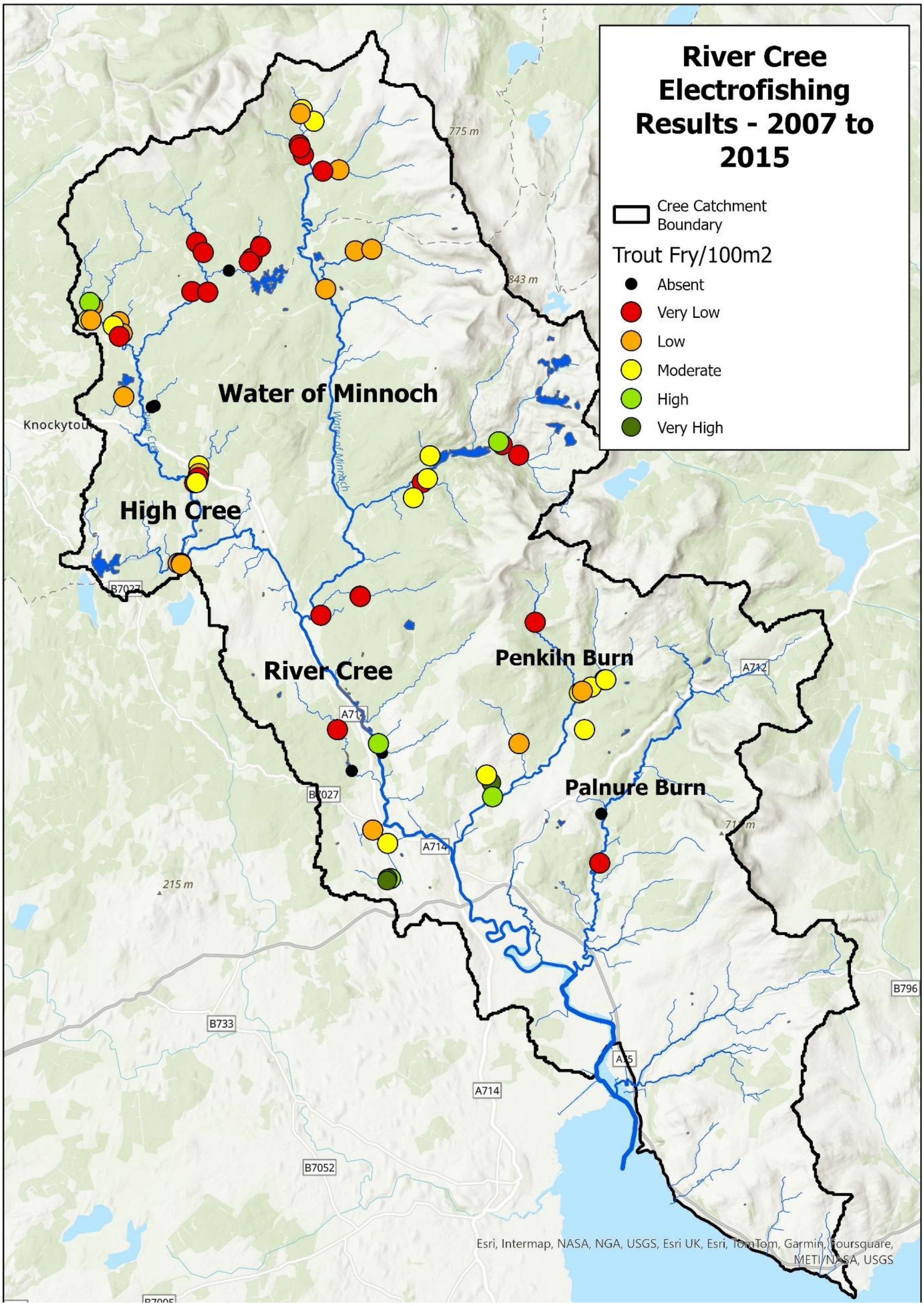
Map 15: Cree salmon fry electrofishing results from 2016 – 2024

As there may be different trends taking place in different parts of the catchment it is easiest to split the salmon fry electrofishing results into three major sections, the Cree, the High Cree and the Water of Minnoch. Looking at these three sections separately we see no obvious change in the salmon fry numbers from the main stem of the river Cree with results generally in the “Moderate” to “Very High” categories throughout. However, there is limited data from the earliest period and the two lowest sites from this period are at the tidal limit of the river which may be below the lower limit of salmon spawning. Likewise, there is no obvious change in the results from the Water of Minnoch with results from the main stem of the Minnoch also generally being in the “Moderate” to “Very High” categories, although again, differences in the locations of sites visited between each period may hide some variation, particularly in the 2016 to 2024 period where there are only three results for main stem sites. The last section, the High Cree shows consistently poor salmon fry results throughout. The exception to this is a relatively small section of the High Cree at Dalnaw where Galloway Fisheries Trust has added limestone gravel to mitigate the water quality impacts from acidification, increasing salmon egg survival as a result. This has not been included within this review as the point is to look at the current impacts of water quality resulting from land use on salmonid egg survival. As the limestone gravel mitigates against the impacts of acidification it has been removed from the results. While much of the main stem of the High Cree appears devoid of salmon fry there does appear to be some limited recovery within the very lower reaches of the river during the 2016 - 2024 period. However, numbers are still low and due to the difference in the location and number of sites between each recording period it is difficult to draw anything conclusive from the results. Salmon fry numbers from the Palnure Burn appear relatively good during all three recording periods.

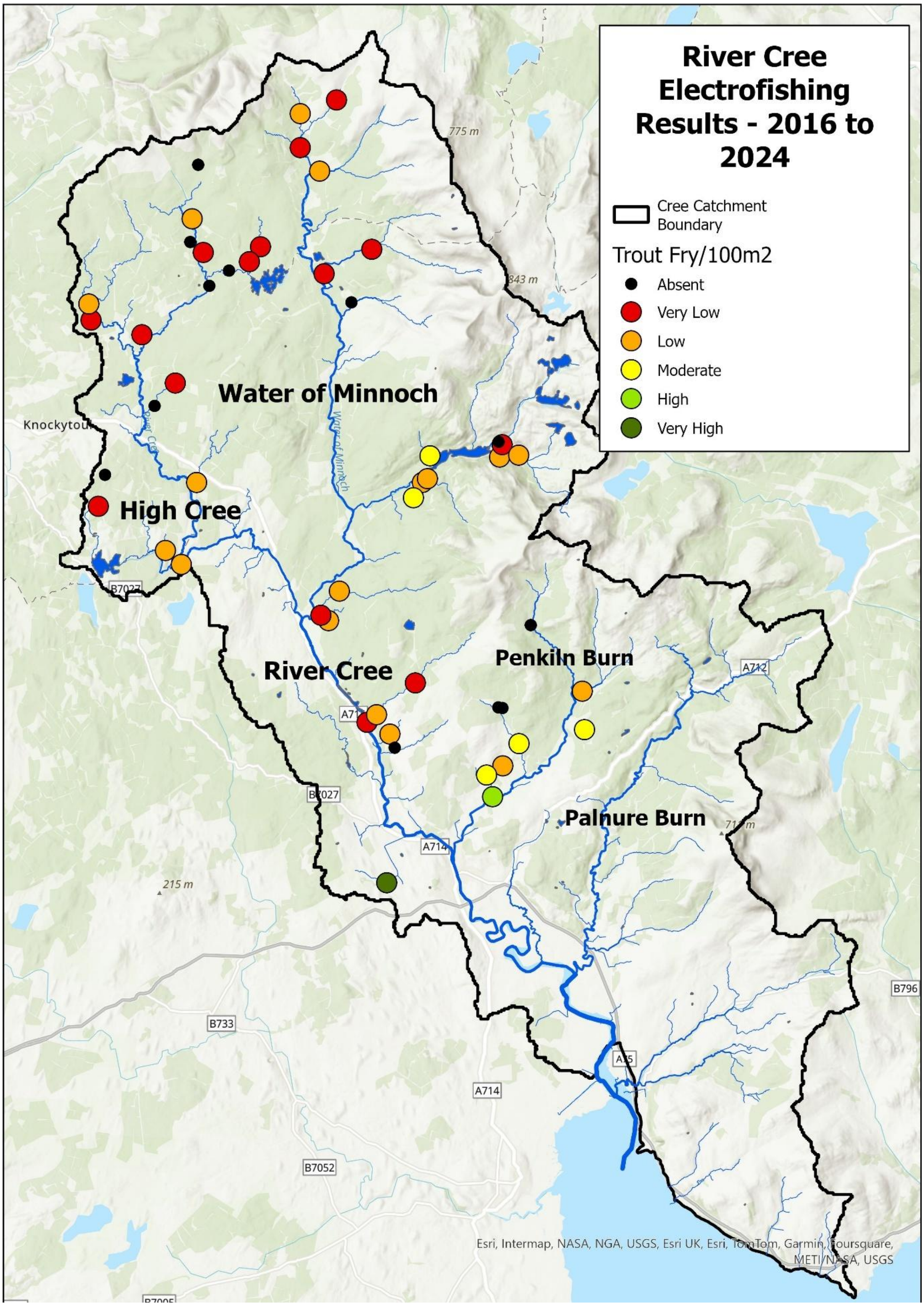
The trout fry results for the River Cree from the 1997 - 2006, 2007 - 2015 and 2016 - 2024 time periods are shown on Maps 16 to 18. Again, within the maps the electrofishing results have been displayed using the colour coding described in Section 2.2.



Map 16: Cree trout fry electrofishing results from 1997 – 2006



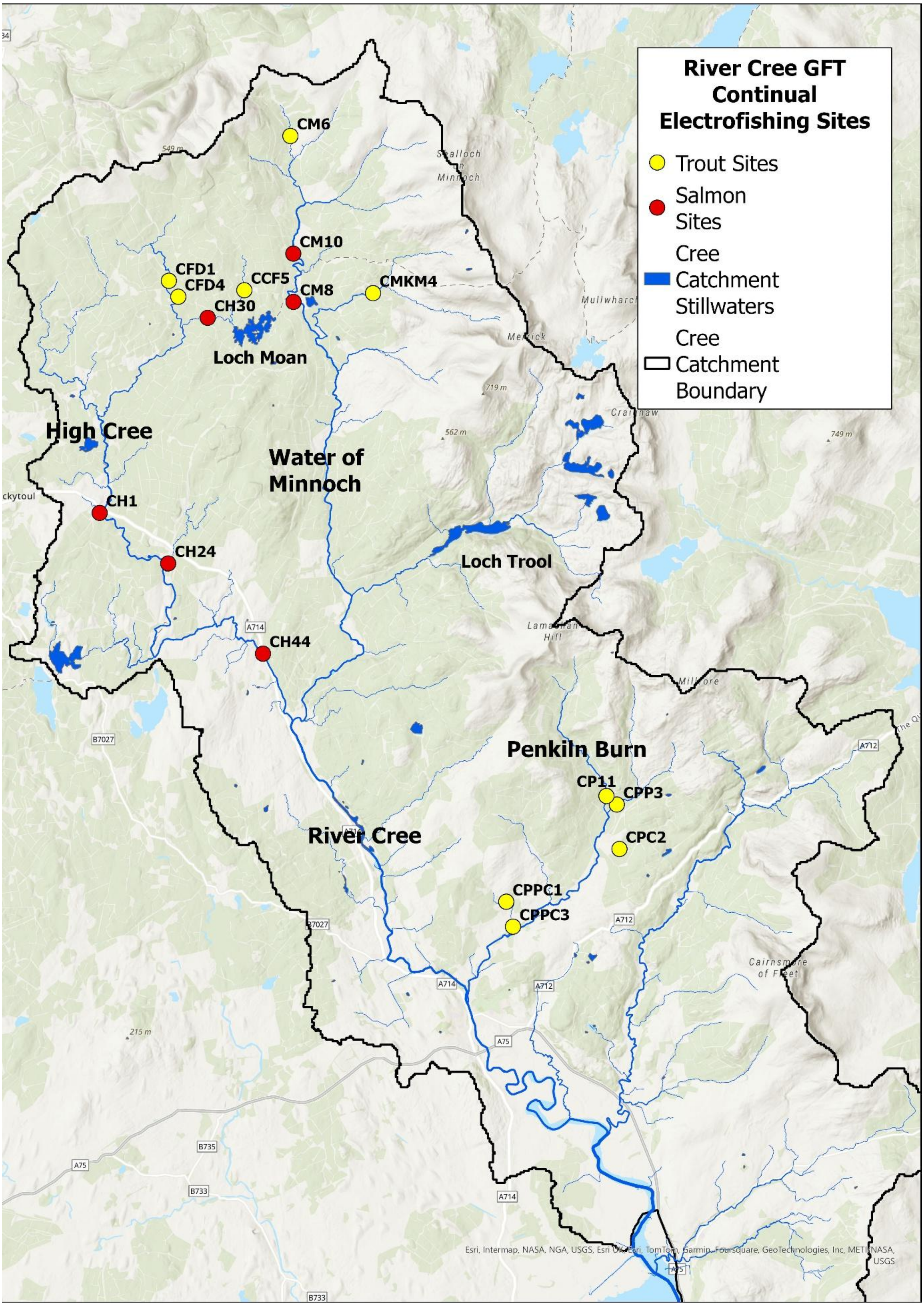
Map 17: Cree trout fry electrofishing results from 2007 – 2015



Map 18: Cree trout fry electrofishing results from 2016 – 2024

As with the salmon fry results, changes in the number and location of trout electrofishing sites between time periods makes it difficult to spot any obvious changes. In addition, the nature of the relationship between resident Brown trout and their marine migratory form, Sea trout, can also complicate results (by attaining a larger size at sea spawning populations dominated by female Sea trout will deposit far more eggs in the streambed than female Brown trout dominated populations). Looking at the results there is possibly a drop in trout fry numbers in burns flowing into the middle High Cree between the earliest period and the two latter periods, although the variation between “Moderate” and “Absent” results from this area in the earliest results makes it far from conclusive. There also appears to be an increase between the earliest period (1997 to 2006) and the latter two periods in the percentage of sites from the Penkiln Burn which score in the “Moderate” to “Very High” categories. This may be showing an improvement in water quality over time. However, this may be explained by the variation in the location of the sites between the three periods. What is clear is that most of the sites which produced “Moderate” to “Very High” trout fry numbers are in the lower Cree catchment and this has remained the case throughout all the GFT electrofishing surveys. Results from trout sized spawning burns are only available for the Palnure Burn in the earliest of the three recording periods. They are located towards the very top of the system and show relatively low fry numbers.

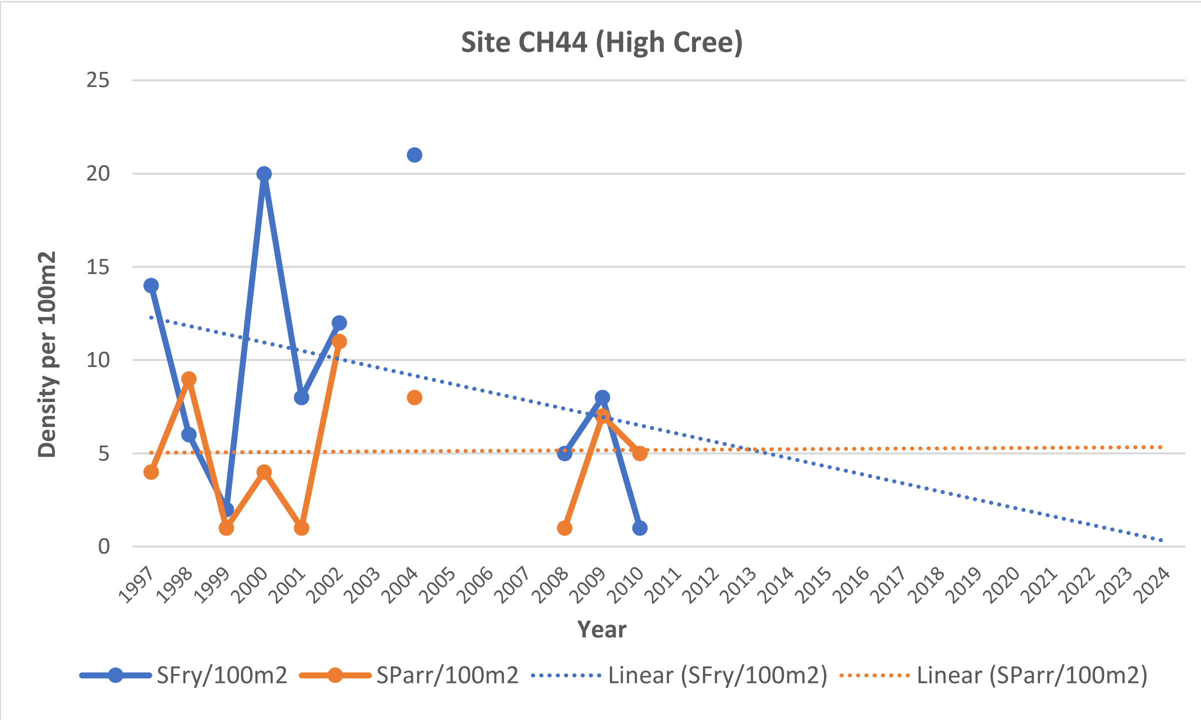
Within the electrofishing results there are several sites that have been visited repeatedly since electrofishing began. Sites with six or more years of data have been analysed. Juvenile trout or salmon results (or both) are shown depending on which should be/is the dominant spawning species within the areas surveyed. Map 19 shows the location of the sample sites, Table 7 gives the site information, and the results are displayed on Graphs 19 to 34. Within the results juvenile salmon sites are shown first followed by trout fry results. Both juvenile trout and salmon results are shown from Site CH30 on the High Cree. It should be noted that the period over which each individual site was surveyed varies and, as such, recording at some sites misses out the earlier, or later, time periods.



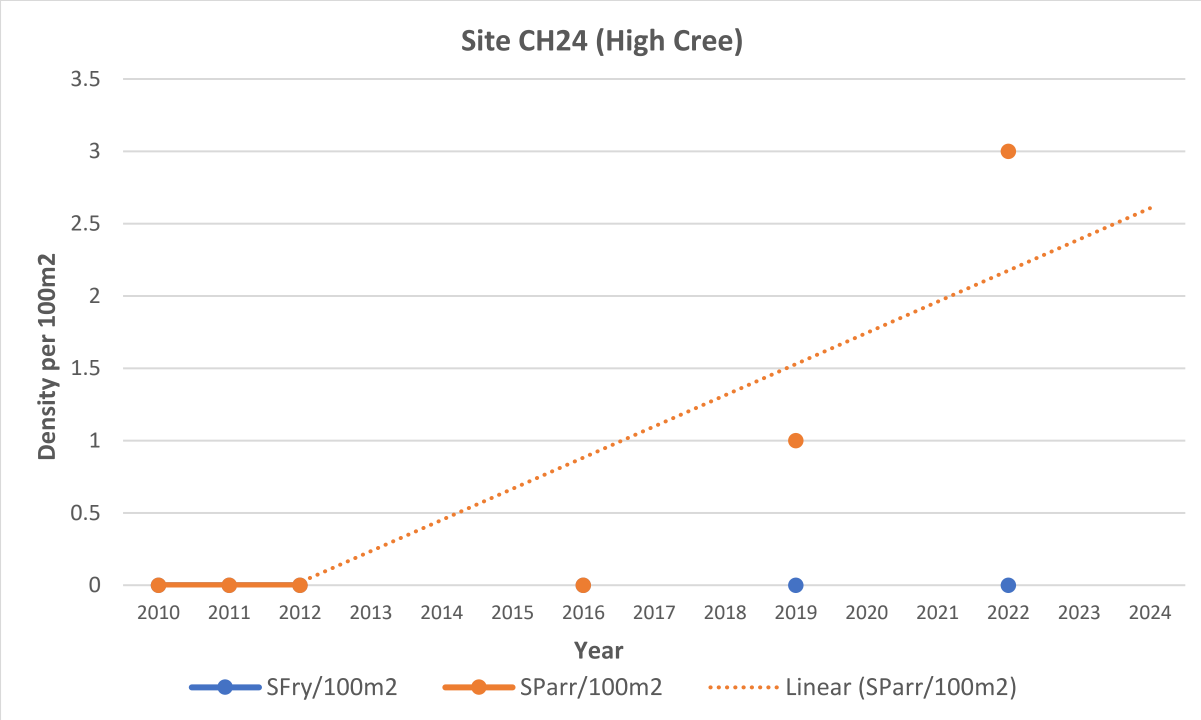
Map 19: Locations of electrofishing sites with six or more years of electrofishing data

Table 7: Location details for electrofishing sites with six or more years of electrofishing data

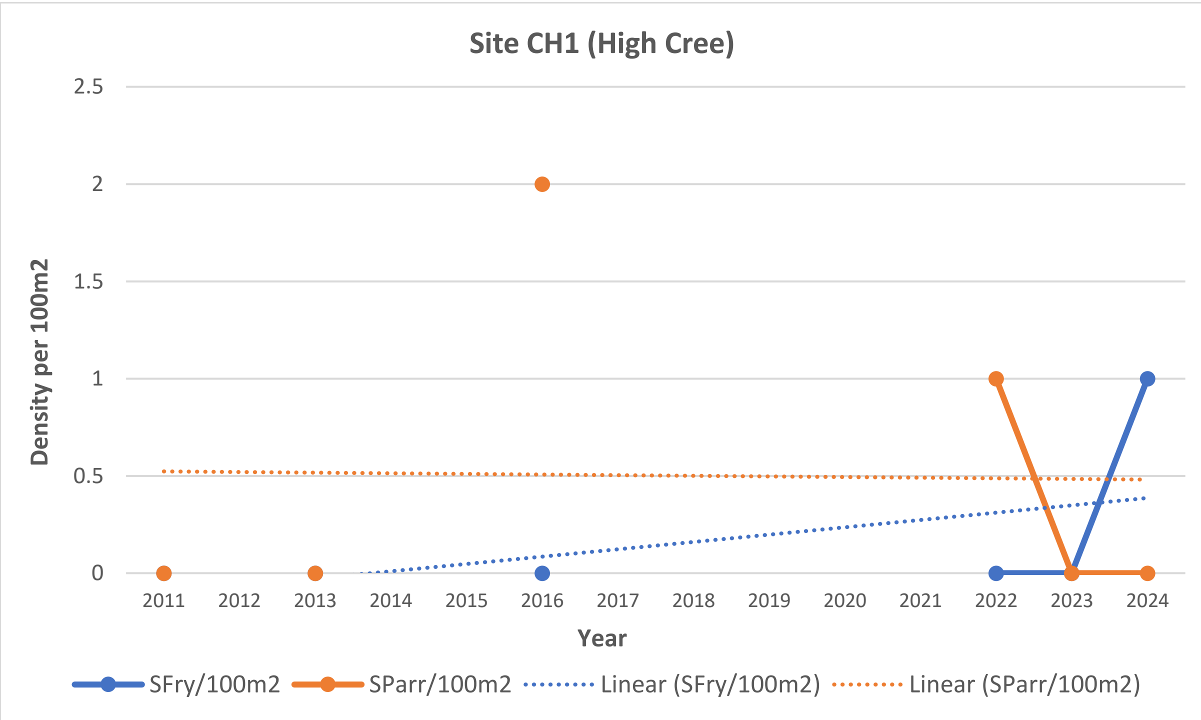
Site Code	Easting	Northing	River Order 1	River Order 2	River Order 3
CH44	235037	576286	*River Cree*	*High Cree*	
CH24	232260	578930	*River Cree*	*High Cree*	
CH1	230255	580412	*River Cree*	*High Cree*	
CH30	233420	586130	*River Cree*	*High Cree*	
CM8	235931	586595	*River Cree*	*Water of Minnoch*	
CM10	235924	588008	*River Cree*	*Water of Minnoch*	
CPPC1	242159	569011	*River Cree*	*Penkiln Burn*	*Pulcree Burn*
CPPC3	242360	568281	*River Cree*	*Penkiln Burn*	*Pulcree Burn*
CPC2	245400	571861	*River Cree*	*Penkiln Burn*	*Campbell's Burn*
CPP3	245477	570557	*River Cree*	*Penkiln Burn*	*Pulbae Burn*
CP11	245098	572113	*River Cree*	*Penkiln Burn*	
CFD4	232552	586745	*River Cree*	*High Cree*	*Fardin Burn*
CFD1	232281	587212	*River Cree*	*High Cree*	*Fardin Burn*
CCF5	234490	586940	*River Cree*	*High Cree*	*Cairnfore Burn*
CMKM4	238259	586852	*River Cree*	*Water of Minnoch*	*Kirriemore Burn*
CM6	235841	591459	*River Cree*	*Water of Minnoch*	



Graph 19: Single run salmon fry and parr densities for electrofishing site CH44



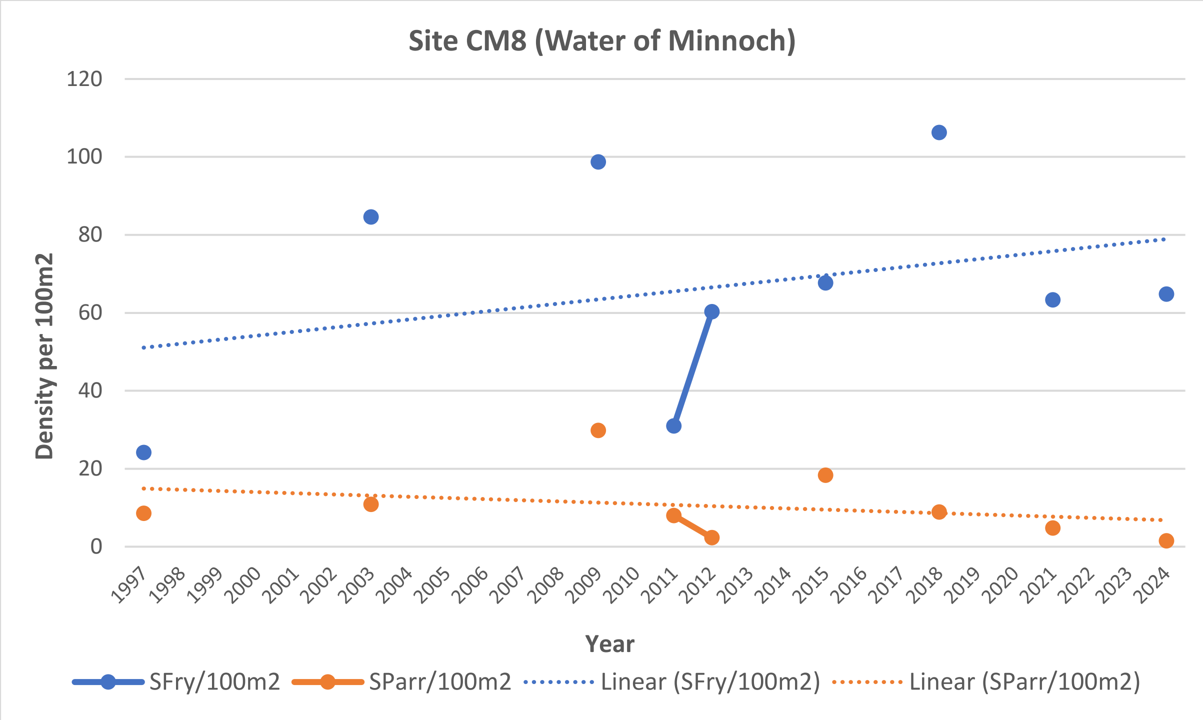
Graph 20: Single run salmon fry and parr densities for electrofishing site CH24



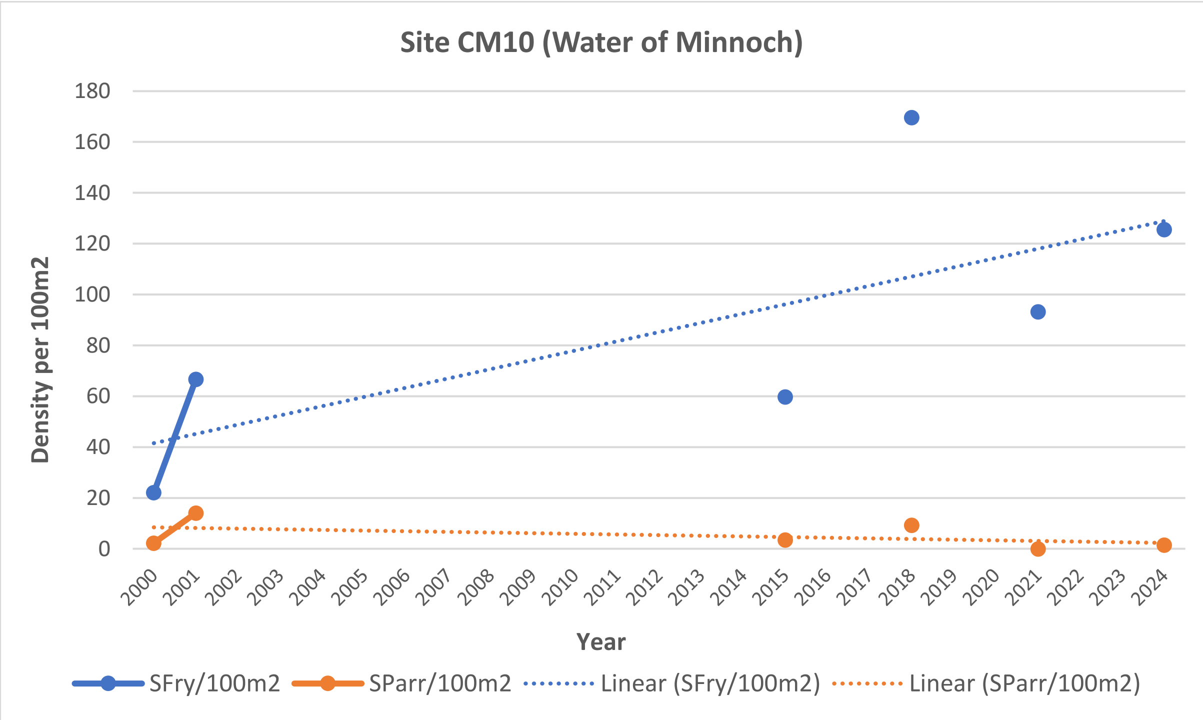
Graph 21: Single run salmon fry and parr densities for electrofishing site CH1

Site CH30 (High Cree): No salmon fry or par were recorded at any time from this site (electrofishing took place during 1997, 2006, 2008, 2010, 2011, 2012 2016, 2019 and 2022).

The results from the High Cree monitoring sites show varying trends in trout fry numbers and stable or improving trends in salmon parr. However, all the fry and parr densities recorded are at relatively low levels.

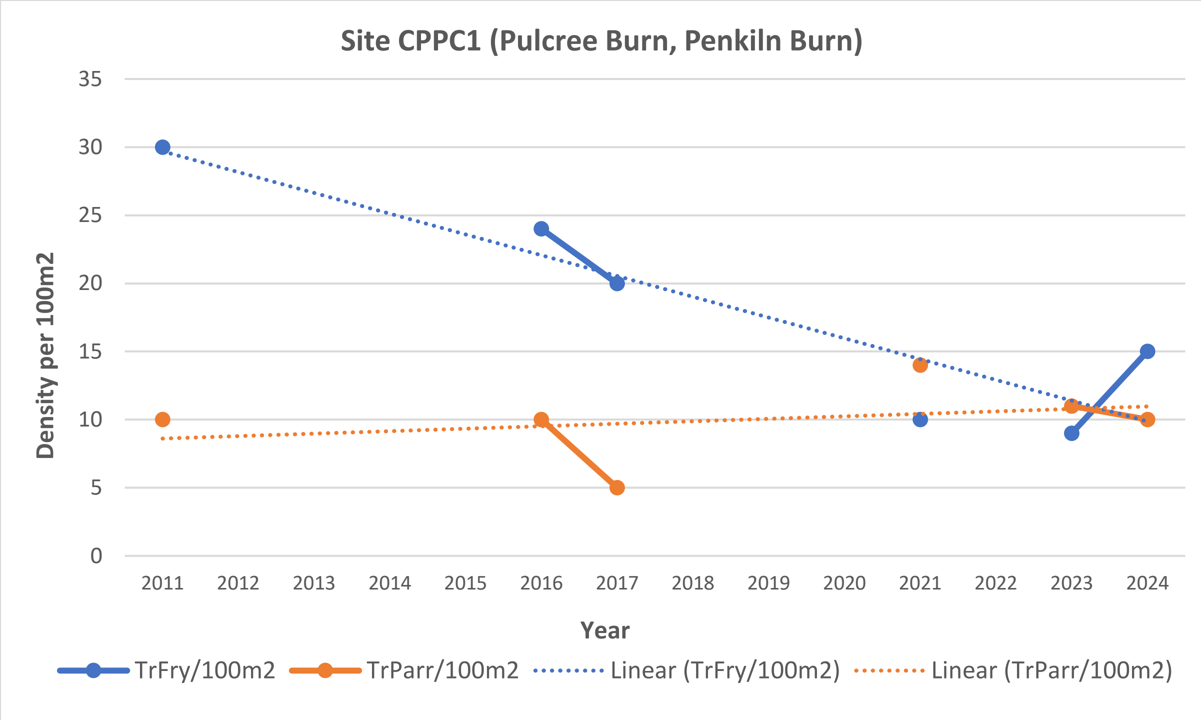


Graph 22: Single run salmon fry and parr densities for electrofishing site CM8

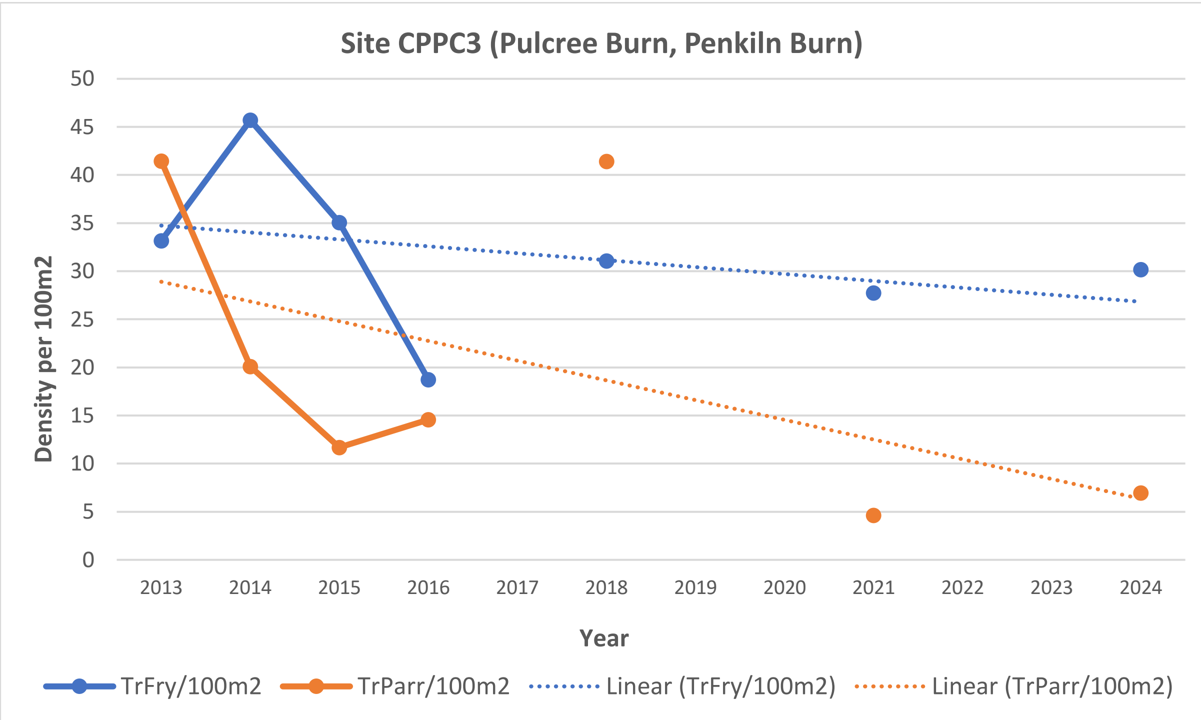


Graph 23: Single run salmon fry and parr densities for electrofishing site CM10

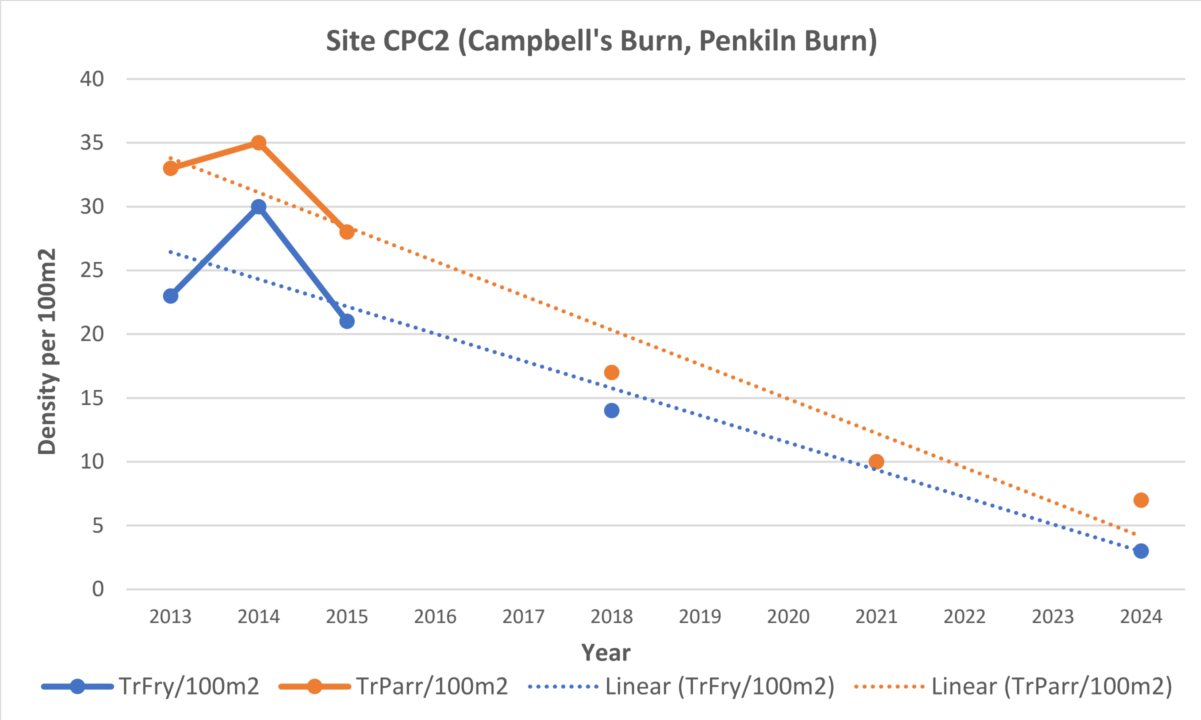
The two juvenile salmon sites on the Water of Minnoch show relatively similar trends over relatively similar time periods. Each show increases in fry numbers, slight decreases in parr numbers and relatively good juvenile numbers overall. It is impossible to say for sure why we see the trends seen in fry and parr numbers. Fry numbers are relatively high at both sites indicating few, if any, impacts resulting from reduced water quality.



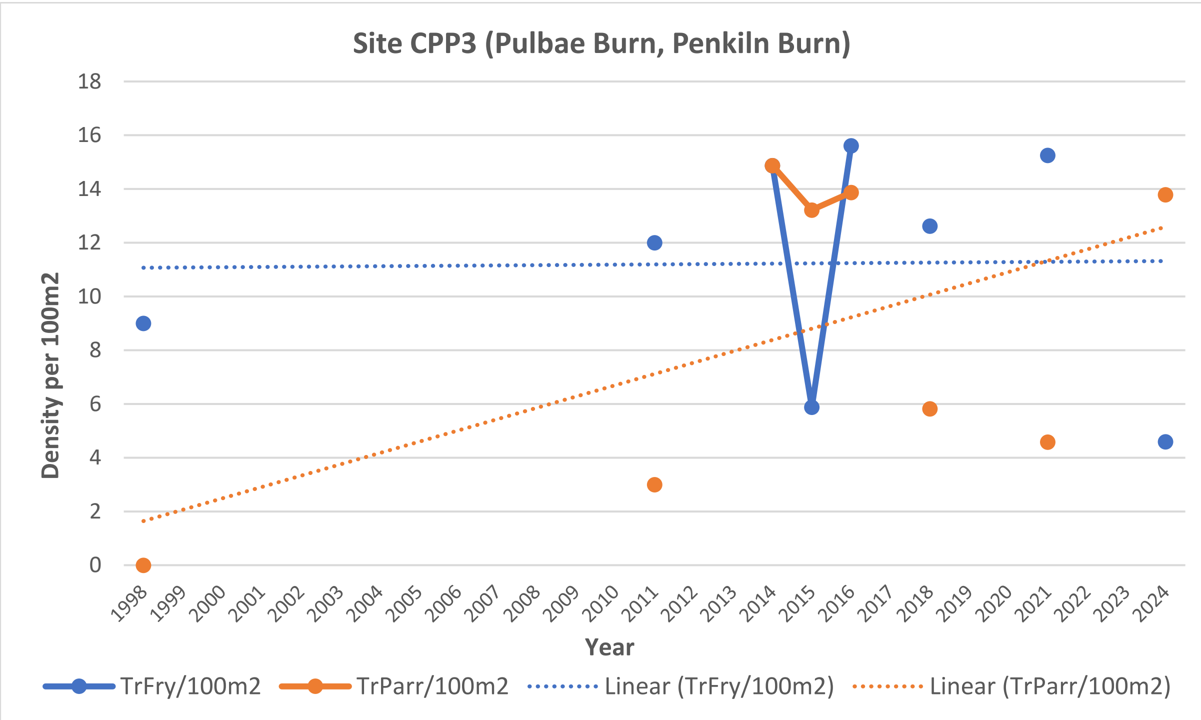
Graph 24: Single run trout fry and parr densities for electrofishing site CPPC1



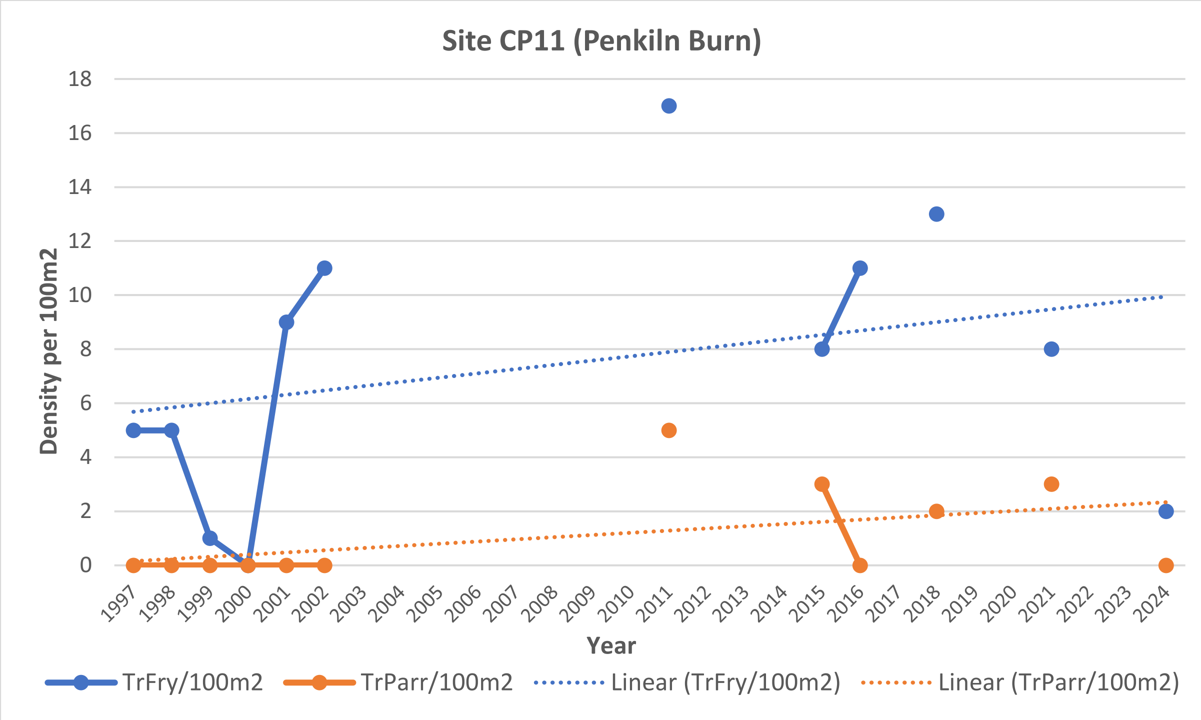
Graph 25: Single run trout fry and parr densities for electrofishing site CPPC3



Graph 26: Single run trout fry and parr densities for electrofishing site CPC2

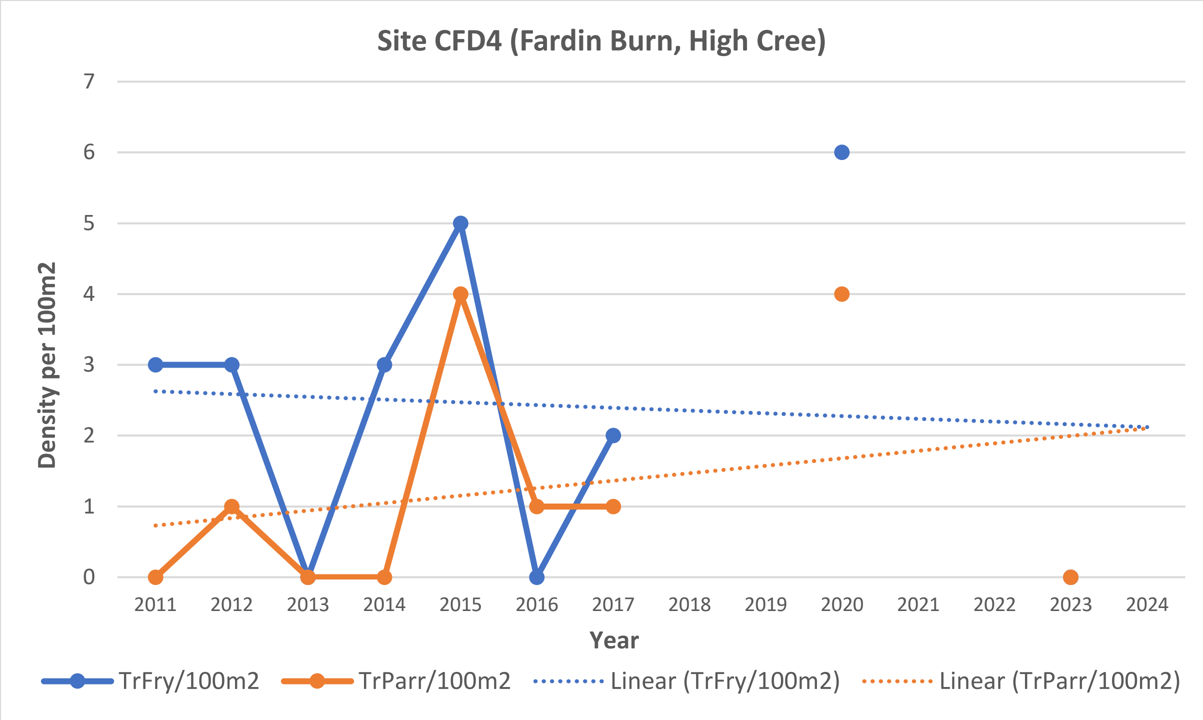


Graph 27: Single run trout fry and parr densities for electrofishing site CPP3

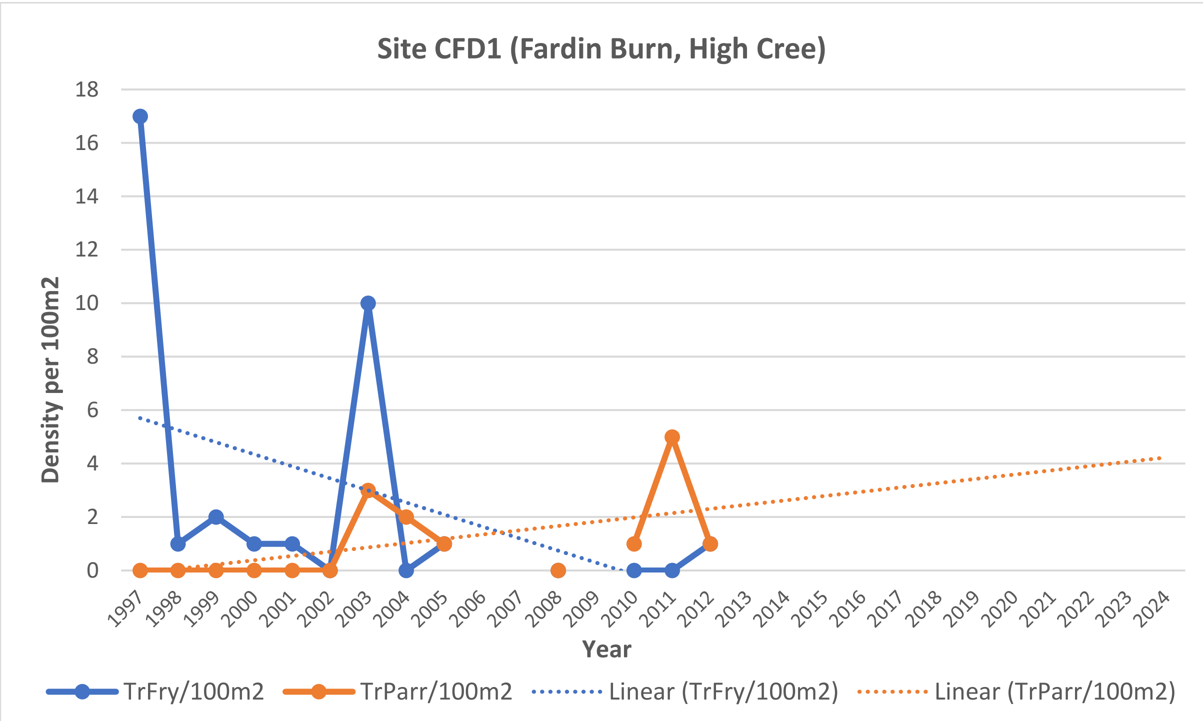


Graph 28: Single run trout fry and parr densities for electrofishing site CP11

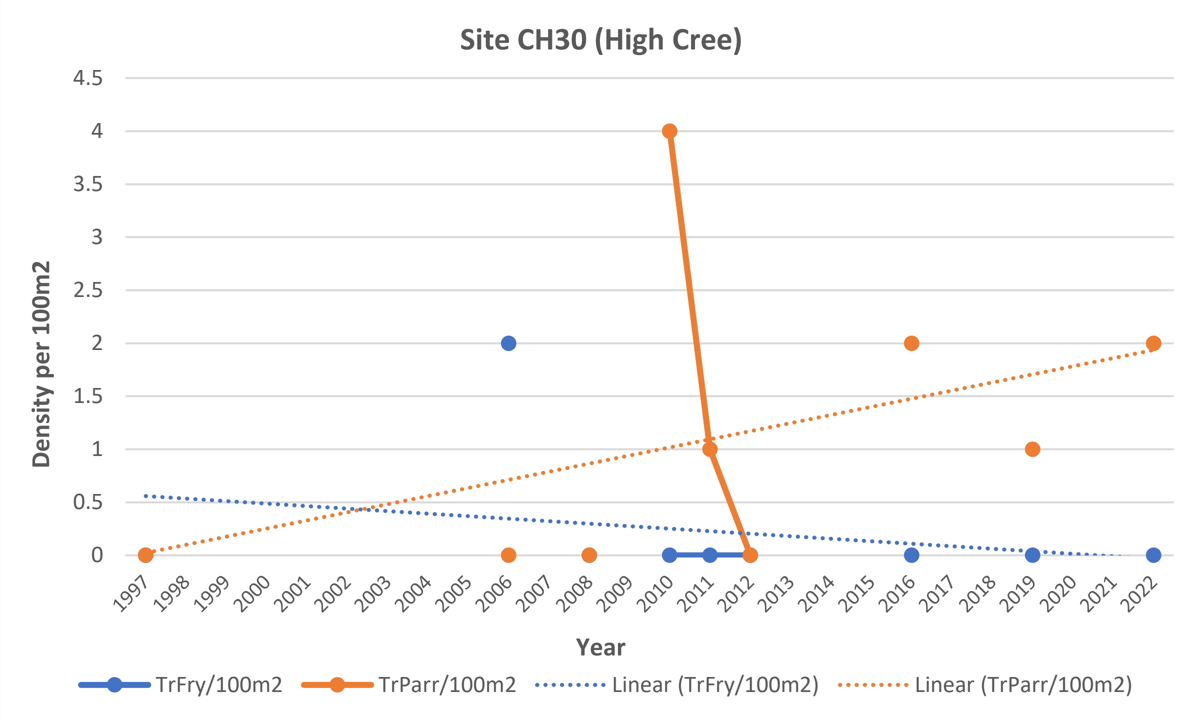
The trout fry and parr results from burns flowing into the Penkiln Burn show contrasting trends. Trout fry numbers are showing a declining trend at the three sites in which monitoring began in the 2010's, but are stable or improving at the two sites where recording began in the late 1990's. Trout parr numbers show a similar trend with declining or stable results from the sites where recording began in the 2010's and an overall improving trend from the two sites where recording began earlier. In terms of juvenile densities, the results from all four sites show a variation between relatively poor and relatively good juvenile numbers. It should be noted that Sea trout rod catches from Scottish Solway rivers unimpacted by acidification indicate a sharp decline in adult Sea trout numbers from the year 2000 onwards (*Fisheries Management Scotland: Fisheries Management Plan Story Maps; 2023*) indicating a reduction in Sea trout survival in the marine environment. If egg deposition in the Penkiln Burn is dominated by female Sea trout then the juvenile trout electrofishing results could indicate initial improvements since the 1990's (potentially) associated with improving water quality), followed by a reduction in egg deposition post 2000 because of a reduction in sea survival.



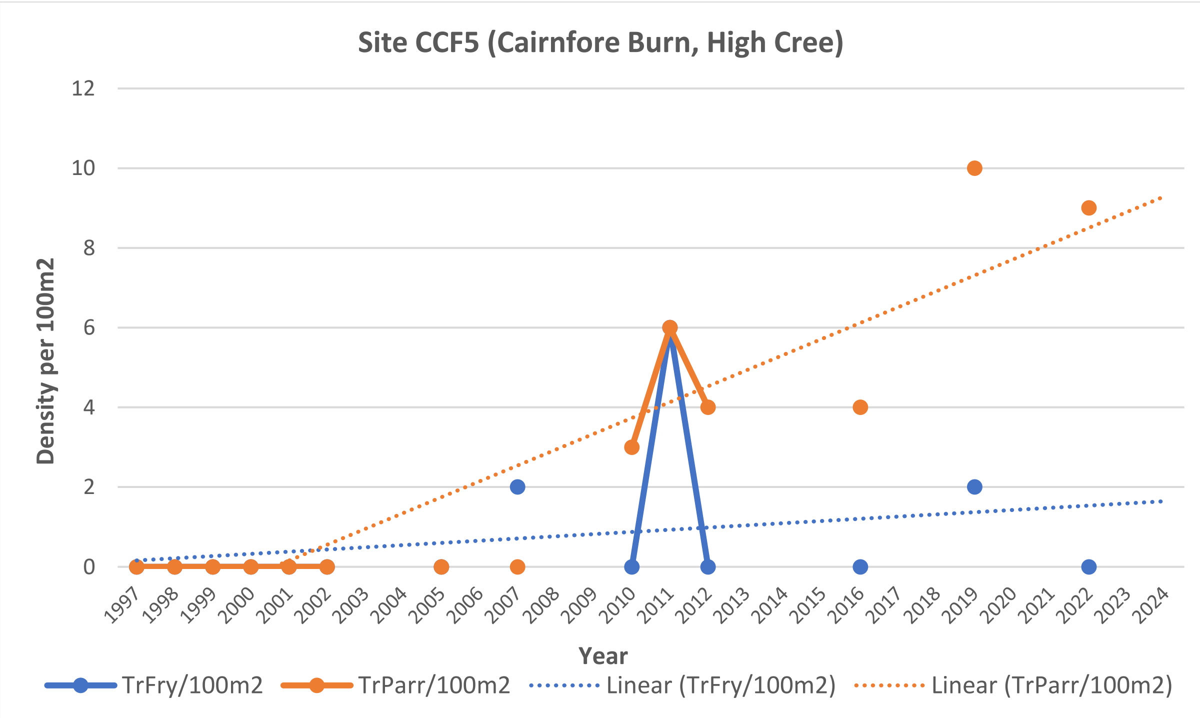
Graph 29: Single run trout fry and parr densities for electrofishing site CFD4



Graph 30: Single run trout fry and parr densities for electrofishing site CFD1

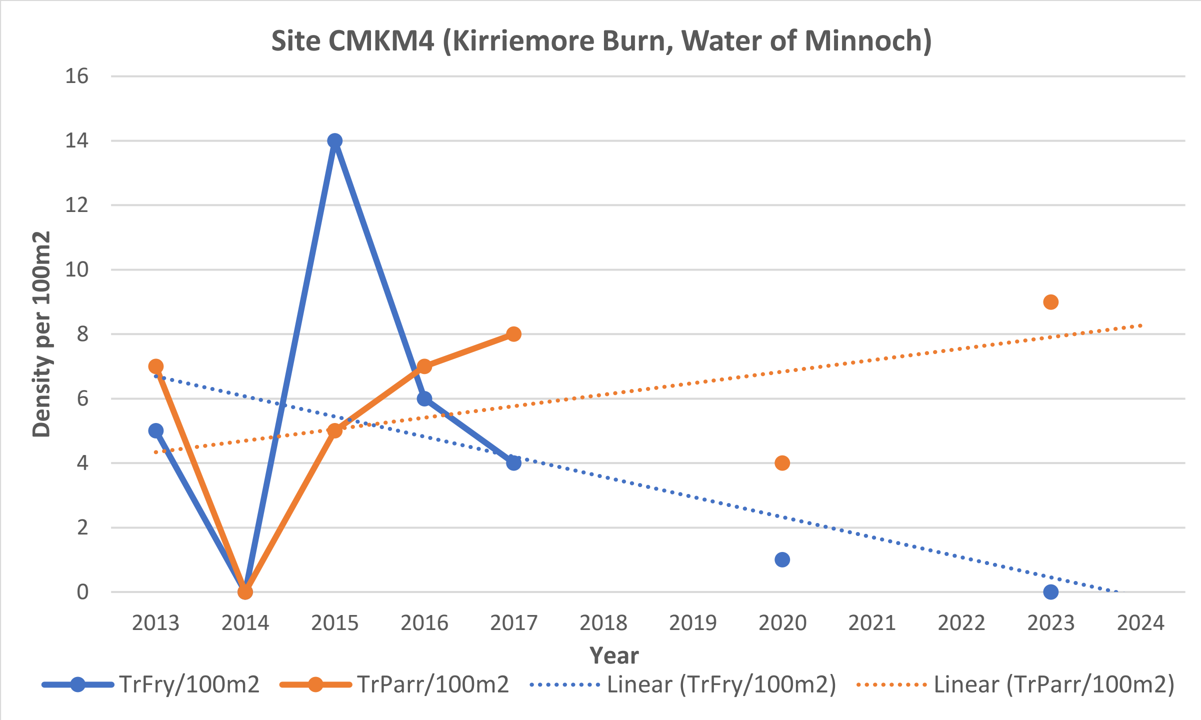


Graph 31: Single run trout fry and parr densities for electrofishing site CH30

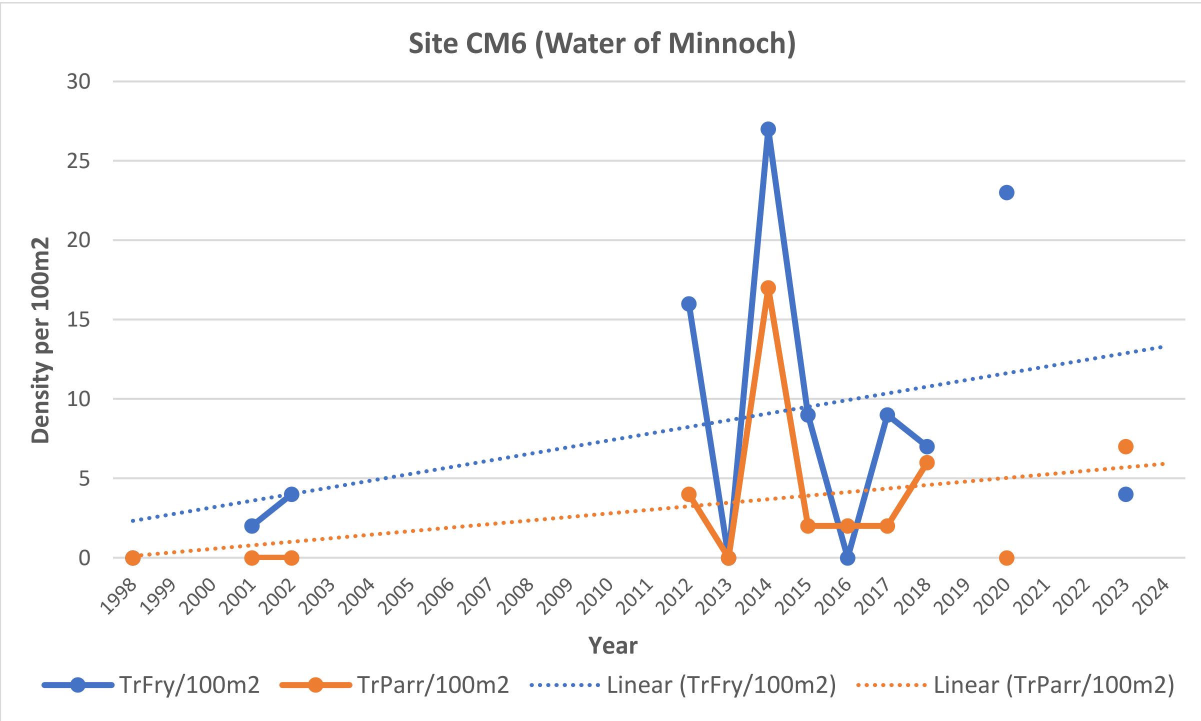


Graph 32: Single run trout fry and parr densities for electrofishing site CCF5

The results from the upper High Cree and its tributaries all show relatively low or absent trout fry and parr numbers, showing the extent of the impact of acidification in these areas and how badly it persists to the present day. Despite the low numbers we do see trends within the data, with fry numbers generally declining and parr numbers generally improving. This may indicate some minor improvements in water quality (by way of the improving parr numbers) with the fry results being more of an indication that the sample sites were not located relatively near to where the few trout which reproduce within these watercourses tend to spawn. However, the trout populations are still well below what would be expected.



Graph 33: Single run trout fry and parr densities for electrofishing site CMKM4

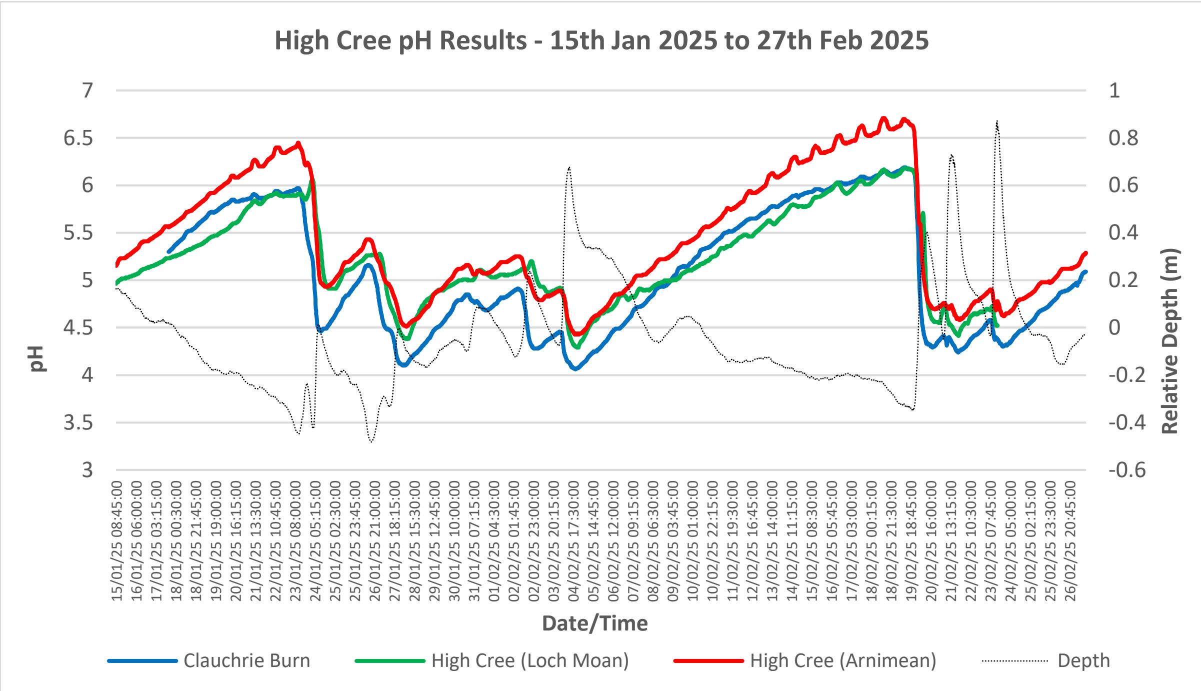


Graph 34: Single run trout fry and parr densities for electrofishing site CM6

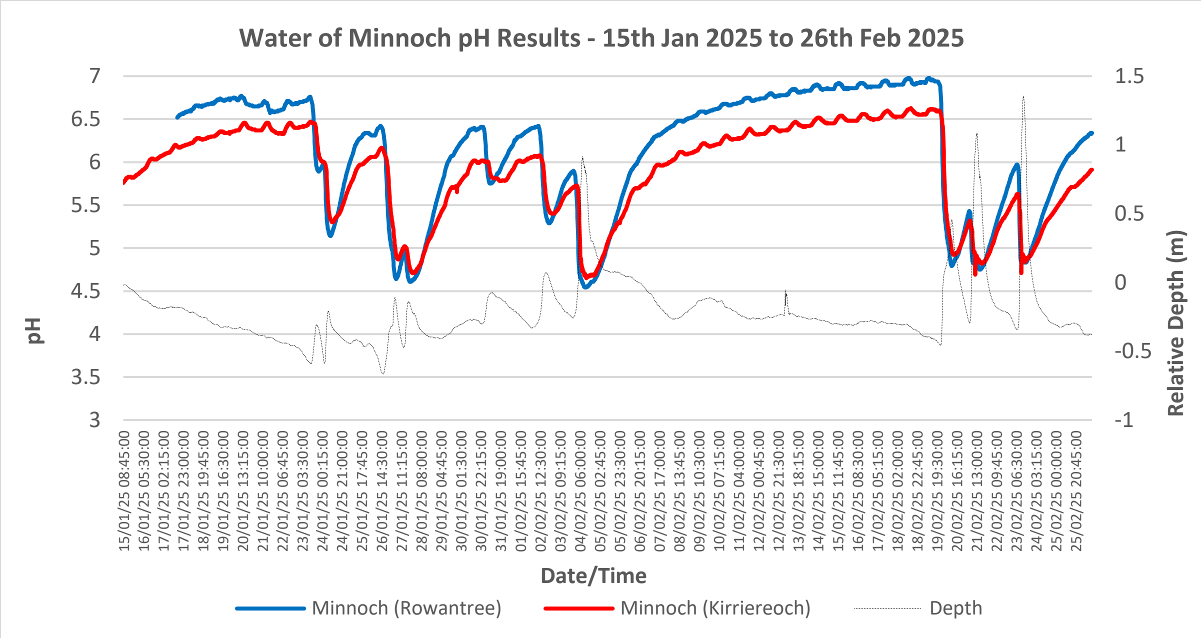
The two trout spawning burn sites on the Water of Minnoch (Kirriemore Burn and Water of Minnoch headwater burn) show differing trends and densities for trout fry, and similar trends and densities for trout parr. The difference in the fry results may simply be as a result of the difference in channel size between the two survey sites (the Kirriemore Burn site is nearly twice the wet width and therefore the majority of trout spawning may be further upstream relative to the Minnoch headwater burn), or it may be as a result of recording beginning 15 year earlier at the Water of Minnoch site and including poor results from earlier years when water quality was potentially poorer.

3.3 River Cree water quality overview

The results for pH, fDOM and Dissolved Oxygen from the continual monitoring sites on the High Cree (and tributaries) and Water of Minnoch for the mid-January to late February deployment are shown below in Graphs 35 to 41, while the results for the High Cree tributaries and the Water of Minnoch for the early to late March recording period are shown in Graphs 42 to 46. Salmonid pH impact summaries are shown in Tables 8 and 9. During recording rainfall (and therefore river levels) was well below average for the time of year. This was especially the case for March when very little rain fell between the 4th and the 29th. The extent of the dry weather is shown in Graph 47 which is taken from the rainfall summary for White Clauchrie on the SEPA website. White Clauchrie is in the lower Clauchrie Burn sub catchment in the upper High Cree.



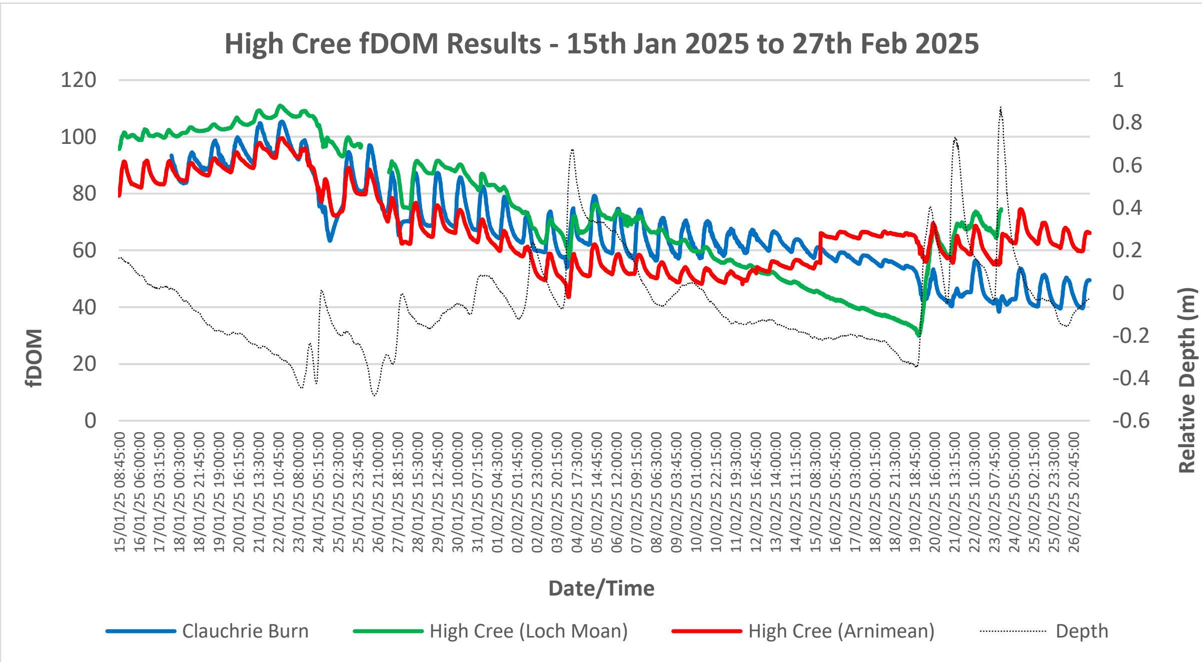
Graph 35: pH comparison between the High Cree (and associated tributaries) monitoring sites during the mid-January to late February deployment



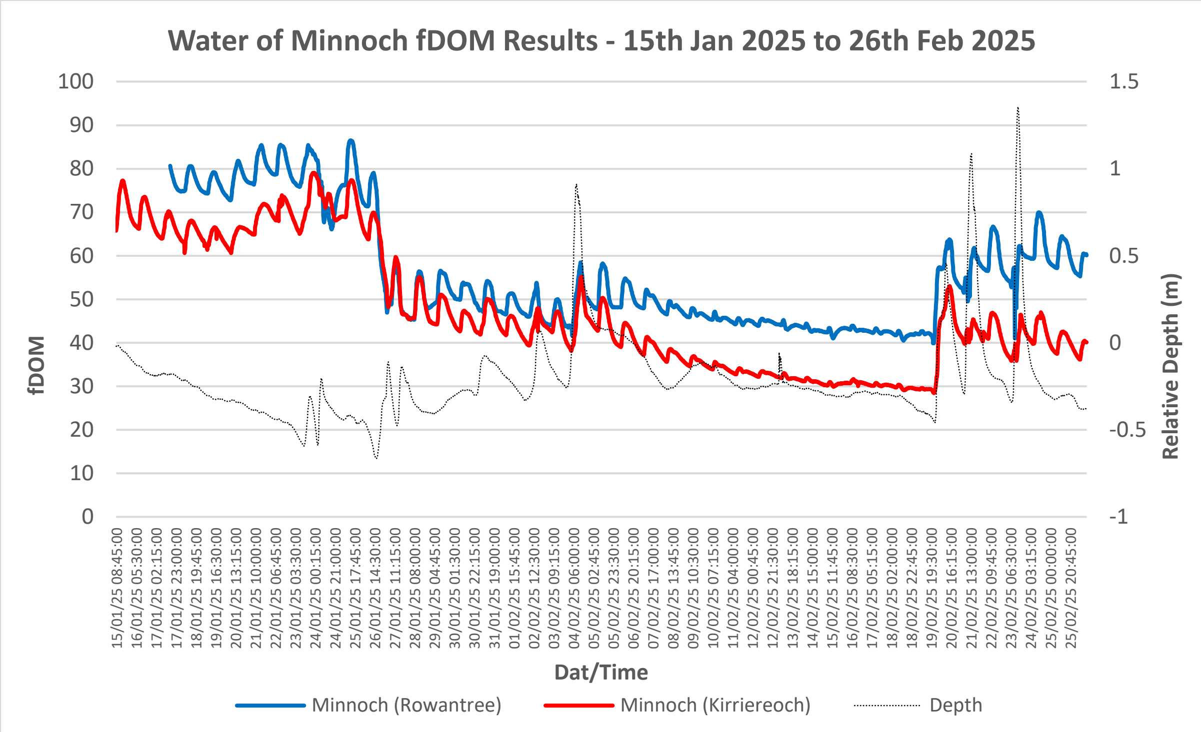
Graph 36: pH comparison between the Water of Minnoch monitoring sites during the mid-January to late February deployment

Table 8: Salmonid pH impact (below pH5) summary table

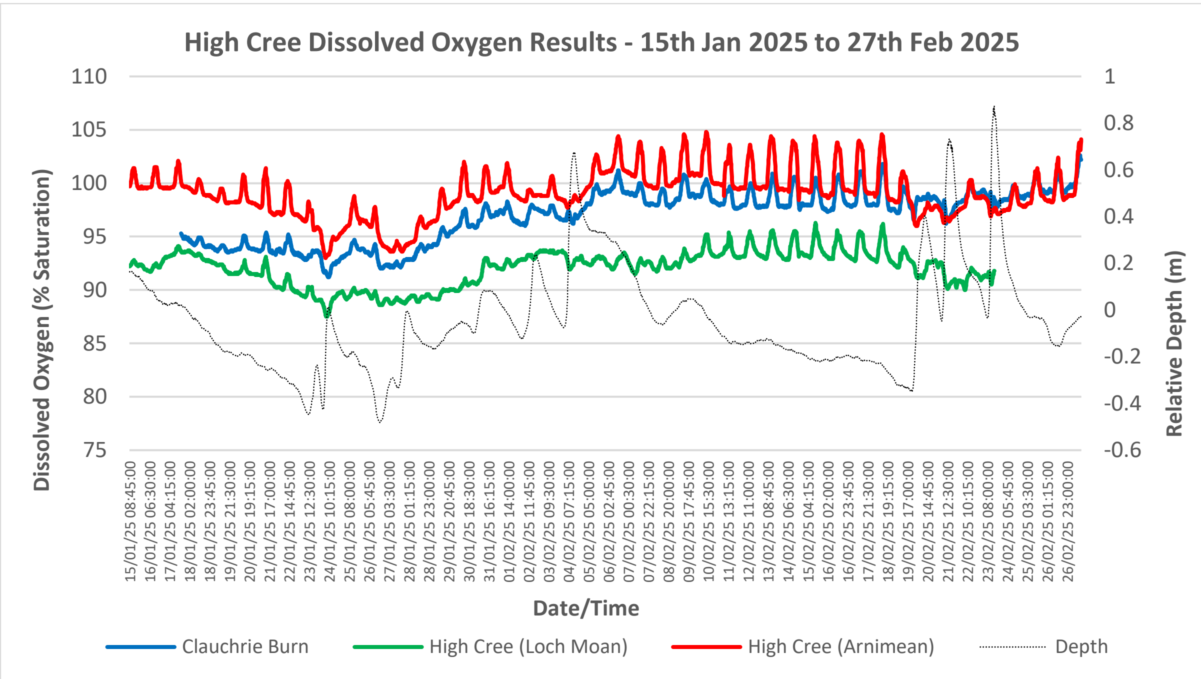
Site	Clauchrie Burn (lower)	High Cree (Arnimean)	High Cree (Loch Moan)	Minnoch (Kirriereoch)	Minnoch (above Rowantree)
Percent. of time below pH5	54%	32%	33%	9%	11%
Percent. of time below pH4.7	36%	10%	16%	1%	3%
Percent. of time below pH4.5	27%	2%	5%	0%	0%



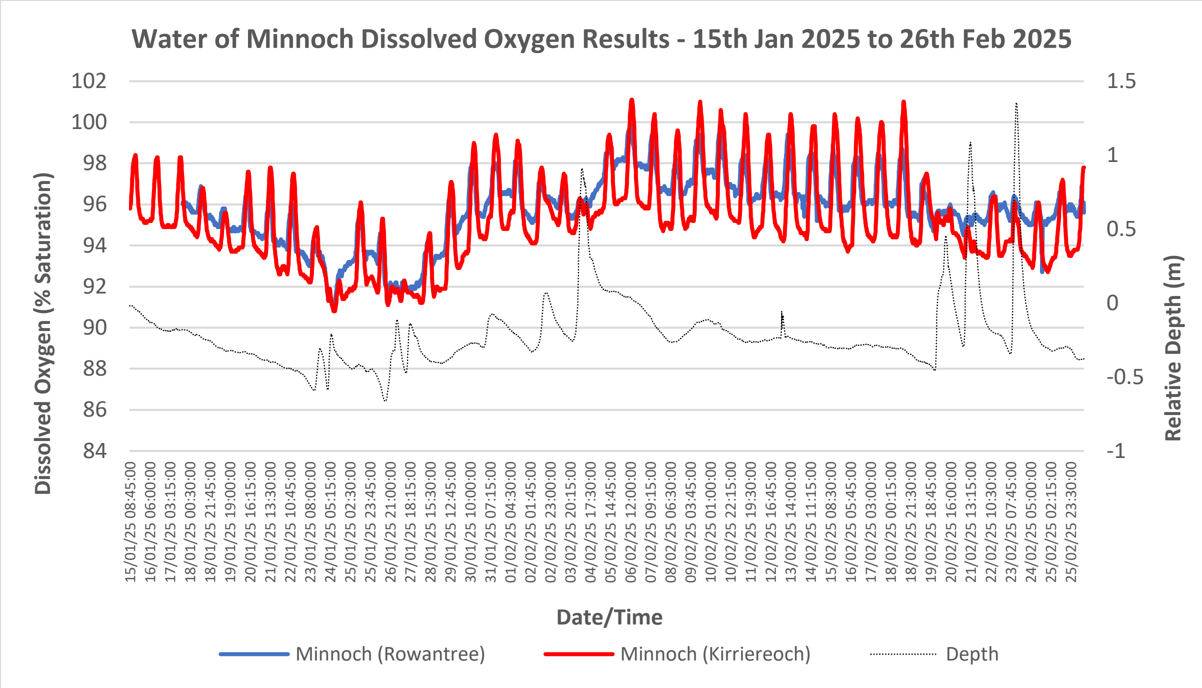
Graph 37: fDOM comparison between the High Cree (and associated tributaries) monitoring sites during the mid-January to late February deployment



Graph 38: fDOM comparison between the Water of Minnoch monitoring sites during the mid-January to late February deployment

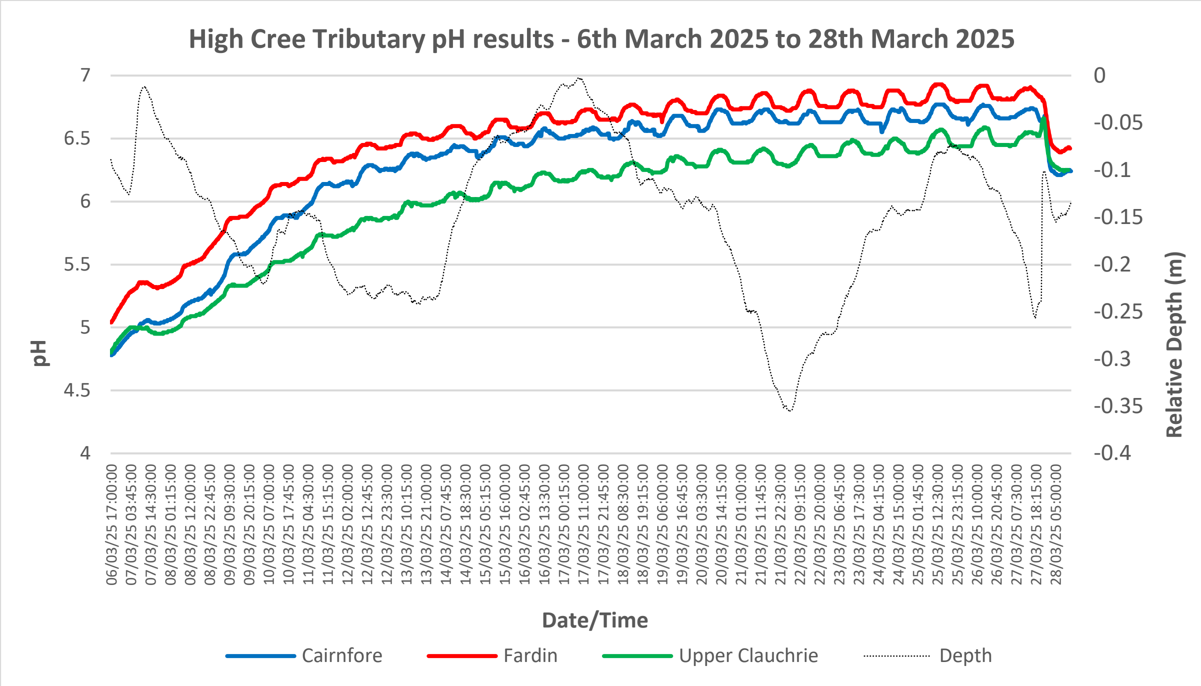


Graph 39: Dissolved Oxygen comparison between the High Cree (and associated tributaries) monitoring sites during the mid-January to late February deployment

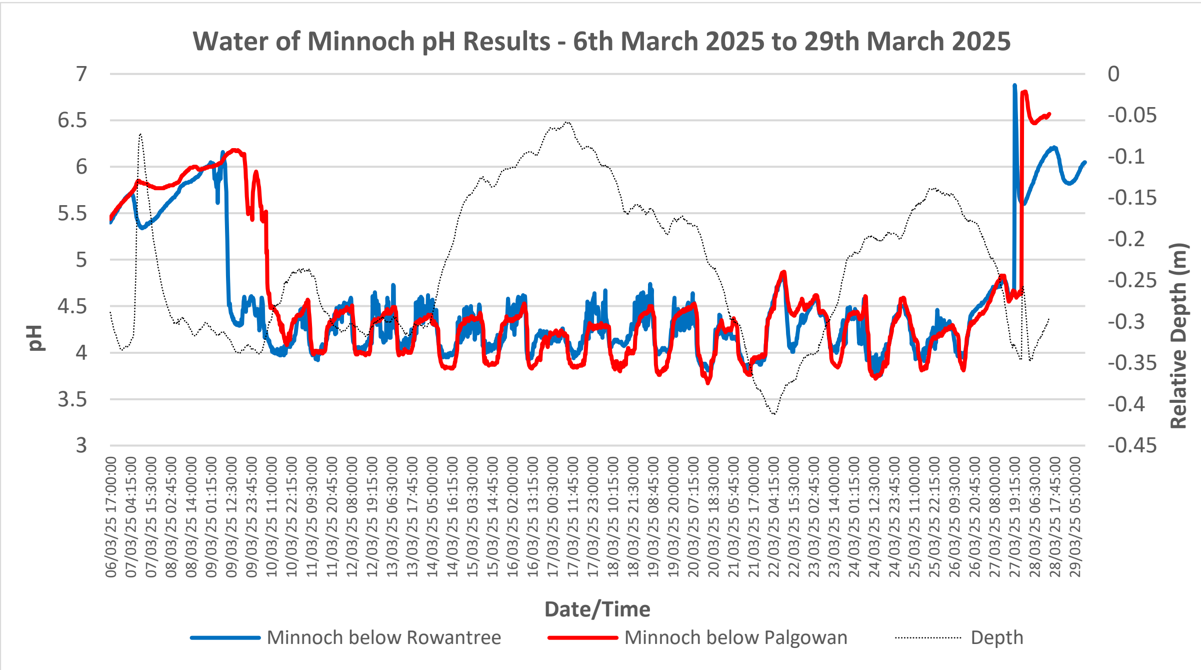


Graph 40: Dissolved Oxygen comparison between the Water of Minnoch Monitoring sites during the mid-January to late February deployment

The relationship between rainfall (river levels/relative depth) and water quality is clear in the data. Although rainfall was below average for the five sites monitored during the January and February monitoring, there was enough rainfall (at times) to show the water quality trends within the data. It is likely that the peak lower limit of pH levels experienced within each water course may not have been reached during deployment, but it is likely that the lower limit recorded would have been close to the actual lower limit experienced at each location. In addition, because some rainfall events were followed by prolonged dry periods this gave very good data on pH recovery at each location. It is clear from the data that, whilst all sites experienced the impacts of acidification, the three monitoring locations on the High Cree (lower Clauchrie Burn, High Cree below Loch Moan and High Cree above Arnimean Bridge) are significantly more acidified than the sites on the Water of Minnoch (above Rowantree Burn inflow and above Kirriereoch bridge). The two sites on the Water of Minnoch only experienced pH levels below five for relatively short periods (9% and 11%), only occasionally got below pH 4.7 (1% and 3%) and saw relatively quick pH recovery during dry/low flow periods. In contrast all High Cree sites showed signs of chronic acidification with all three recording levels below pH 5 for over one third of the deployment time, with the lower Clauchrie Burn site recording below pH 5 for over 50% of its deployment. All High Cree sites also recorded pH levels below pH 4.5, with the Clauchrie Burn recording below pH 4.5 for 27% of the deployment. Recovery from periods of low pH was also relatively slow on the High Cree, especially when compared to the Minnoch sites. This is most clearly shown by comparing the pH recoveries between all five sites after the flood on the 4th and 5th February, which was followed by a prolonged dry period. The low pH results for the High Cree sites are backed up by the fDOM results. All three High Cree sites recorded higher fDOM results, particularly during the earlier, wetter period in recording, likely indicating higher levels of dissolved peat within the High Cree that are driving lower pH levels recorded. Dissolved oxygen levels within all five recording sites were relatively high. This is to be expected as the watercourses at all five sites are relatively fast flowing and shallow with a high reoxygenation potential. However, it should be noted that the DO levels were below 100% at times, with the High Cree below Loch Moan generally recording at about 5% less dissolved oxygen than the other sites. This may suggest lower oxygen levels within Loch Moan (as there is likely to be some re-oxygenation between the loch outflow and the recording site).



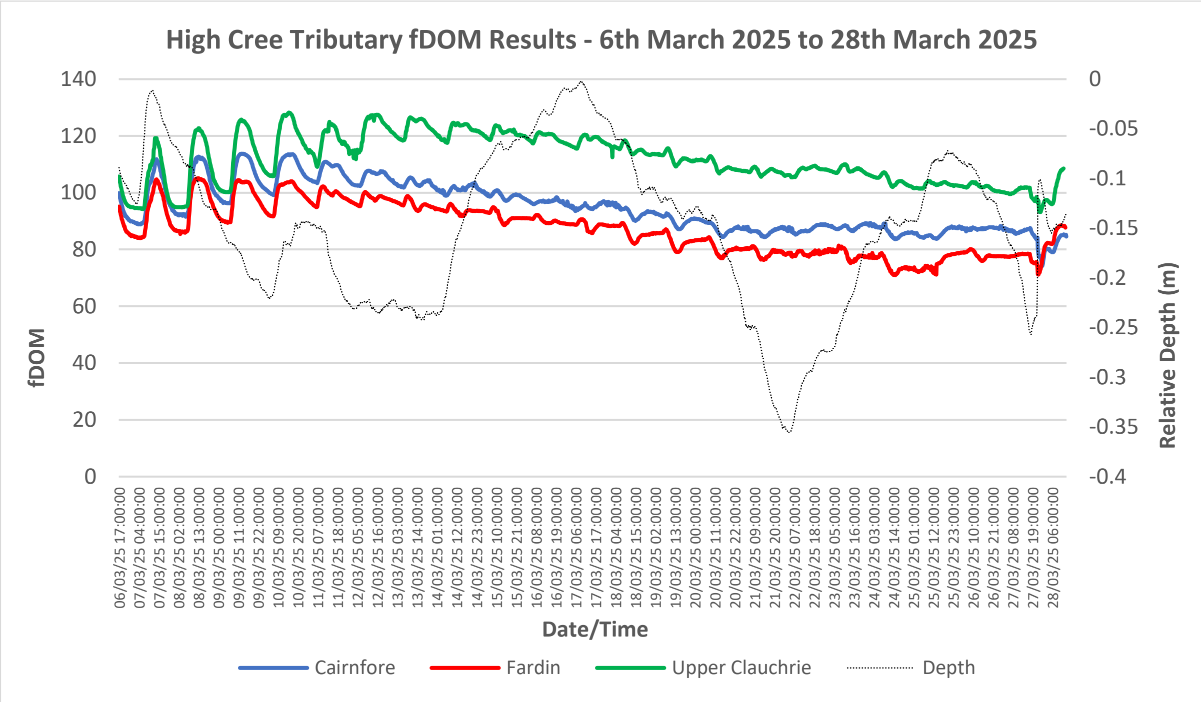
Graph 41: pH comparison between the High Cree tributary monitoring sites during the March deployment



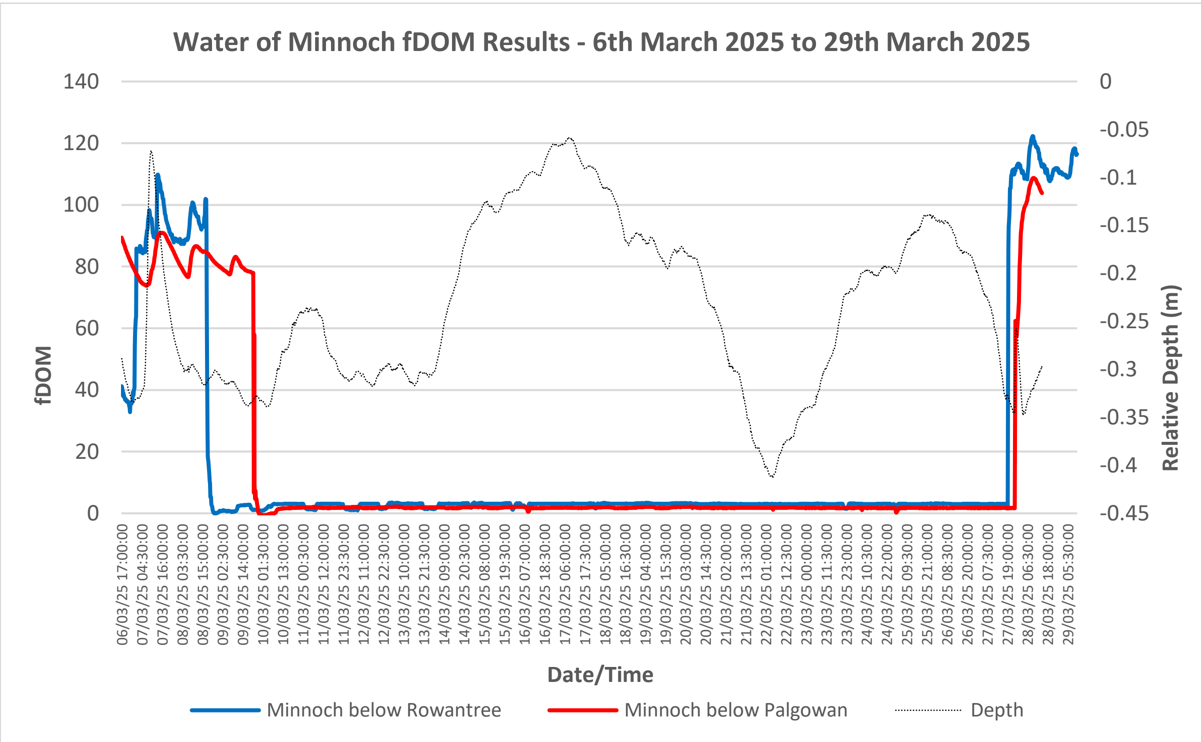
Graph 42: pH comparison between the Water of Minnoch monitoring sites during the March deployment

Table 9: Salmonid pH impact (below pH5) summary table

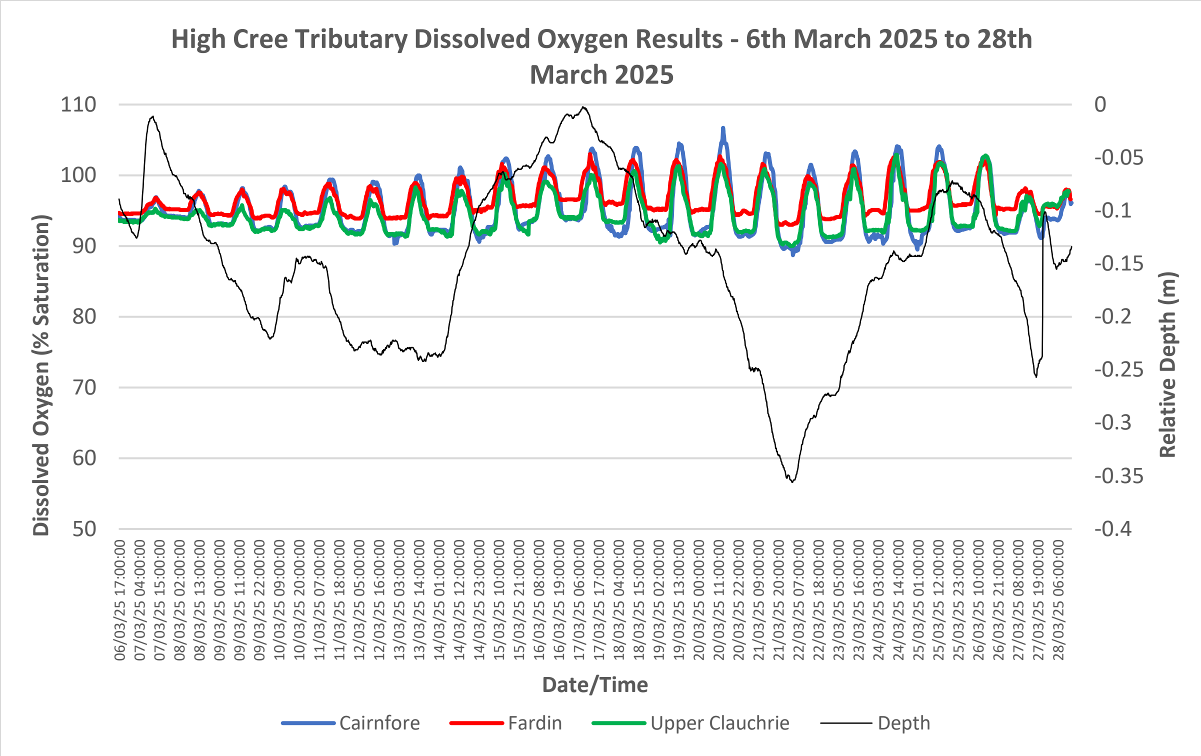
Site	Cairnfore Burn	Fardin Burn	Clauchrie Burn (upper)	Minnoch d/s Rowantree	Minnoch d/s Palgowan
Percent. of time below pH5	2.8%	0%	5.9%	n/a	n/a
Percent. of time below pH4.7	0%	0%	0%	n/a	n/a
Percent. of time below pH4.5	0%	0%	0%	n/a	n/a



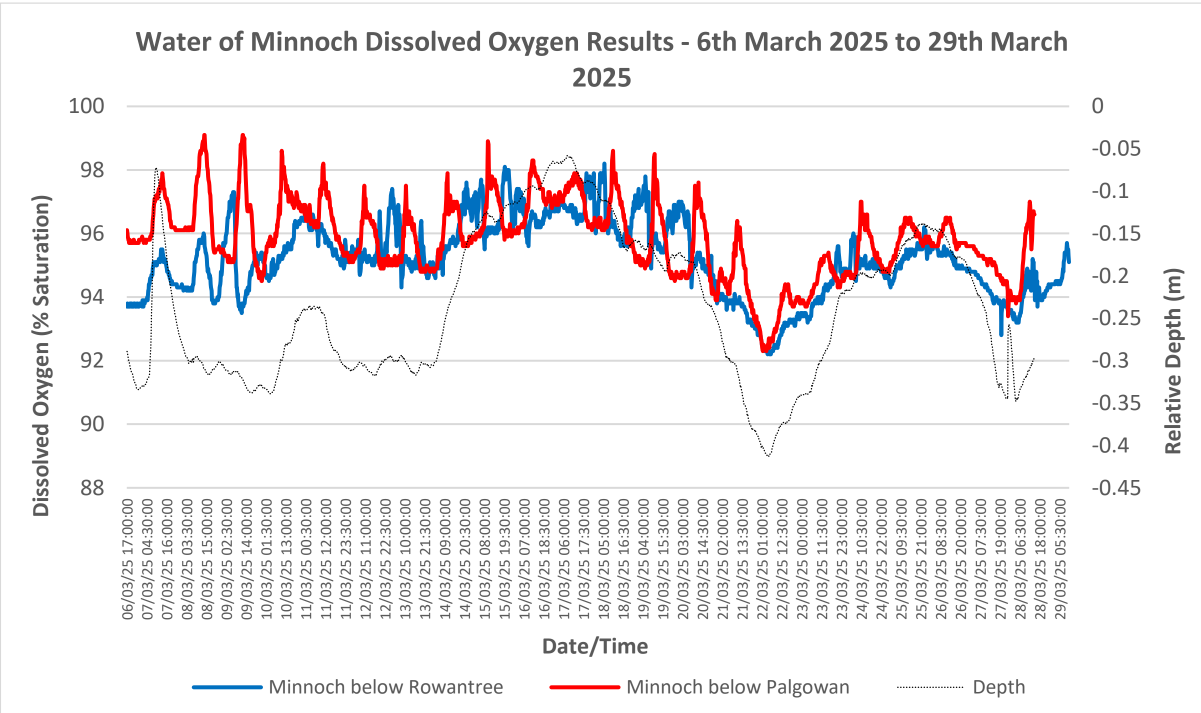
Graph 43: fDOM comparison between the High Cree Tributary monitoring sites during the March deployment



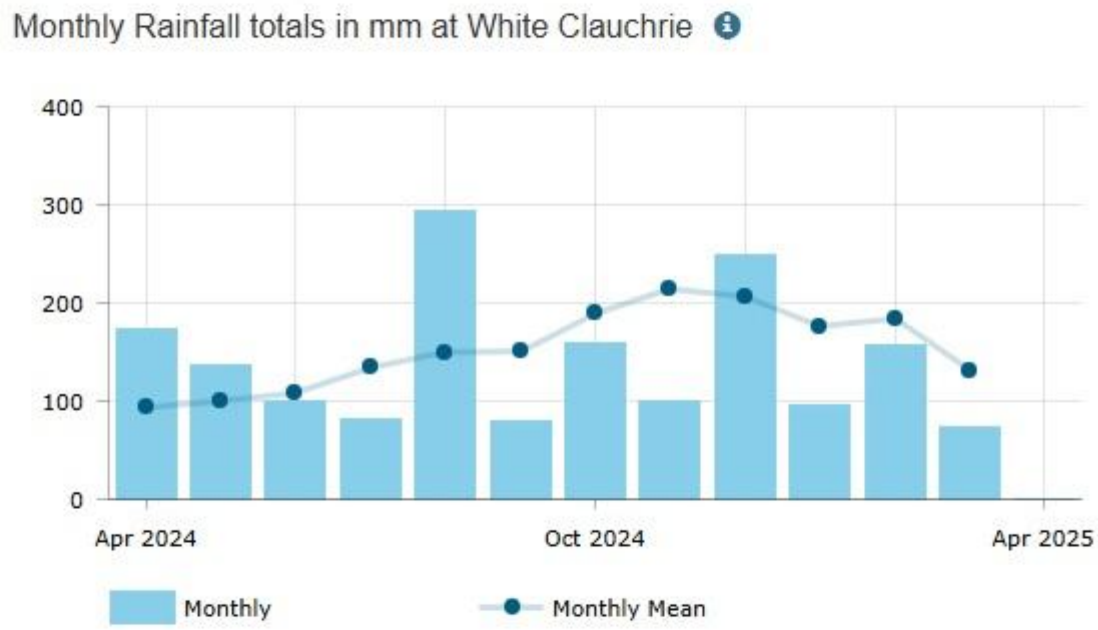
Graph 44: fDOM comparison between the Water of Minnoch monitoring sites during the March deployment, 0 readings are because of sensors being exposed to air during low flows



Graph 45: Dissolved Oxygen comparison between the High Cree tributary monitoring sites during the March deployment



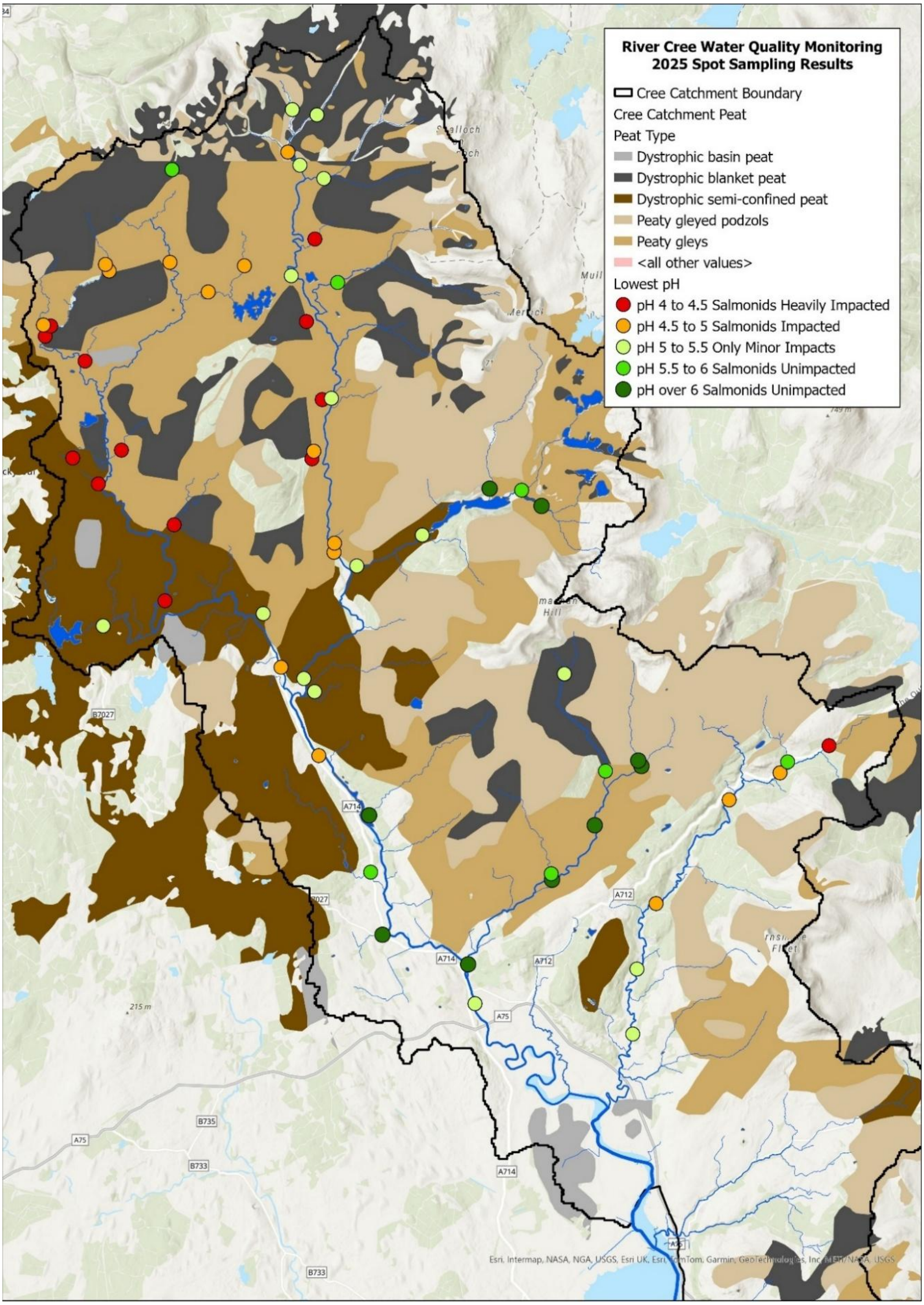
Graph 46: Dissolved Oxygen comparison between the Water of Minnoch monitoring sites during the March deployment



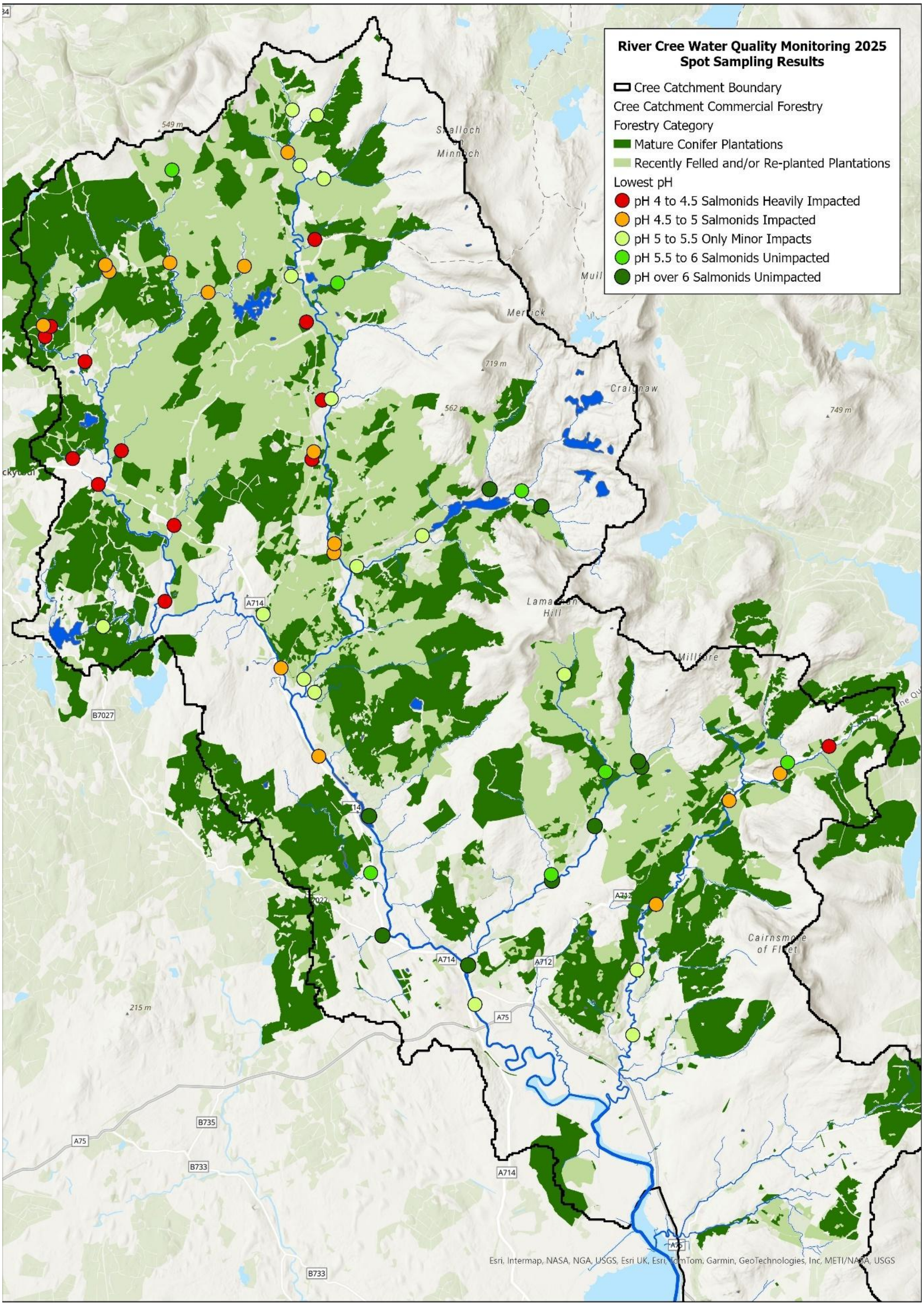
Graph 47: Average monthly rainfall totals for White Clauchrie in the upper High Cree showing the totals for January, February and March 2025 against the site averages (taken from the SEPA website)

The second recording period (6th to 29th March) was beset by low flows resulting from a lack of rainfall. As a result, flow levels got so low that there was insufficient water depth to fully cover the sonde sensors at the two Water of Minnoch recording sites (below Rowantree inflow and below Palgowan). The river is relatively shallow at each location (with the sonde requiring around 40cm to 50cm water depth) and while deeper water was available mid channel the sonde frame must be attached to the bankside, with the two Minnoch sondes being deployed in the deepest sections available in areas that it was thought (at the time) would retain enough flow. The results indicate that the pH and fDOM sensors were in insufficient depth to give accurate readings during low flows but the depth over the Dissolved Oxygen sensor was sufficient to record data. The sondes at all three High Cree tributary sites (Cairnfore Burn, Fardin Burn and upper Clauchrie Burn) remained submerged throughout deployment. However, due to the lack of flow/rainfall the results are unlikely to be representative of “typical” winter flows/results and do not show the full extent of water quality issues. Despite the low flows some inferences can be made from the data. The initial data immediately post deployment shows the Water of Minnoch sites to have higher pH (less acidified) and faster recovery from low pH levels than the three High Cree tributary sites. Again, higher fDOM levels match with the lower pH levels and slower recovery from periods of lower pH. The readings from when the Minnoch sensors are re-submerged at the end of the recording period, when compared to the High Cree tributary data, suggest the sensors had fallen out of calibration whilst there was insufficient depth to record accurately.

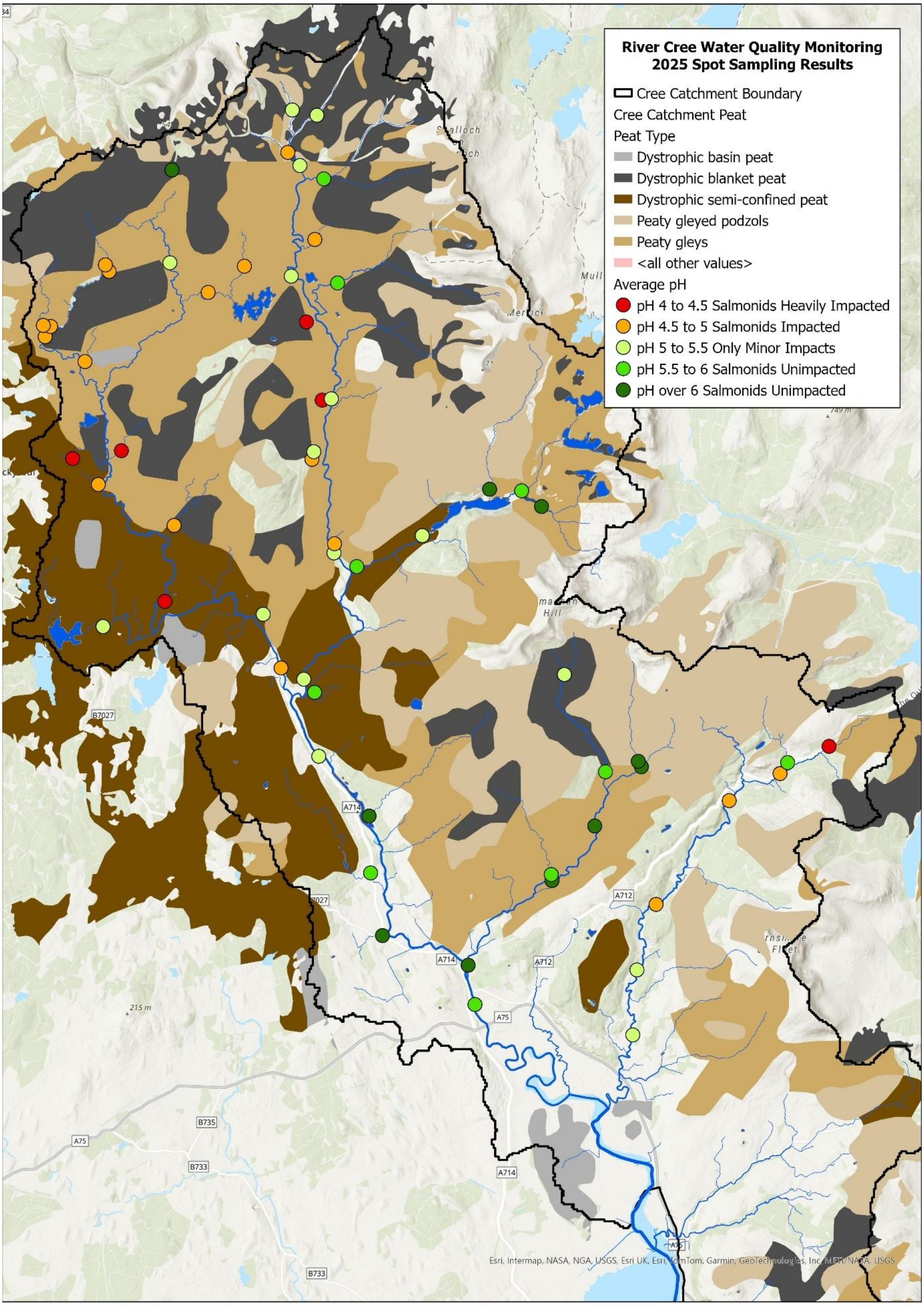
In addition to the Sonde data spot samples were taken to show spatial variation in pH across the Cree catchment. Sampling took place on 28/01/2025, 31/02/2025, 21/02/2025, 24/02/2025, 07/03/2025 and 24/03/2025. Due to the number of sites involved and the distances between sites not all sites could be sampled within a single day. Sampling was carried out in a variety of flows but was not carried out during low flow periods. Spot sampling results from each individual sampling day are shown in Appendix 1. However, to ease interpretation the results have been combined and are summarised in Maps 20 to 23. Within the maps the results are displayed using a rudimentary “traffic light” scoring system based on salmonid pH tolerance. This is to help visualise how native fish populations are impacted across the whole catchment. In maps 20 and 21 the results are shown for the lowest pH recorded to help show which sites are most acidic, whilst maps 22 and 23 show the average recorded pH to give an insight into pH persistence at each sampling site, although it should be noted that a small number of sites were only sampled once.



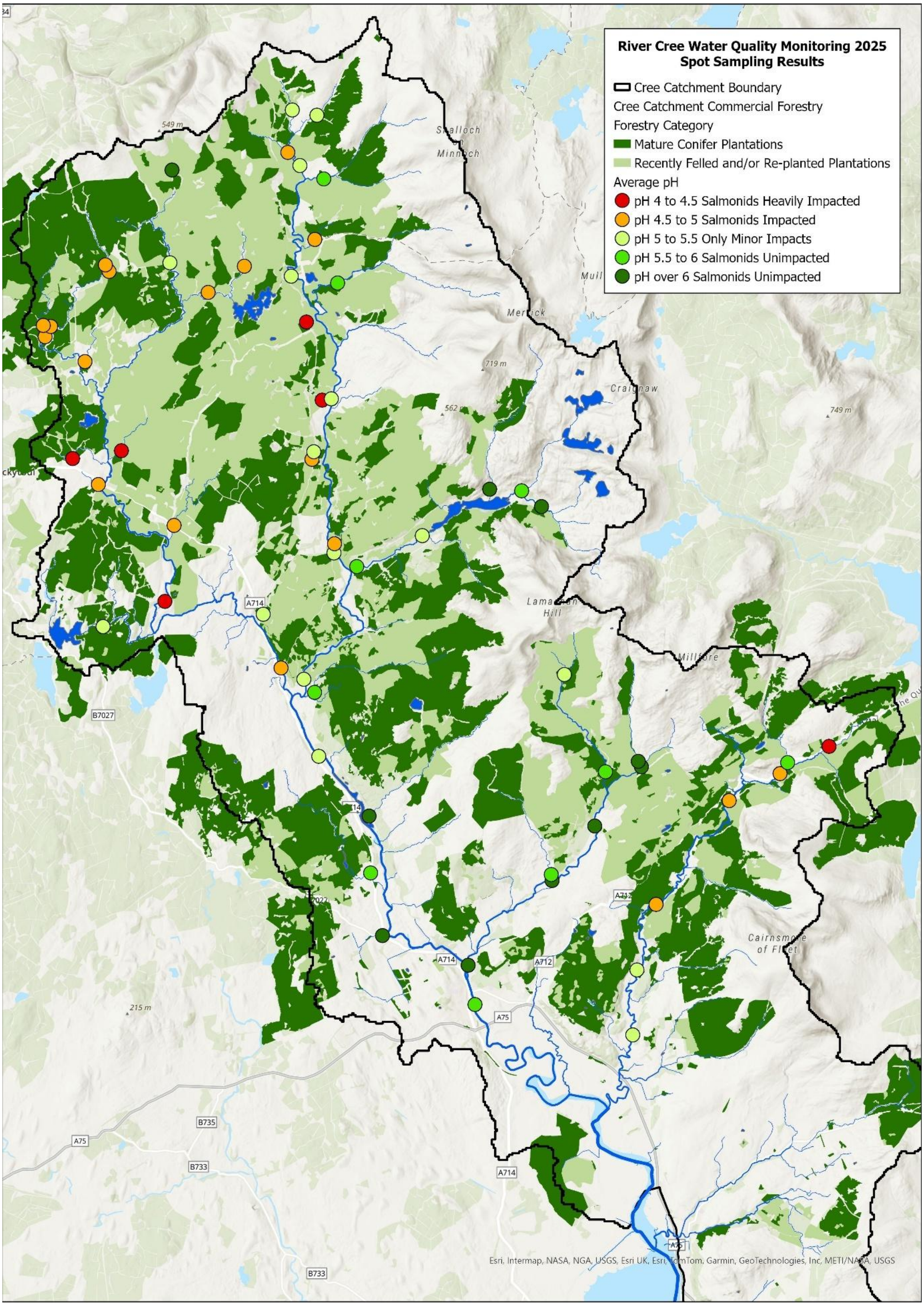
Map 20: Lowest pH recorded from each sampling site during all spot sampling events against peat type



Map 21: Lowest pH recorded from each sampling site during all spot sampling events against commercial forestry cover



Map 22: Average pH recorded from each sampling site during all spot sampling events against peat type

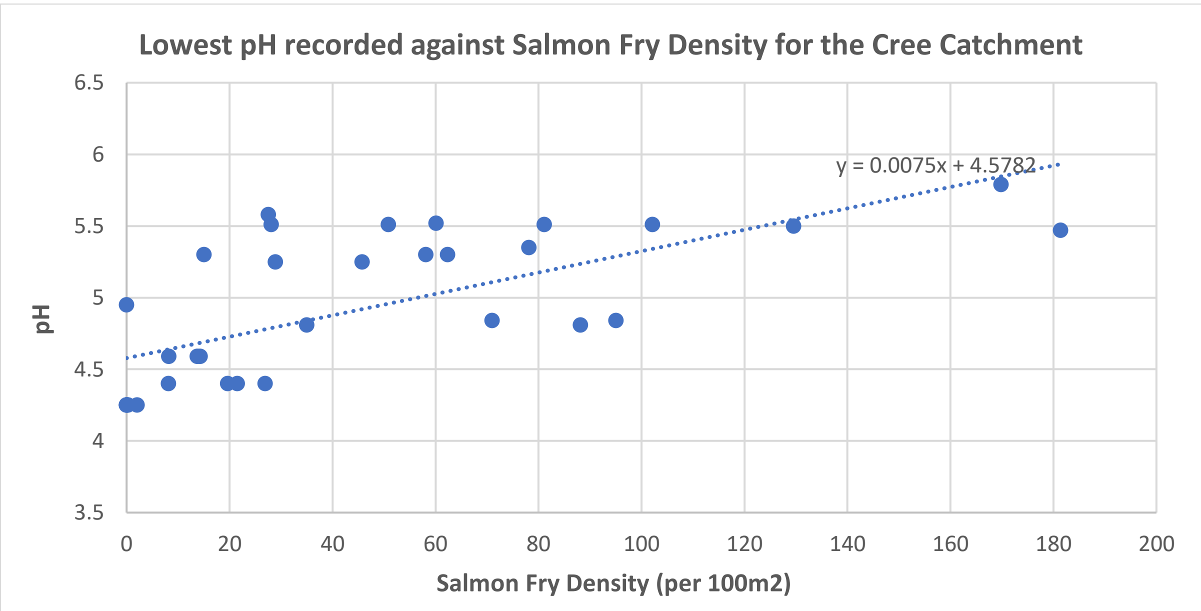


Map 23: Average pH recorded from each sampling site during all spot sampling events against commercial forestry cover

The spot sampling results from the Cree clearly show considerable variation across the catchment. However, low pH is being experienced in a significant proportion of the catchment at a level that is heavily impacting salmonid populations. The spot sampling results back up the fish survey data and the sonde monitoring data, showing that the High Cree sub-catchment is the most heavily acidified section within the greater Cree catchment. Both the lowest pH and average pH maps show the extent of the acidification within this watercourse with the acidification from the High Cree having a knock-on effect on the River Cree below the Minnoch/High Cree confluence. The area of River Cree impacted is roughly 1km of river before the river widens and deepens at Loch of Cree and becomes unsuitable for spawning Atlantic salmon (until around another 3.5km downstream). Both the lowest pH and average pH results show that while the whole High Cree is acidified there is an intensification of the acidification within the middle reaches of the watercourse around where the Clauchrie Burn flows in. There is some minimal recovery in the lower High Cree. While the Clauchrie Burn is clearly the most acidified of the major High Cree tributaries, the increase in pH seen within the general area, combined with the results from the nearby Laniwee and Cairnderry Burns indicate that the particularly low pH results are indicative of this part of the catchment and not the result of a single inflowing watercourse.

While the results indicate that rest of the Cree catchment is much less acidified, or un-acidified in the case of some of the lower catchment, there are still some localised impacts that may be causing localised damage within watercourses. Two are of note. Firstly, the watercourses flowing into the West bank of the Water of Minnoch, particularly around the middle reaches. These include the Black Burn below Kirriereoch and the Butter Burn at Palgowan. As a result, there appears to be a pH dip in the middle reaches of the Water of Minnoch and while fish survey results suggest there is no major impact on juvenile salmon numbers within the river there may be localised issues where the burns flow in. Any trout attempting to spawn within the burns themselves are likely to experience widespread egg mortality. The second area is the headwaters of the Palnure Burn (which flows into the Cree estuary). While the results indicate that the water input into much of the watercourse is mildly acidified or un-acidified, very low pH reading were recorded from the very top of the burn. As a result, lowered pH persists for a significant distance downstream.

To highlight the connection between pH levels and fry densities the scatterplot below (Graph 47) plots (nearest) lowest recorded pH levels against salmon fry density for 2016 – 2024.



Graph 47: Single run salmon fry densities for 2016 to 2024 against lowest recorded pH

4 DISCUSSION

4.1 Tannylaggie peatland restoration water quality data collection

There has been no additional peatland restoration at Tannylaggie Flow since the last recording window (winter 2023/2024). As such, it has still only been a modest percentage of the planned peatland restoration that has taken place to date and any potential difference between the previous and current water quality monitoring would be the result of the current restored section "settling in" post restoration. The results from the 2024/2025 water quality monitoring suggest that, to date, if the FLS peatland restoration at Tannylaggie is having any impact, it is not yet obvious enough to detect. This is not unexpected at this stage, with only a modest section within the Dargoal Burn catchment having been restored. It could be expected that this monitoring project will highlight the need to undertake forest to bog restoration at a sufficient scale to realise water quality improvements. Although small differences in water quality were recorded the small differences in pH levels recorded between years sampled are most likely because of variations in flow between years. It may be possible to tease out any differences between years by taking flow levels or rainfall into account. Whilst all/any available flow/rainfall data will be sought out going forward any statistical analysis that can tease out subtle differences may be beyond the abilities of the current project. As such, it would be necessary to bring in additional statistical expertise going forward to ensure the results can be sufficiently analysed to draw firm conclusions. However, this would be most beneficial when a significant amount of post-restoration data has been collected after the completion of the project when it may be possible to use the data for a PhD or Masters project.

A point of note from the monitoring is the continued low Dissolved Oxygen (DO) levels recorded within the Dargoal Burn. Current levels are likely to have a significant impact of aquatic life and when combined with the pH results paint a bleak picture. However, the results from the additional monitoring site just above the confluence of the Dargoal Burn and the Polbae Burn suggest that, during the season/conditions monitored, re-oxygenation is occurring in the faster flowing, lower reaches of the burn and, as such, the reduced oxygen levels are localised within the Tannylaggie Flow region of the burn.

Although not recorded or measured within this document it was evident from site visits during data recording that conifer regeneration with Tannylaggie Flow, and within the greater Tannylaggie Forest, is a major problem with some areas surrounding the Dargoal Burn appearing to have a higher Sitka density than would be planted commercially. Given the relationship between peatlands, commercial forestry and water quality this would indicate that the regen has the potential to reduce water quality and potentially counteract the benefits gained though the on-going peatland restoration. Thankfully, FLS have indicated that regen clearance should begin in summer 2025.

Overall, as previously stated, there is no obvious impact on water quality of the Tannylaggie peatland restoration to date. Again, this is not unexpected as only a small percentage of the Dargoal Burn catchment area has been restored. One of the major issues slowing down restoration to date has been the time scale for clearing conifer crops that are currently still standing within the proposed restoration site. FLS reported during winter 2024/2025 that most of the remaining crop is to be harvested during 2025, with the next round of peatland restoration hopefully taking place soon after. Going forward it is possible that we may see an initial reduction in water quality following full tree harvesting and restoration, followed by a long-term improvement on the current conditions. This was demonstrated by Shah and Nisbett (2019) who investigated deforestation for peatland restoration at three separate lowland raised bogs and found an initial decrease in some aspects of water quality. This highlights the need to continue monitoring long term.

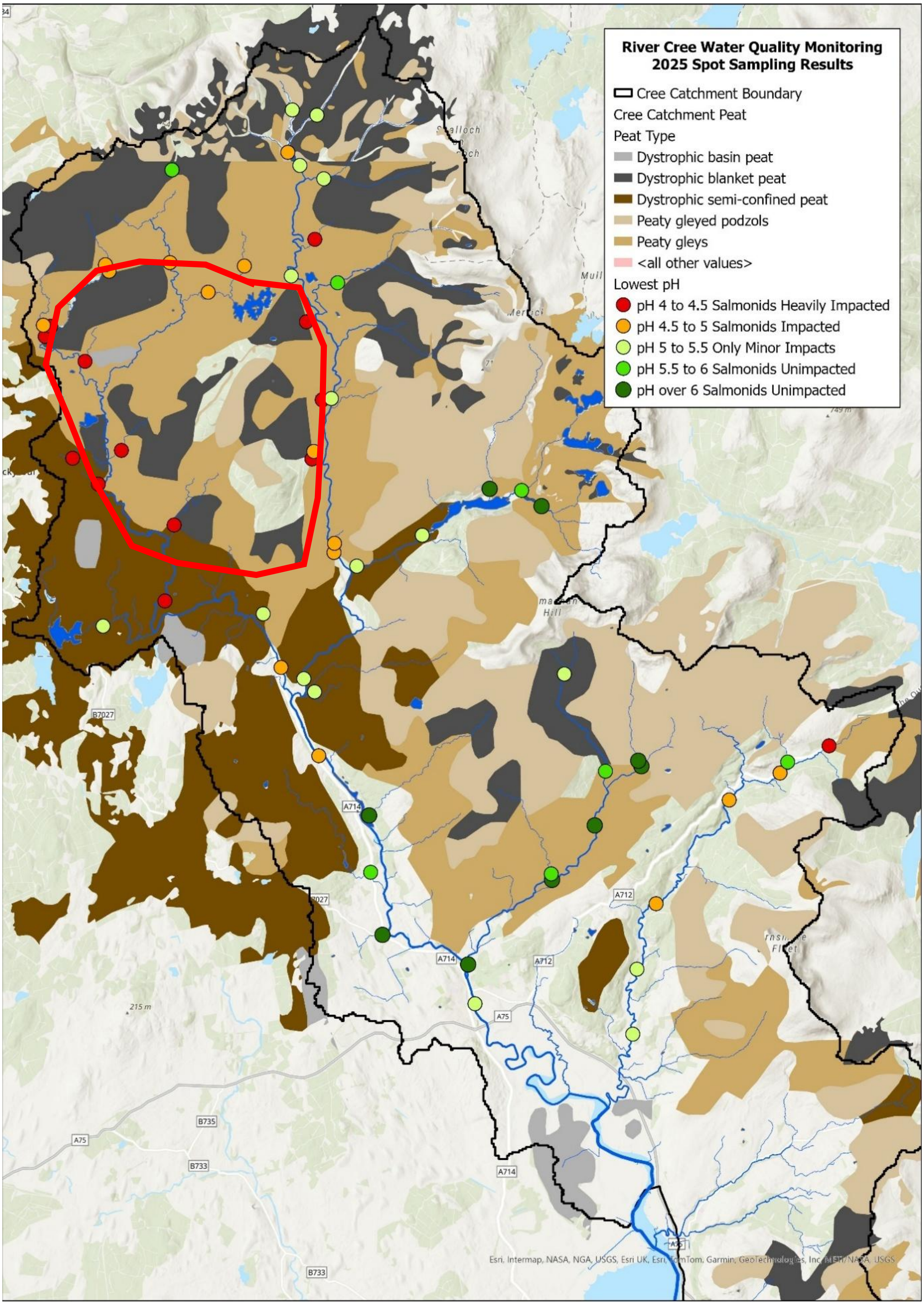
4.2 River Cree electrofishing data review and water quality overview

The River Cree fish survey and water quality monitoring results match up quite well, with areas of poorest water quality (primarily pH) generally having the most depleted salmonid fish populations (with an almost complete absence of salmonids in some instances). In contrast may areas where pH appears to only occasionally reach levels damaging to salmonids generally show high densities of trout or salmon fry. In terms of juvenile Atlantic salmon production, the lower River Cree, Water of Minnoch and, to a lesser degree (by area), the Penkiln Burn appear to be the backbone of salmon production within the river, and this is backed up by the water quality data. Within the lower Cree pH does get close to pH5 at times, but the extent and duration of the low pH is likely to have only minor impacts on salmonids. Given the pH values recorded for most lower catchment inflowing tributary burns it is likely that the pH levels within the main stem of the lower Cree are lower than should be expected. This is due to the legacy of acidification issues further up the catchment. However, despite pH be lowered by water quality further up the catchment it has recovered to a level which results in salmonids being generally unimpacted. Likewise, the Minnoch and Penkiln have water quality that is generally suitable for salmonid fishes, with mostly minor impacts from acidification, except for some localised issues. There is some indication of recovery from acidification within the Minnoch and Penkiln Burn, particularly within the juvenile trout numbers, but the fish survey results suggest that, in general, juvenile salmon never experienced severe impacts from water quality in either watercourse during the period that fish populations have been monitored (although, as already mentioned, there will have been a number of localised issues throughout each time period). In contrast the High Cree electrofishing results indicate a watercourse where juvenile Atlantic salmon production was, and still is, being heavily impacted by low pH levels, to the point where high salmonid egg mortality is likely during most winters. This is backed up by the water quality monitoring which shows that pH levels below 4.5 are relatively common within many parts of this sub-catchment, and pH levels below 5 are common throughout. Although few published accounts exist, there are many old local accounts of healthy salmon and trout rod catches in the High Cree before acid rain and the build-up of commercial forestry. This indicates the High Cree should hold healthy salmonid populations. The electrofishing results possibly do show some minor recovery in fish numbers (and therefore water quality) within the lower reaches of the High Cree, but the current rate of recovery indicates that Atlantic salmon populations can only be restored if changes/improvements in land use practices are carried out. One exception within the High Cree electrofishing results is the High Cree at Dalnaw. To help mitigate the impacts of acidification GFT have added limestone gravel to the river at this location. Whilst the gravel has had only minor impacts on surface waters at high flows, reduced acidity within the water flowing through riverbed gravel has resulted in higher survival of salmon eggs and increased juvenile numbers within this section of river. Mitigation measures such as limestone gravel addition provide short to medium term solutions that compensate for poor water quality in the hope that long term changes in land use can be achieved. In addition to the impacts across the High Cree sub-catchment the reduced pH within the High Cree is most likely having an impact on the main River Cree downstream of the High Cree/Water of Minnoch confluence, with pH levels as low as 4.85 being recorded downstream of this point. In terms of damage to fish populations this appears to impact just over 1km of the main River Cree before the river deepens and widens to form Loch of Cree (becoming unsuitable for salmon spawning). By the time the river narrows and shallows again (just over 3.5km further downstream at Cut Island) water quality has improved (although not completely recovered). It is likely that water quality recovery is due to the additional dilution from inflowing burns and groundwater.

The results for juvenile trout, which generally spawn in burns instead of main stem, show similar trends to juvenile salmon. Again, trout juvenile production appears heavily impacted across most of the High Cree sub-catchment, although there is possibly some minor improvement within upper tributary burns like the Fardin and Cairnfore burns. However, both can still be classes as acidified and will likely experience significant egg mortalities during some winters, albeit at a lower rate than some other burns that flow into the High Cree (as backed up by the water quality monitoring results). Although water quality is generally better within the Water of Minnoch it has potentially seen some recovery in juvenile trout numbers within the (previously more heavily impacted) headwaters of the river. Despite being much less acidified than the High Cree, the river still has some significant localised water quality issues. The water quality results indicate that some Minnoch burns, particularly those flowing in from the West side of the sub-catchment, remain heavily acidified and are highly likely to be impacting any trout populations therein. There may also be very localised impacts on the main stem of the Minnoch in the immediate area where each acidified burn flows in, but it is likely that the dilution factor when these burns enter the Water of Minnoch will keep any impacts very localised, if indeed there are any impacts at all. In general, trout appear more impacted by water quality/acidification than salmon within the Minnoch, although the complicated relationship between the resident (Brown trout) and migratory (Sea trout) trout, and the differences in egg deposition between the two strategies, can complicate fish survey results.

In addition to the main Cree catchment water quality data was collected from the Palnure Burn (esturine). The burn is locally important for biodiversity and was included for that reason. Water quality (primarily pH) is good/acceptable across much of the watercourse, except for the very top of the watercourse. Due to the extent of the low pH within this section is has a “legacy effect” which extends downstream for a significant distance before being diluted enough for water quality to fully recover. Due to the size of the burn and the presence of a waterfall approximately two thirds of the way up the burn salmon are restricted to the lower two thirds of the burn. Electrofishing results show juvenile salmon production is unimpacted by water quality. However, although trout data is relatively scarce for smaller burns within the system what data is available appears to indicate that water quality at the very top of the Palnure Burn is impacting juvenile trout production.

The links between geology, commercial afforestation, degraded peatlands and water quality are well known, as described earlier in the document. As with neighbouring catchments like the Bladnoch and Water of Fleet, there is a clear connection between peatland presence/condition and water quality within the Cree catchment. This highlights the extent of the water quality issues within western Galloway. Due to the extent of the commercial forestry within the Cree catchment it is difficult to disentangle and compare pH results between afforested and non-afforested areas. However, the pH spot sample maps, backed up by the sonde water quality data collection, clearly show that, except for one result, all the burns that produced pH results below 4.5 were associated with drainage from areas of deep blanket peat within areas of commercial forestry. There are clearly some areas of afforested deep blanket peat where water quality is less of an issue and, as such, the main area impacting water quality appears to be a large section of the mid to upper Cree catchment that extends between the East side of the middle High Cree over to the West side of the middle Water of Minnoch. An approximation of this section has been (crudely) highlighted in red on Map 24, although the exact boundaries are not known (there may not be an exact boundary, and any change may be gradual around the edges).



Map 24: Lowest pH recorded from each sampling site during all spot sampling events against peat type, with the general area of the catchment having the biggest impact on water quality enclosed within a red line

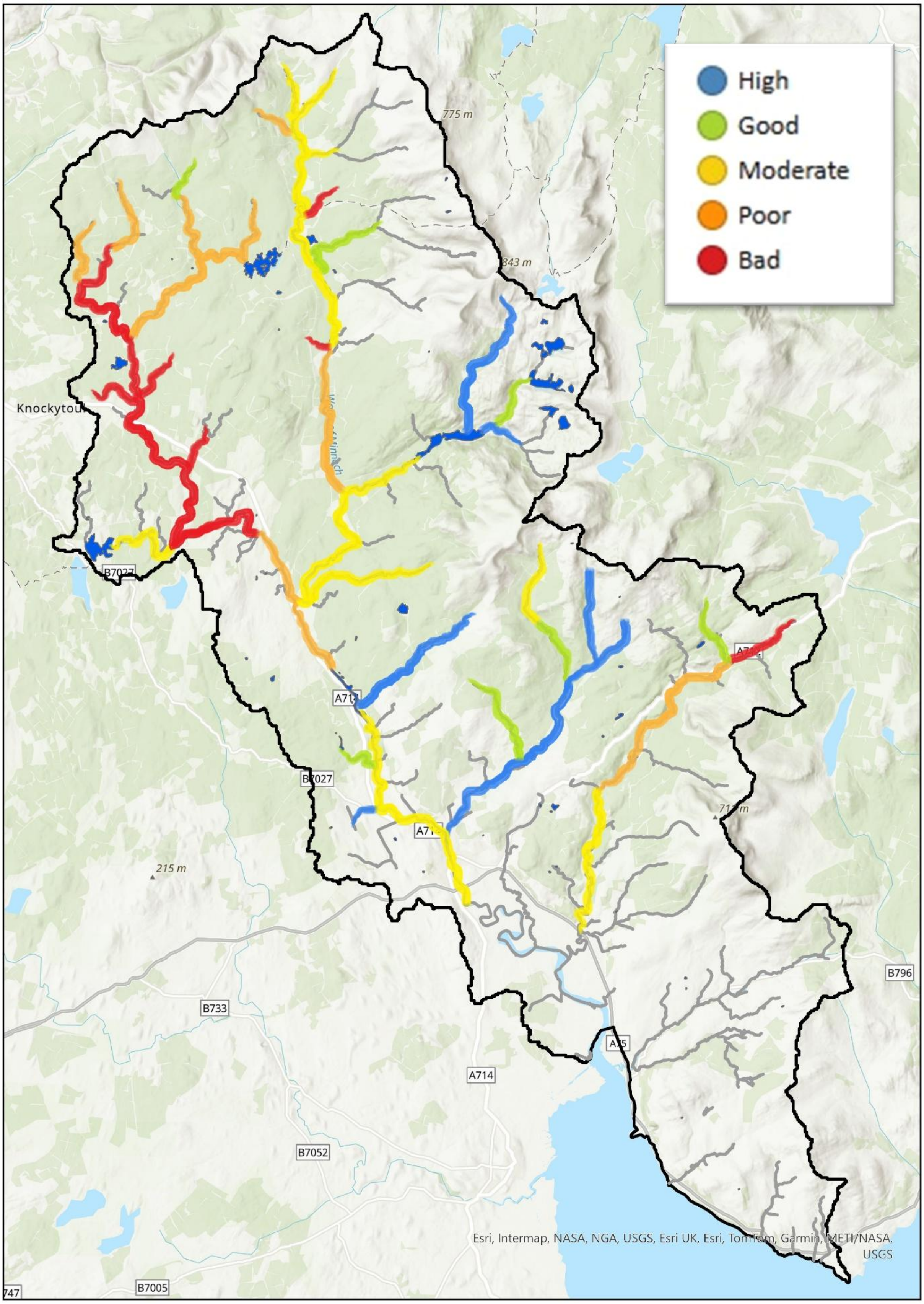
As a result of this section of the catchment both the High Cree and the Water of Minnoch experience an increase in acidification within their middle reaches, although the impact is much less within the Water of Minnoch as it only drains a relatively small section of the this area. Therefore, to address water quality issues and impacted aquatic ecosystems within the Cree catchment the restoration of areas of degraded dystrophic blanket peat within the highlighted section of the High Cree sub-catchment should be considered a priority. Extending this to the small section of the Western side of the Water of Minnoch sub-catchment that the highlighted area covers would also address a significant proportion of the localised water quality issues within the Water of Minnoch.

Although the degraded blanket peat appears to be having the biggest impact on water quality and aquatic ecosystems, the impacts of acidification are not limited to just areas of blanket peat, as can be clearly seen within the High Cree catchment. The areas surrounding the blanket peat within the High Cree catchment mostly consist of Peaty Gleys according to the (NatureScot) peat map. Despite the classification there are significant areas of deep and shallow peat with the areas classed as Peaty Gleys. An example of this is an area of peatland restoration that is being planned immediately due Southwest of Loch Moan (peat depths have been taken and show the presence of significant areas of deep peat). The James Hutton soil map recognises this and highlights that there are areas of dystrophic semi-confined peat present within this general area, but like the NatureScot map does not identify where. As such, more work is required to identify these areas of peat, their condition and any impacts on water quality. While restoring dystrophic blanket peat will go a long way to addressing water quality, due to the extent of the water quality issues within the High Cree sub-catchment, the restoration of some areas of semi-confined peat may also be required to improve survival within aquatic ecosystems/native fish populations.

As part of the sonde water quality data monitoring lowered dissolved oxygen levels were picked up at the Sonde monitoring site below Loch Moan. Between the loch and the monitoring site is a 500-600m section of the High Cree that is relatively shallow and fast flowing with significant potential for water oxygenation. The reduced oxygen levels at the monitoring site may indicate a significant oxygen deficit coming out of Loch Moan. Dissolved oxygen monitoring should be carried out in the area around the loch outflow to establish if there is an oxygen deficit, as the most likely reason for any deficit would be oxidative decomposition of peat washed into the loch from the surrounding land, much of which appears to be afforested peatlands.

In the case of the Palnure Burn water quality issues appear to be stemming from blanket peat and semi-confined peat on the boundary between the Palnure Burn headwaters and the Black Water of Dee catchment. Peatland restoration should be considered for this section of the Palnure catchment.

On final point of note is the SEPA classifications for the Cree catchment (listed in Section 1.3). It was described earlier how the results for different criteria often appear to contradict each other with only a small number appearing consistent with GFT fish and water quality data. For comparison with the SEPA data the lowest pH results (based on salmonid egg tolerance (Map 20))) from this report has been converted to the SEPA colour scoring (Map 25). We do not have the exact units used by SEPA to classify water quality, so the map keeps the same salmonid pH tolerance used in this report but with the colours and water quality classification descriptions changed to the ones used by SEPA.



Map 25: *Lowest pH recorded from each sampling site during all spot sampling events, converted to the SEPA classification system.*

The map aids the visual identification of the areas most impacted by acidification. In terms of comparison with the SEPA classifications the map does give similar results to the SEPA "Overall Status", "Overall Ecology" and (unsurprisingly) "Fish Ecology" classifications. However, the pH results from this study differ greatly from the SEPA "pH" classifications. SEPA scores the Cree system as "High" and "Good" pH water quality throughout, with only the Water of Trool scoring lower. In contrast this report has recorded very low pH levels in many areas classed as "High" by SEPA (the entire High Cree is classed as "High" water quality scoring for pH). The current SEPA pH methodology does not appear to identify heavily acidified catchments that are having widespread impacts on native fish species.

4.3 Tannylaggie Flow and River Cree catchment management recommendations

- There are no obvious improvements in water quality within the Dargoal Burn at this early stage of the Tannylaggie Flow peatland restoration. This is not unexpected as only a small percentage of the sub-catchment has been restored. As such peatland restoration at Tannylaggie Flow needs to resume and progress before any significant improvements in water quality are likely to be seen. Long-term monitoring is likely required at Tannylaggie Flow/the Dargoal Burn if the full water quality benefits are to be recorded. Future monitoring should also consider further investigation into the impacts of the reduced DO levels recorded within the burn.

- Additional data analysis carried out by experienced statisticians will aid data interpretation once the full Tannylaggie peatland restoration has been completed. This is necessary to draw firm conclusions and further support long term peatland restoration and management in the catchment as an aid to restoring water quality and native fish populations. The data collected from the Dargoal Burn may be suitable for a Masters or PhD project.

- Salmon are all but absent from much of the High Cree because of water quality (low pH). The likely cause for the poor water quality is degraded/afforested peatlands, with areas of degraded dystrophic blanket peat appearing to make the biggest contribution to the low pH levels. This report has identified a section of land running from the middle reaches of the east bank of the High Cree to the middle reaches of the west bank of the Water of Minnoch as having the biggest contribution to water quality/low pH and it is advised that wherever possible peatland restoration should be undertaken on dystrophic blanket peat within this area. This will also address localised water quality issues within the Water of Minnoch.

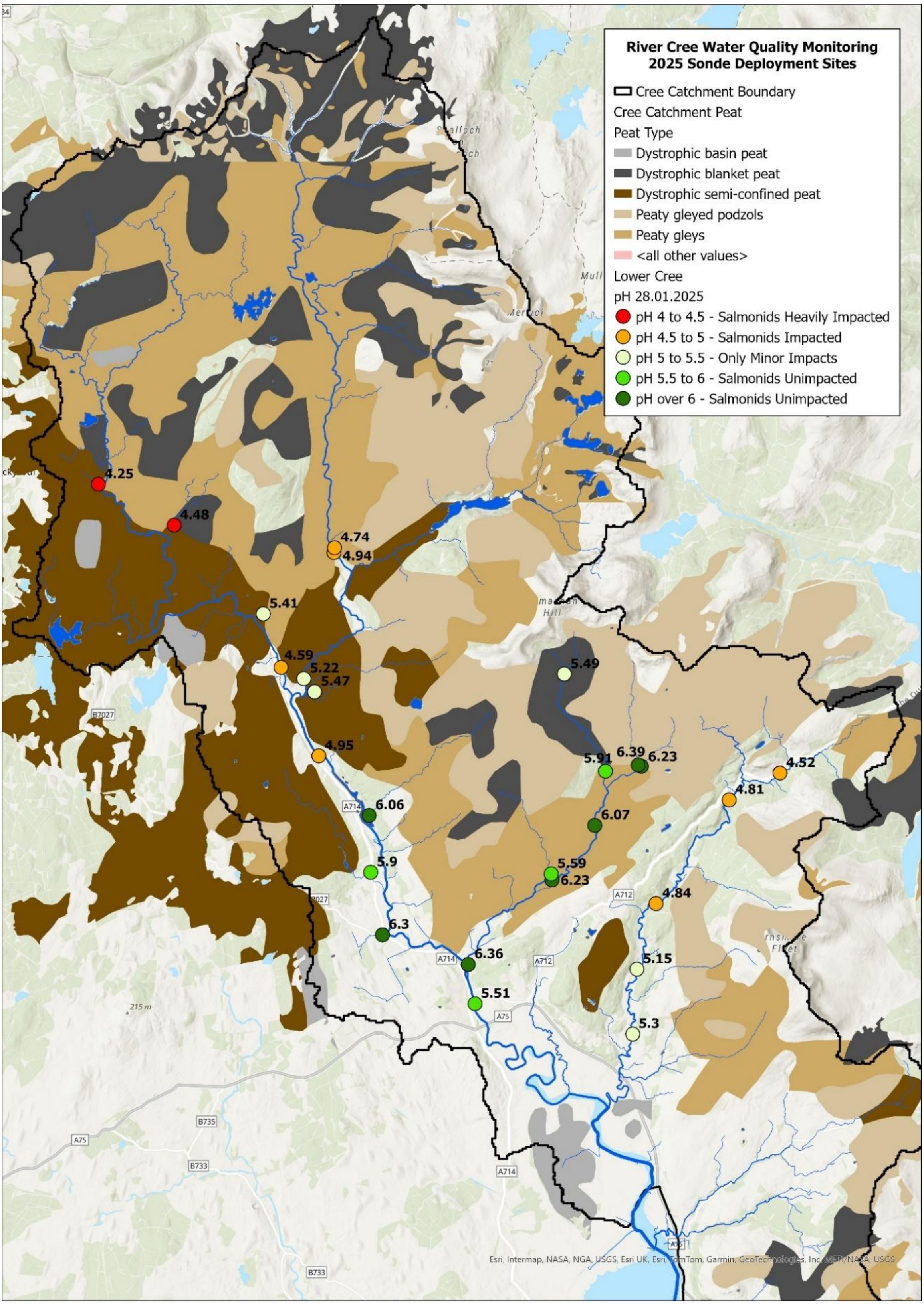
- Much of the dystrophic blanket peat within the High Cree sub-catchment is surrounded by soils classed as peaty gleys (within the NatureScot peat map). There are known to be areas of semi-confined peat within these peaty gleys which are also likely to be contributing towards degraded water quality (to a lesser extent than the blanket peat but still having a significant impact). More work is needed to locate the peatlands within these areas, identify their condition and assess their impact on water quality.

- There is a potential oxygen depletion within the waters flowing out of Loch Moan and more data is required to identify if this is the case.

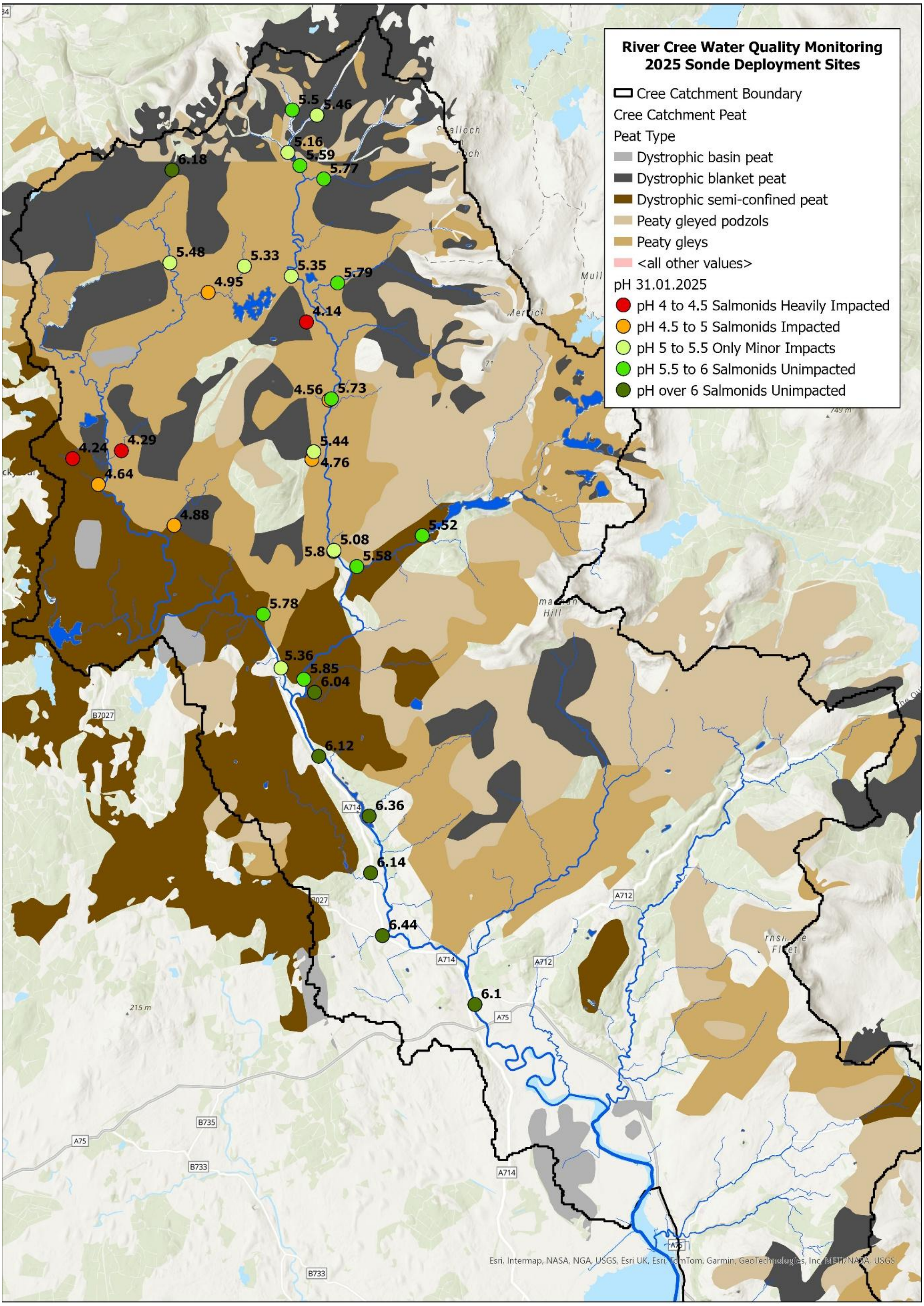
- Poor water quality at the very top of the Palnure Burn is having an impact further downstream. As the burn is of local importance for freshwater biodiversity peatland restoration should be considered on the boundary between the top of the Palnure Burn and the Black Water of Dee.

5 APPENDIX

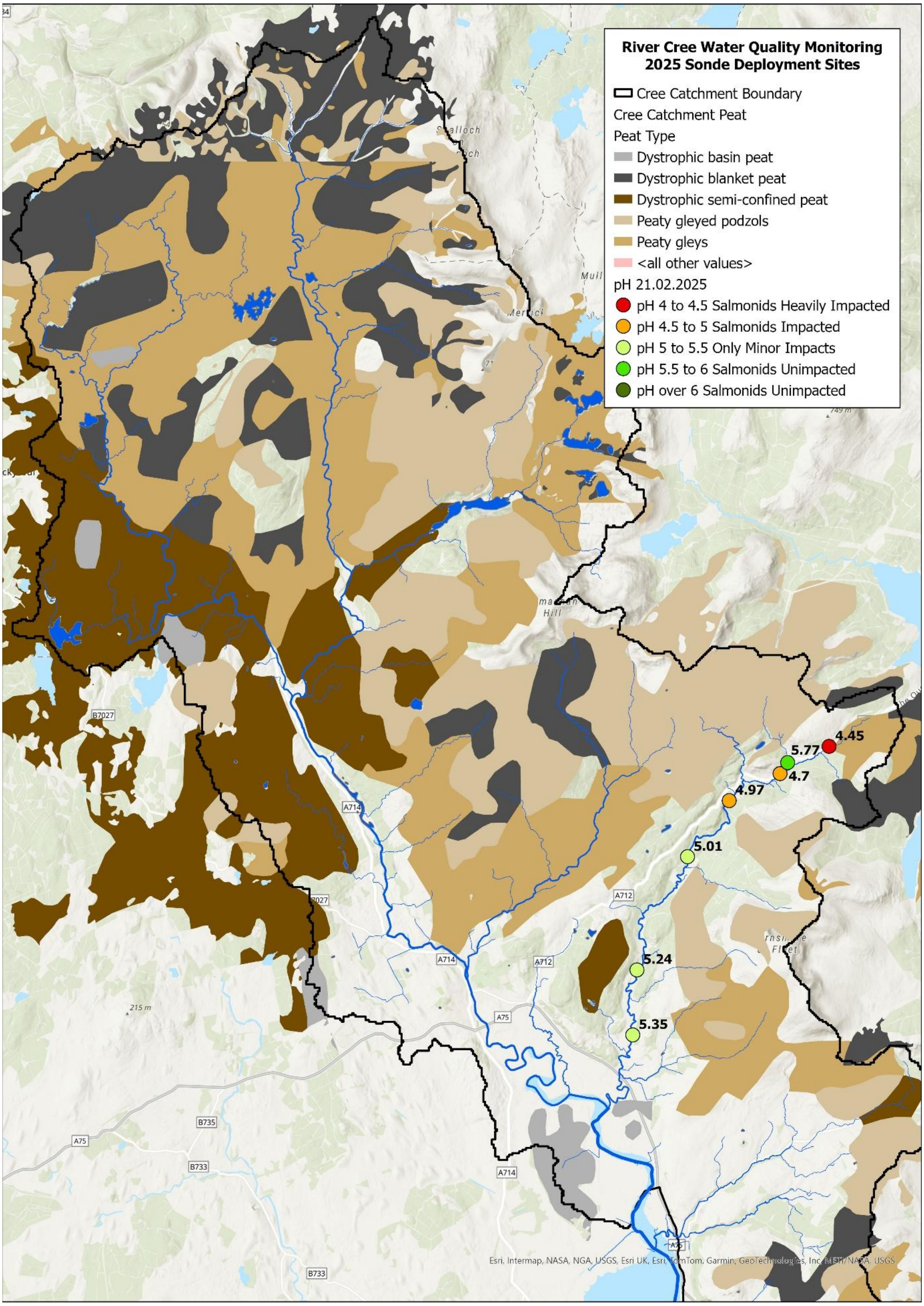
Results from individual water quality monitoring spot sampling days.



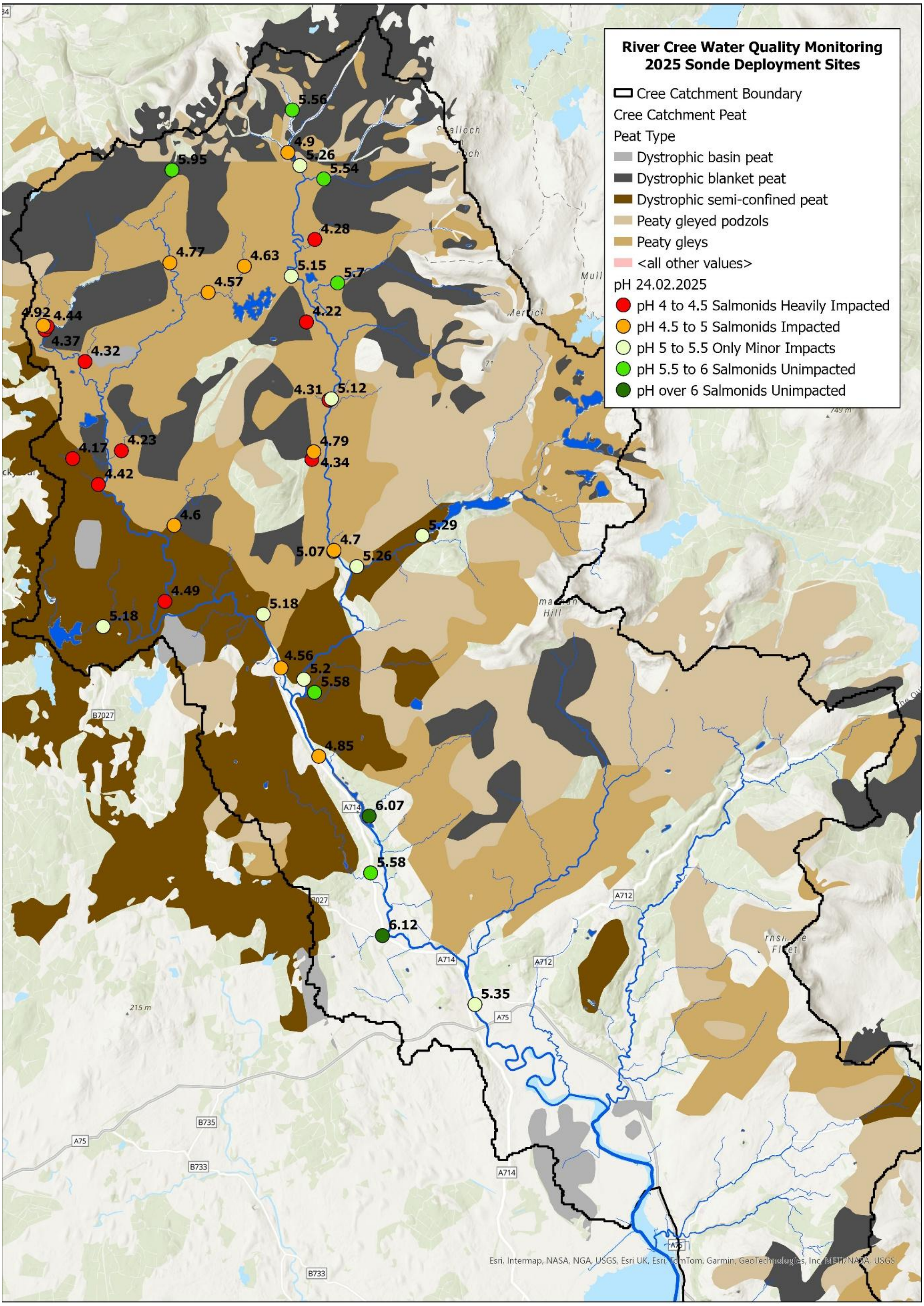
Map 26: The pH levels recorded during spot sampling 28.01.2025



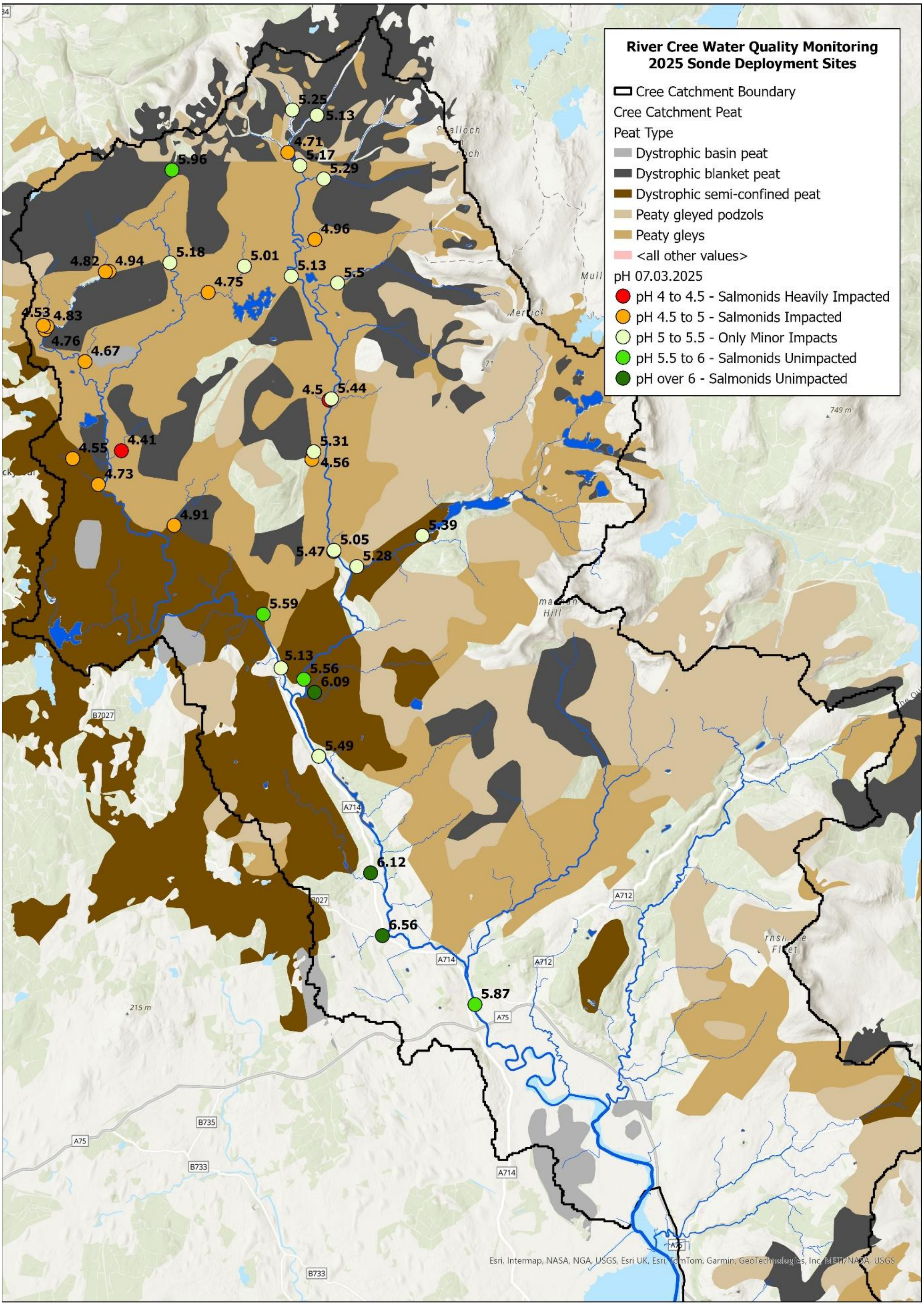
Map 27: The pH levels recorded during spot sampling 31.01.2025



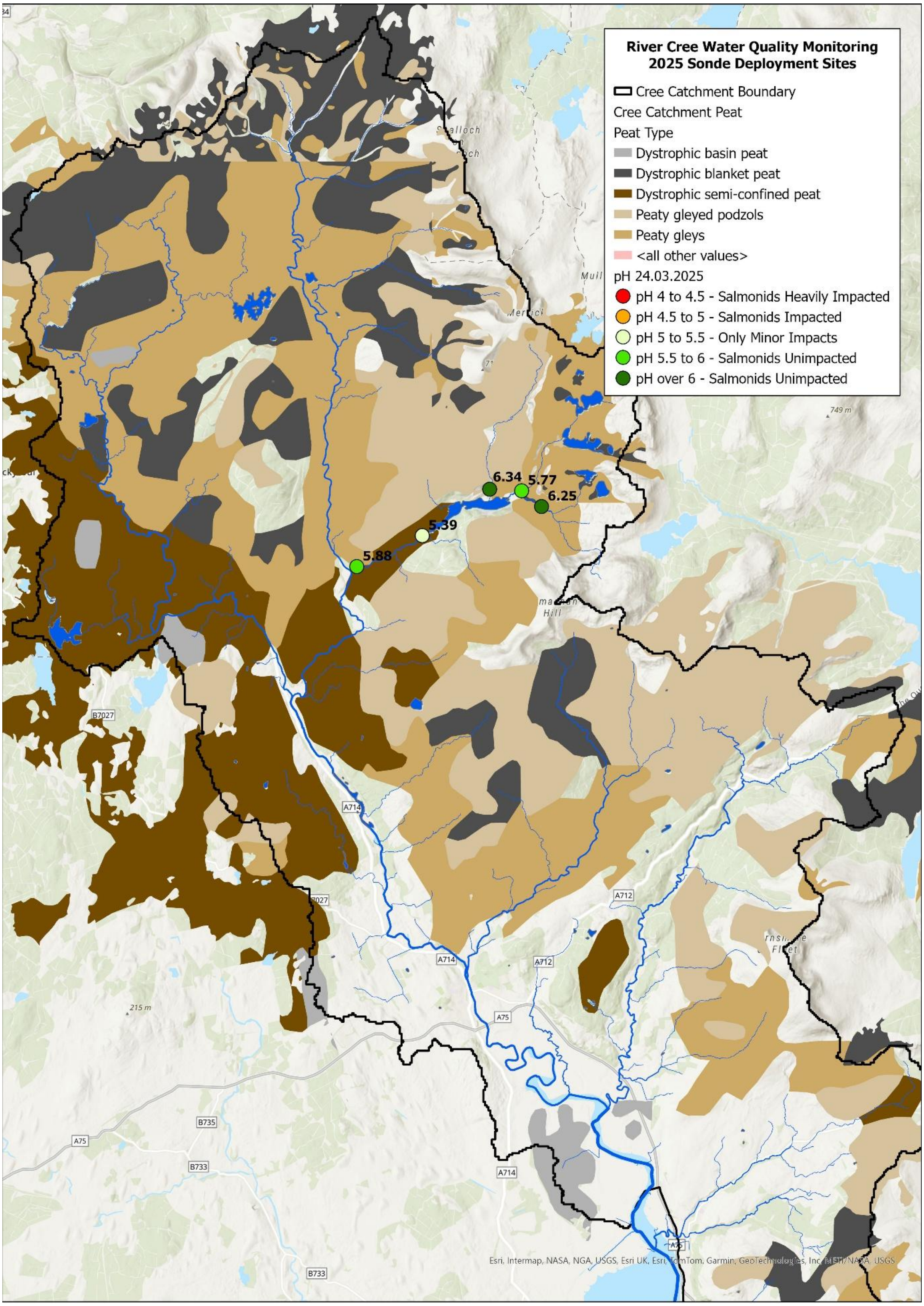
Map 28: The pH levels recorded during spot sampling 21.02.2025



Map 29: The pH levels recorded during spot sampling 24.02.2025



Map 30: The pH levels recorded during spot sampling 07.03.2025



Map 31: The pH levels recorded during spot sampling 24.03.2025

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